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Clait E. Braun

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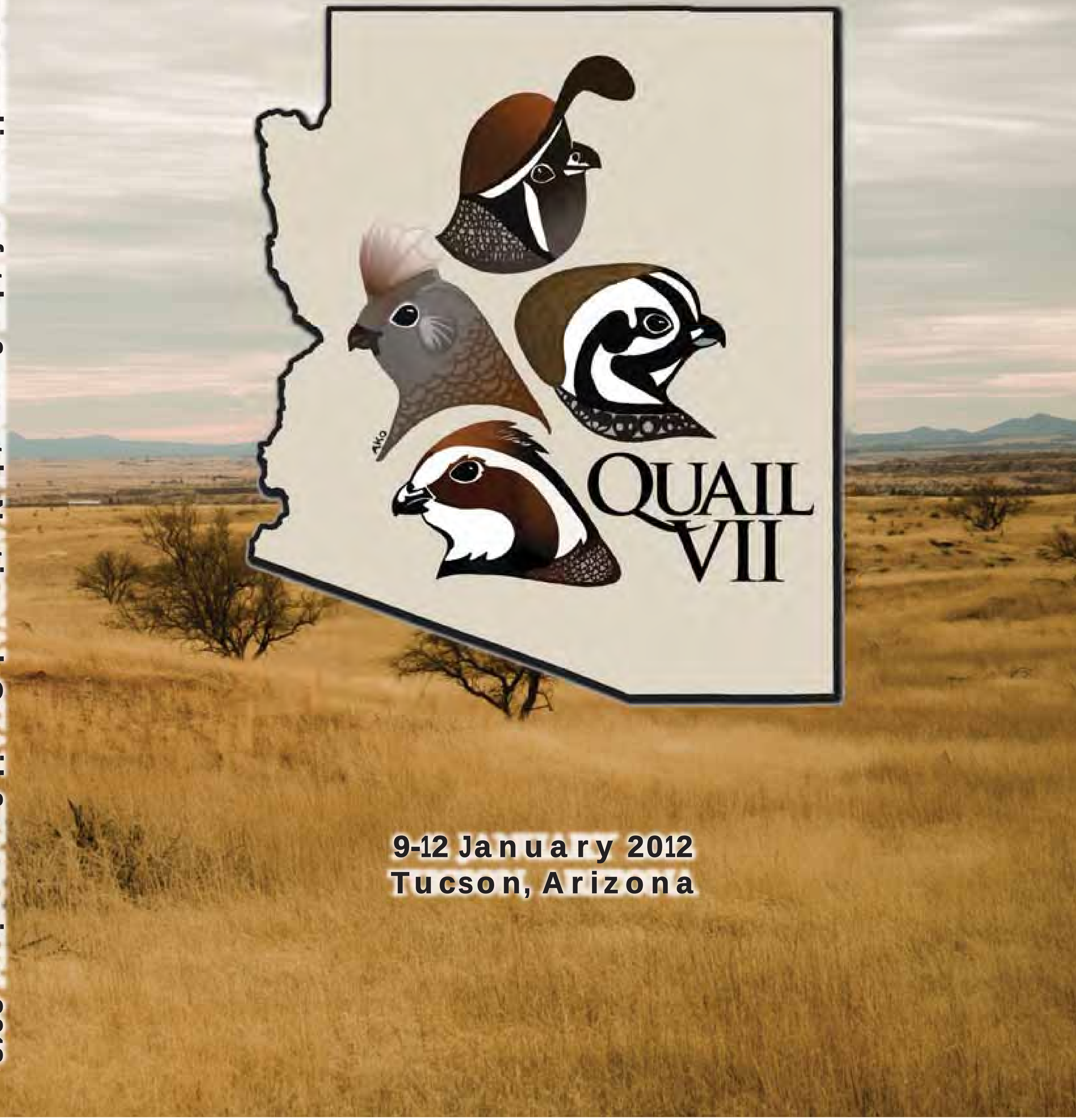
QUAIL VII: Proceedings of the Seventh National Quail Symposium



9-12 January 2012
Tucson, Arizona

QUAIL VII: Proceedings of the Seventh National Quail Symposium 2012

QUAIL VII: PROCEEDINGS OF THE SEVENTH NATIONAL QUAIL SYMPOSIUM

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FOREWORD

Thomas V. Dailey
Quail VII Program Chair
Assistant Director/Science Coordinator
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University of Tennessee, Knoxville

The Arizona Game and Fish Department (AZGFD) hosted Quail VII, the Seventh National Quail Symposium, in Tucson, 9-12 January 2012. This scientific meeting and peer-reviewed proceedings have occurred every 4-10 years at locations around the country. In 1972 and 1982 in Stillwater, Oklahoma the meeting was known as the National Bobwhite Quail Symposium, and, as the National Quail Symposium (Quail Series) in 1992 in Kansas City, Missouri (Quail III), 1997 in Tallahassee, Florida (Quail IV), 2002 in Corpus Christi, Texas (Quail V) and 2006 in Athens, Georgia (Quail VI).

Quail conservation has changed dramatically since Quail III in 1992. Kevin Church and I co-chaired Quail III, so I bring a long-term perspective to this foreword. Major ideas brought forth in 1992, and reinforced at subsequent symposia, bore much fruit in Tucson.

The seeds were sown for conservation of all North American quails at Quail III, the first *national quail symposium*, an expansion of the bobwhite series held in Oklahoma. As part of this expansion, we asked Lenny Brennan to lead the Quail III Strategic Quail Planning Workshop. Two decades later, top features of Quail VII were ideas hatched at Quail III: The National Bobwhite Conservation Initiative 2.0 (NBCI) and The Western Quail Plan. The publication of essential elements of each plan in the proceedings ensures a permanent record of these ground-breaking initiatives. For bobwhites, the conservation movement was rapid, with South Carolina Department of Natural Resources hosting a quail meeting in 1995 that launched the Southeast Quail Study Group, the predecessor of the National Bobwhite Technical Committee and NBCI.

For western quail, Quail VII is *the* national launch of the multi-species restoration plan. Progress for western quail conservation, relative to bobwhites, has been slower: Kevin Church and I struggled in 1992 to find any current research on western species and over the past 20 years key research has been sporadic; and as reported at Quail VII, the masked bobwhite is near extinction. The location of Quail VII in Arizona is a testament to renewed interest in western quails and we anticipate significant progress as the western plan is implemented. Moreover, AZGFD has emerged as a premiere advocate for quail conservation, fitting for a state agency with the Gambel's quail as the centerpiece of the department's logo.

Amid the growth of quail conservation, leaders of previous quail symposia, Lenny Brennan, John Carroll, Steve DeMaso, Bill Palmer, Theron Terhune, and I agreed the quail series needed permanent management. Quail VII, the first collaboration between a host (AZGFD) and NBCI resulted from steps made by the Research Subcommittee of the National Bobwhite Technical Committee (NBTC) to create a permanent home for the Quail Series. This is a service provided to all professional quail enthusiasts by NBTC and the National Bobwhite Conservation Initiative (NBCI). Quail Symposium Series proceedings and digital data are now permanently available from the NBCI.

Over the years we learned that successful bobwhite conservation is very complex, requiring a mixture of basic science, study of management, the latest technology and thinking, and consideration of philosophy, political science and public relations. Quail VII papers were very diverse, and included 76 volunteered abstracts and invited presentations–a record number for the National Quail Series. Meeting participants were treated to unique invited presentations by leading conservationists, including the directors of Arizona's and Kentucky's state wildlife agencies, Larry Voyles and Dr. Jon Gassett, respectively, who addressed the importance of the new quail plans; Katharine Armstrong, former commission chair of Texas Parks and Wildlife, provided insights on the role of politics in conservation; Bollenbach-endowed chair, Dr. Fred Guthery, Oklahoma State University, provided a historical/philosophical review; Dave Brown, Arizona State University, analyzed western quail conservation; and Dr. James Grand, U.S. Fish and Wildlife Service/ Auburn University, provided the latest thinking on decision making. Dr. Leonard Brennan, Endowed Chair, Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, wrapped up the meeting with closing remarks.

Quail VII papers were diverse, covering translocation of mountain quail and northern bobwhite, phylogeography of scaled quail and bobwhites (northern bobwhite, Yucatán bobwhite, spot-bellied bobwhite and crested bobwhite), hybridization of Gambel's and California quail, Montezuma (Mearns') quail, nutrition, arthropods, exotic grasses, the Conservation Reserve Program, predation, parasites, survival, reproduction, thermoregulation, harvest prescriptions, climate change, economics, conservation planning, attitudes of private landowners, etc. Geographically, these findings have implications for an area bounded by Brazil, Oregon, Nebraska, New Jersey, and south to Florida. The majority of Quail VII authors covered Texas bobwhites and scaled quail. Twenty-seven state and federal agencies, universities and institutes reported on their work at Quail VII.

A pervasive theme of quail management, pen-reared bobwhites, was also covered, providing some breaking 'peer-reviewed news'. The 21st Century brought the latest approach for releasing pen-reared bobwhites, the Surrogator®, a system backed by a plethora of well-marketed testimonials. Two independent Quail VII papers, in the Southeast and Texas, describe the *actual* efficacy of this system. This proceedings also published a groundbreaking advancement, use of prenatal and post-hatch imprinting to improve survival of pen-reared bobwhites. Harkening back to Quail III, Kevin Church and I were chagrined when one of our plenary speakers, the late Ed Kozicky, insisted on expanding his topic, 'history of quail management': "...I accepted with the proviso that I could discuss the dire need for more assistance from the academic community in the production of quality, pen-reared bobwhite for hunting purposes." Dr. Bill Palmer and associates appear to have fulfilled part of this vision in their Quail VII paper on parent-rearing–a genetically wild, but pen-raised bobwhite.

A long-standing highlight of the Quail Series is recognition of outstanding contributions to quail conservation. At the banquet, Dr. Lenny Brennan recognized lifetime contributions by John Roseberry, Fred Guthery, Dave Brown, Walter Rosene (in memoriam), and John Crawford (in memoriam).

The first-ever NBCI led Quail Symposia partnership was made possible by AZGFD, led by Mike Rabe. AZGFD put on an excellent event, and were gracious hosts, particularly by providing the guided quail hunting all Quail VI attendees dreamed of at Quail VI in 2006. For a conservation movement so inextricably tied to hunting, first-hand experience by biologists is not a luxury.

The expeditious publication of Quail VII was made possible by the editorial leadership of Clait and Nancy Braun, and by due diligence by associate editors, reviewers, authors, and the NBTC Research Subcommittee (Chaired by Theron Terhune). Guidance for the technical program and proceedings was provided by the Quail VII editorial panel, including Lenny Brennan, Kirby Bristow, Steve DeMaso, and Theron Terhune.

The proceedings were made possible by generous contributions by the National Wild Turkey Federation, Caesar Kleberg Wildlife Research Institute, Tall Timbers Research Station and Land Conservancy, Texas Tech Quail Tech Alliance, Rolling Plains Quail Research Ranch, and National Bobwhite Technical Committee.

The Eighth National Quail Symposium (Quail VIII) will be hosted by the University of Tennessee in 2017, and will feature progress and 'lessons learned' from implementation of the National Bobwhite and Western Quail plans. Regardless of the outcome of these and other initiatives, because of the passion for quails, we can be assured of another thought-provoking symposium and unique opportunity to mark the trajectory of quail populations.

ACKNOWLEDGMENTS

Mike Rabe
Quail VII Steering Committee Chair, Arizona Game and Fish Department, Phoenix, AZ

Tom Dailey
Quail VII Program Committee Chair, National Bobwhite Conservation Initiative, Knoxville,TN

Quail VII was made possible by collaboration between the Arizona Game and Fish Department (AZGFD) and the National Bobwhite Conservation Initiative (NBCI)/National Bobwhite Technical Committee. Key staff for AZGFD included, Kirby Bristow, Doug Burt, Ron Day, Tom Duval, Johnathan O'Dell, Connie Weise and, for NBCI, Heather Inman and John Doty. Ron was the initial Steering Committee Chair and laid most of the groundwork for the Symposium. Similarly, Kirby was involved since the inception of Quail VII, at Quail VI. Doug developed the AZGFD Quail VII web site and Tom handled the contract work necessary to make everything flow smoothly. Johnathan managed registration and kept the books. Connie Weise was the prime organizer and conscience who kept everyone on track. Heather and John handled meeting announcements, established the National Quail Symposium page on the NBCI web site, and guided non-technical content for the proceedings.

We are grateful for the enjoyable receptions and field trips hosted by Arizona Game Rangers (special thanks to Wildlife Managers Brad Fulk and Joe Saco), Safari Club International, and Buenos Aires National Wildlife Refuge. The Arizona Chapter of The Wildlife Society provided essential registration services.

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The proceedings were made possible by generous contributions by the National Wild Turkey Federation ($5,000), Caesar Kleberg Wildlife Research Institute ($5,000), Tall Timbers Research Station and Land Conservancy ($5,000), National Bobwhite Technical Committee ($5,000), Texas Tech Quail Tech Alliance ($2,500), and the Rollings Plains Quail Research Ranch ($2,500).

RECOGNITION OF EXCELLENCE AWARD RECIPIENTS

DAVID E. BROWN

David E. Brown was the Small Game Management Supervisor for the Arizona Game and Fish Department from 1968 to 1979. A prolific writer of scores of magazine and peer-reviewed scientific articles, Dave is also author of 3 landmark books: *Arizona Game Birds, Arizona Wetlands and Waterfowl,* and *The Last Grizzly and other Southwestern Bear Stories.*

Dave's efforts and persuasion were instrumental during the masked bobwhite conservation efforts from the 1960s through the 1980s. He also Chaired the Grazing and Range Management Section of the Quail III Strategic Planning Workshop in 1992. Even in retirement, Dave has stayed active by continuing to write papers (including 2 for this Proceedings). In 2009, he received the Arizona Game and Fish Department Educator of the Year award from Arizona State University.

FRED S. GUTHERY

At the time of this writing, Fred S. Guthery holds the Bollenbach Chair for Wildlife Research at Oklahoma State University. Since moving from Texas to Oklahoma in 1997, Fred has unleashed a series of publications that will remain prominent mileposts along the road of scientific wildlife literature for years to come. For example, his books such as *On Bobwhites* (2000), *The Technology of Bobwhite Management* (2002), *A Primer of Natural Resource Management* (2008), and *Beef Brush and Bobwhites, Second edition* (2012) as well as his paper *Aspects of the Thermal Ecology of Bobwhites in North Texas* (2005) published as a *Wildlife Monograph* have received national acclaim as have his legions of peer-reviewed scientific articles on quail ecology and management as well as the philosophy of science.

Taken as a whole, Fred's body of work forms the backbone of what has become the fundamental scientific basis for quail management in the semiarid subtropical region of the Southern Midwestern U.S. The breadth, depth, and sheer output of scientific publications that Fred has generated during the course of his career is the gold standard by which all other quail researchers are currently judged.

JOHN L. ROSEBERRY

It can be easily argued that John L. Roseberry single-handedly brought bobwhite science from the qualitative natural history era into the arena of contemporary population ecology. His seminal book *Population Ecology of the Bobwhite,* published in 1984, accomplished this task. This book remains a key reference for all students of quail nearly 30 years after it first appeared. John has also authored and co-authored numerous scientific publications and monographs that have become widely cited by today's quail researchers. His paper *Bobwhite Population Responses to Exploitation: Real and Simulated,* which appeared in the *Journal of Wildlife Management* in 1979, was the first to use simulation analyses to examine how bobwhite populations might respond to hunting.

John Co-chaired the Population Dynamics and Effects of Hunting Section of the Quail III Strategic Planning Workshop in 1992, and contributed the Concluding Remarks from the Researchers Perspective at Quail IV in 1997. John has remained active in the quail conservation area and remains a constant advocate for quail in Illinois and the Midwest.

—Leonard A. Brennan and the Quail VII Program Committee

IN MEMORIAM

WALTER ROSENE JR. 1912–2005

Walter Rosene was born in Iowa and graduated from Iowa State University. He moved to Alabama in 1936, enrolled in Auburn University, and was the first student to earn a Master's degree in their wildlife program. Walter worked for the Soil Conservation Service until 1942 when he enlisted and served in the Navy Signal Corps in World War II.

From 1946 to 1964, he worked as a biologist for the Bureau of Sport Fisheries and Wildlife (the precursor agency to the U.S. Fish and Wildlife Service) and then became a private consultant to numerous Quail Hunting Plantations in the Southeastern U.S. Walter received numerous awards for his publications on quail biology and management, including the Outstanding Publication in Wildlife Management award from The Wildlife Society for his 1969 book *The Bobwhite Quail: Its Life and Management*.

What many people do not know about Walter is that he conducted an important series of investigations on the impacts of heptachlor on quail and songbirds. The results of this work demonstrated that widespread use of heptachlor for control of fire ants had a far greater negative impact on birds and the environment than the negative impacts from fire ants alone.

Late in Walter's career, the advent of miniature radio transmitters in quail research brought forth a great degree of skepticism from him regarding this technology. His opinion was that fastening radios on wild bobwhites would only make them more susceptible to predation and thus exacerbate their already high natural mortality rates. The recent kerfuffle between Midwestern and Southeastern quail researchers about the potentially negative effects of radio-handicapping bobwhites in the name of research is an indication that Walter may have been on to something.

Walter was a prominent attendant at The First National Bobwhite Quail Symposium in 1972 and again in 1982. In 1992, he Co-chaired the Forest Practices section of the Quail III Strategic Planning Workshop. He regretted not being able to attend Quail IV in 1997, but he kept up with the quail research world by requesting copies of those Proceedings as well as the Proceedings from Quail V held in 2002.

Walter was the kind of person who never did anything halfway. He was a meticulous observer and student of nature who developed great insight and understanding about how to manage Southern Piney Woods to grow wild bobwhites. Finally, although a Midwesterner by birth, Walter developed a deep appreciation of Southern U.S. culture and history. In addition to being a great wildlife biologist, he was also a national expert Numismatist who published an award–winning book on Confederate paper money in Alabama in 1984.

JOHN A. CRAWFORD 1946–2010

John A. Crawford was born in Fort Dodge, Iowa. He received his Ph.D. in Range and Wildlife from Texas Tech University in 1974. During his time in Texas, John conducted important studies that shed light on the comparative ecology of bobwhites and scaled quail, especially from the standpoint of how they share habitat and food resources.

In 1974, John went to Oregon State University where he directed their Game Bird Research Program for the next 27 years. During his time at OSU, John generated more than 70 publications and received numerous awards and recognition for his work on sage-grouse, turkeys, and quail. John contributed important papers on California quail and mountain quail to the Quail III and Quail IV Proceedings, respectively. He also Co-chaired the Agricultural Practices and Pesticides Section of the Quail III Strategic Planning Workshop in 1992.

John had a great sense of humor and positive outlook that was infectious to nearly everyone who interacted with him. His passing is a huge loss to galliform research, management, and conservation in the American West.

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ON SOME FOUNDING IDEAS OF QUAILOLOGY AND THEIR PROPOUNDERS

Fred S. Guthery[1]
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ABSTRACT

Powerful ideas in quailology affect thinking over generations, even if the ideas are wrong. I discuss great ideas put forth by Aldo Leopold, Herbert Lee Stoddard, and Paul Lester Errington and comment on aspects of their personalities. Leopold, an extraordinarily good father, posited the Law of Dispersion (Interspersion), which became known as the Principle of Edge. The Law is a tautology that can be paraphrased 'edge-obligate animals require edge.' Leopold observed the 'law' held 'within ordinary limits,' which he did not define but which could mean 'within compositionally simple landscapes.' As a child, Stoddard, who dropped out of high school to support his family, recognized the value of fire in northern bobwhite (*Colinus virginianus*) habitat management in the Southeast; later he came to see tenant farming (patchwork agriculture) set up conditions favorable to northern bobwhites. Stoddard was given to after-the-fact hypothesis formulation (retroduction) on the causes of events he observed. Through this logically weak process he bequeathed many 'facts' that are really untested hypotheses. Errington, an apparent loner who survived polio as a child, had 2 great ideas. The Threshold of Security was a fairly constant spring density which implied harvest up to a certain level is fully compensatory (doomed-surplus model). The Principle of Inversity implies that relative productivity declines as breeding density increases. Errington's own work refuted the doomed-surplus model because he could not have simultaneously observed a constant breeding population and inversity, which requires a variable breeding population. These great founding ideas, although not without flaw, arose through observation of nature and thought, not through null hypothesis significance testing and model selection.

Citation: Guthery, F. S. 2012. On some founding ideas of quailology and their propounders. Proceedings of the National Quail Symposium 7:1–8.

Key words: *Colinus virginianus*, Errington, Leopold, northern bobwhite, Stoddard

INTRODUCTION

> Most theoretical breakthroughs in ecology have come from thinkers accomplished in field natural history.—Thomas L. Fleischner (2005:6).

My library contains *Six Great Ideas* by Mortimer J. Adler (1981). Adler's great ideas are from philosophy: truth, goodness, beauty, liberty, equality, and justice. He categorizes great ideas as those "basic and indispensable to understanding ourselves, our society, and the world in which we live" (1981:3) and suggests such ideas constitute "the vocabulary of everyone's thought."

Great ideas in northern bobwhite management are, of course, blind hairless puppies in comparison with the great ideas of human philosophy. However, these ideas help us better understand and appreciate our world. The great ideas affect our thinking over human generations, even if they are wrong. If they are wrong, flaws in thinking obviously have been discovered and perhaps a greater idea has emerged. Indeed, science is all about the birthing of greater ideas from lesser ones.

I discuss the great ideas put forth by what low-handicap colinologists call the Big Three: Aldo Leopold (1886–1948), Herbert Lee Stoddard (1898–1968), and Paul Lester Errington (1902–1962). (By twist of fate the lives of these intellectual giants intertwined in Wisconsin.) Their great ideas have to do with the Law of Interspersion and basic theory of wildlife management; research, prescribed burning, and cultural aspects of landscapes; and the nature of harvest and production in bobwhite populations. I will inject some personal and career tidbits about each that will help us appreciate that they were, indeed, mortals. I conclude with a brief comment on their *modus operandi* in comparison with obsessive use of significance testing and model selection today.

LEOPOLD AND THE LAW OF DISPERSION

Aldo the Father

Aldo Leopold was a wonderful dad. "He treated us with considerable dignity," said A. Starker Leopold, the eldest child (Meine 1988:292). "Aldo inevitably began conversations by asking the children what they thought about this or that. At the dinner table, he would routinely inquire of each of the five [children] in turn, 'What happened today in your life that was interesting?'" He and his wife, Estella, also gave the children responsibility and trust. Each of his children had exemplary careers and three were elected to the National Academy of Science.

Forgive me this bit of sentimentalism on Leopold. I simply believe it is nice that a busy man of some import would listen to his children, and I think we should know this about him. Such an anecdote sits nicely upon the

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palate like the after effects of spice from a gourmet soup. This also explains how his personality might have intensified the esteem in which he was held by contemporaries and future observers.

Perhaps this reference to being a father also is appropriate because he is regarded as the father of *game* management. Indeed, he published *Game Management* in 1933. This book was a compendium on the natural history and management principles of game animals. Leopold was fascinated with all the wild plants and animals he encountered, not just game, as apparent from his essays in *A Sand County Almanac* (1949). His campaigns for wilderness preservation also attest to this fact.

Leopold was born to Carl and Clara (Starker) Leopold in Burlington, Iowa, on 11 January 1887 (Meine 1988). His parents were first cousins (cross cousins). This is not unprecedented among great biologists as Charles and Emma Darwin were first cousins. Neither was marriage of cousins unusual in late 19th century America.

His father, Carl, kindled Leopold's interest in the out-of-doors through field excursions with the family, hunting, and fishing. Leopold began hunting at about 13 years of age (Meine 1988). He also did considerable hiking whenever he had the opportunity, which was often; being a child of privilege, Leopold did not have to work for wages until he graduated from college.

The Principle of Edge

Hunting and otherwise tramping about the hinterlands provided diverse observations for Leopold's mind to stir and ponder. These observations led to inductions about the workings of nature. His most famous induction is what he called the Law of Interspersion (Leopold 1933:131). He also called it the Law of Dispersion (1933:132). Today, we know it as the Principle of Edge.

> The potential density of game of low radius requiring two or more types is, within ordinary limits, proportional to the sum of the type peripheries.—Aldo Leopold 1933:132.

The phrase 'low radius' means an animal with low mobility (travels short distances in daily activities) such as bobwhites or cottontails (*Sylvilagus* sp.). 'Type' means 'cover type' such as wheat field, prairie, brushland, and others. Leopold did not explain what he meant by the phrase, 'within ordinary limits' and we will return to this phrase.

The law may be stated mathematically as:

$$D = k\sum P_i = k(P_1 + P_2 + \ldots + P_n),$$

which reads 'potential density (D) is proportional to (k) the sum of type peripheries ($\sum P_i$)'. The equation reveals an oddity: 'potential density' (no./area) implies that some area (length and width) is under consideration but $\sum P_i$ is a measure of length. That leaves the units for the constant of proportionality in question. Let us suppose, however, that Leopold intended to use edge density ($\sum P_i/A$; edge per area) (Guthery and Bingham 1992). The corrected equation then becomes

$$D = (k/A)\sum P_i = (k/A)(P_1 + P_2 + \ldots + P_n).$$

The units for the constant of proportionality then become no./edge and we have the Principle of Edge in words as:

$$\text{no./area} = (\text{no./edge})(\text{edge/area}).$$

Thus the Principle of Edge is mathematically tautological (all equations are) because edge cancels out on the right side of the equation and we find:

$$\text{no./area} = \text{no./area}.$$

The principle is verbally tautological, too: Leopold defined an edge-obligate animal and asserted it occurs with edge. This could be stated, 'animals that require edge live near edge.'

The corrected principle, when expressed as an equation, reveals a strong assumption. First, consider that if an area has n different cover types and we are interested in 2-type edges (e.g., prairie-forest edge), there potentially are a maximum of $n!/(2!(n-2)!)$ unique 2-type edges. (There could be fewer edge types depending on how cover types are dispersed.) If an area has 5 cover types, for example, there are potentially $5!/(2!(5-2)!) = 10$ 2-type edges. By virtue of the *constant* of proportionality, k, in the corrected principle, each edge type is *assumed* to be of identical value to wildlife. When the assumption fails, the principle becomes:

$$D = (1/A)\sum k_i P_i = (1/A)(k_1 P_1 + k_2 P_2 + \ldots + k_n P_n),$$

where k_i is no./edge for edge type i. One supposes that, given the above expression of the Principle of Edge, the principle would be virtually useless in complex landscapes (many cover types). The reason is the value of any 2-type edge could be hopelessly confounded with the value of any other 2-type edge. Moreover, given what we know about habitat use (i.e., an animal uses different cover types to fulfill different needs) it is difficult to imagine that all 2-type edges are of identical value to the animal in different edge contexts.

Perhaps the hopeless confounding of edge values in complex landscapes was a consideration for Leopold's qualifier, 'within ordinary limits,' but there are other possibilities. Weather catastrophes could make unlikely or obscure any relation between abundance and edge, at least in the near term (J. H. Shaw, Department of Natural Resource Ecology and Management, Oklahoma State University, personal communication). It is mathematically possible to create an infinite amount of edge on a 3-×-5 note card and one could play the same kind of mind games on a square kilometer or any area. Obviously, there would be no relation between animal abundance and edge as edge density increases without bound leading to redundant edge (Guthery and Bingham 1992).

Another consideration is a property of cover configurations called 'slack'; the property implies that different amounts and arrangements of cover types can be of equal value to a wildlife population (Guthery 1999). To the extent that slack operates, the Principle of Edge is inapplicable because abundance stays the same as amount of edge varies.

Guthery and Bingham (1992) reasoned that 'within ordinary limits' might entail a maximum possible density. Indeed, density is problematic in Leopold's rendition of the Principle of Edge because standardized density (e.g., no./ha) may have little variation from low to high. Leopold probably was thinking of density as a synonym for population size (N); Errington (1945) used the words as synonyms. Any statement of population size is a statement of density because the population is implicitly confined to some area of interest. If Leopold used density as a homologue of population size, his principle is more reasonable if the identified problems are corrected. If, however, Leopold was implying standardized density (no./unit area) we have mystery. Suppose all usable space on an area is occupied (maximum population size) and we add edge. Density (and abundance) would increase under a strict interpretation of the Principle of Edge. This is contrary to empirical reason: what mysterious force would cause abundance to increase with the addition of edge that is unnecessary from the standpoint of usable space?

These concerns could explain individually or as a group why Leopold constrained his principle to ordinary limits. I suspect he had a hunch the principle would work only on simple landscapes (few cover types). 'Within ordinary limits' perhaps means 'given relatively simple arrangements of a few cover types on a landscape.'

Edge vs. Usable Space

Guthery (1997) developed what he called the usable space 'hypothesis', which is a generalization of the Principle of Edge. The 'hypothesis' may be expressed as

$$N = pDA,$$

where

$N =$ population size on an area,
$p =$ the proportion of the area that is usable by quail,
$D =$ average density in usable space at some time of interest, and
$A =$ the size of the area (e.g., ha).

The quantity of usable space is pA. The 'hypothesis' is in fact a tautology. Letting $p = 1$ (all space usable) we have:

$$\text{number} = (\text{number}/\text{area})(\text{area}) = \text{number}.$$

Because the Principle of Edge has an implicit statement of area (Guthery and Bingham 1992), it is contained in the usable space hypothesis. If l is the length of edge and w is its effective width (usable space $= lw$), it can be shown by algebra that $lw = pA$ and by substitution:

$$N = Dlw,$$

which contains edge (l). However, $N = pDA$ is a better conceptual model because it deals with quandaries such as redundant edge and 'slack' (different amounts of edge have the same value to a wildlife population).

Leopold's Principle of Edge is now a conceptual debacle, but his philosophical contributions to wildlife conservation are properly treated with reverence. He was a champion of wilderness preservation throughout his career. His writing gave conservation a moral compass. *A Sand County Almanac* is regarded by many as the bible of the conservation movement (McCullough No Date).

Leopold noticed smoke coming from the direction of a neighbor's house on 21 April 1948 (Meine 1988). He, his wife, and his daughter (Estella Jr.) gathered up fire-fighting tools and went to help extinguish the fire. Leopold died of a heart attack while fighting the fire.

"There were no witnesses to [his] final moments....He apparently set down the full [water] pump, lay down on his back, rested his head on a clump of grass, and folded his hands across his chest. The attack did not subside. The fire, still alive but weakened in intensity, swept lightly over his body" (Meine 1988:520).

STODDARD AND TENANT FARMING

The Improbable Rise to Eminence

A remarkable absence in Herbert L. Stoddard's (1931) classic, *The Bobwhite Quail: Its Habits, Preservation and Increase*, is a section listing references. Technical articles on bobwhites were largely non-existent in the 1920s. In contrast, *Texas Quails: Ecology and Management* (Brennan 2007) cites about 1,000 different articles.

The absence of literature was a bane to Stoddard because "there was little precedent to assist in the planning or execution of the project" (Stoddard 1931: xxi). However, a paucity of knowledge was also a blessing in that all the information gathered was original.

Stoddard was in some ways ill-qualified by background and education to take on leadership of the Cooperative Quail Investigation. He was born in Rockford, Illinois on 24 February 1889. His father was an intensely religious person who taught mathematics and penmanship at Stoddard-Winans Business College in Rockford (Stoddard 1969). His father died when he was 5 weeks old. His mother remarried and Louis S. Flint, the stepfather, moved the family to Florida in 1893. Flint had no talent for 'the earning of a dollar,' said Stoddard and the family returned to Rockford in poverty in 1900.

Stoddard dropped out of school at the age of 15 in 1905 owing to 'the never-ending shortage of money' in his family (Stoddard 1969). He went to work near his Grandfather Stoddard's farm near Prairie du Sac, Wisconsin. (This locale would later play prominently in Paul L. Errington's career.) The young Stoddard worked 15 hours a day for $15 a month.

Stoddard worked as a taxidermist for the Milwaukee Public Museum and the Field Museum of Natural History in Chicago during 1910–1924. World War I interrupted this work and he was stationed near Bordeaux, France, when the war ended in November 1918. Stoddard saw no combat duty. "I left the service with a clearer understanding of myself and my lifework," Stoddard (1969:137) averred.

The Cooperative Quail Investigation

Early in the 20th century, declining bobwhite populations on plantations in the general vicinity of Thomasville, Georgia, and Tallahassee, Florida, prompted a meeting of wealthy landowners at the Links Club in New York City (Stoddard 1931). These preserve owners decided research might help identify and resolve the problems of quail. (This is one of the earliest examples in America where research was invoked to solve a conservation problem. Leopold [1948] also was an early advocate of research.) They affiliated with the U.S. Bureau of Biological survey to administer the project. The landowners anteed up $46,250.52 to fund the project.

The objectives were to study "all phases of the life history of the bobwhite, with special emphasis on the character and improvement of the food supply and general environment, and on the factors of mortality as represented by predatory enemies, the elements, parasites, diseases, and regulated and unregulated shooting" (Stoddard 1931: xxiii). The project started in March 1924 and ended in June 1929.

Fire and Bobwhite Management

Besides being the first wildlife monograph of American origin and a lode of descriptive natural history information, *The Bobwhite Quail* presented 2 great ideas. The first was use of fire in habitat management.

Stoddard's insight on the role and value of fire was a product of his youth in Florida, not of his work in the Cooperative Quail Investigation (Stoddard 1969:180). He wrote that fire had 3 main positive effects for bobwhites: increased food supplies, reduced or eliminated jungle-like aggregations of deciduous shrubs and high biomass aggregations of forbs and grasses (non-usable space), and sterilized the countryside for ticks, chiggers, and certain intestinal parasites. Today we would question the value of increased food supplies and sterilization for parasites but agree with the creation of usable space as the key factor in increasing bobwhites (Guthery 1997).

Stoddard (1931:411) recognized that *fire is not imperative for bobwhite habitat management*: "The cover on many upland preserves can be kept in shape . . . largely with the use of tractors and plow-harrows, but the expense is greater [than fire] and in many cases might be prohibitive." (I doubt the expense would have been prohibitive for the wealthy hunters who supported the Cooperative Quail Investigation.)

"Such burning as proves desirable," wrote Stoddard (1931:412), "should preferably be carried on during the dampness of the night and against the wind if there is any blowing." Today we know that Stoddard wrote this anemic burning prescription under duress from the U.S. Forest Service and the American Forestry Association (Way 2006). These organizations were dogmatically opposed to burning for any purpose in the 1920s.

Tenant Farming and Primitive Agriculture

Stoddard's second great idea was dependent upon the emancipation of slaves in the South. This ushered in an era of tenant farming and associated small fields, lower successional patches intermixed with open pine (*Pinus* spp.) forests, and high landscape diversity. Bobwhites thrived under these conditions. Stoddard came to recognize that "early twentieth-century quail abundance—a big part of what made [the southeastern] landscape attractive to wealthy northerners seeking recreation in nature—was as much a cultural phenomenon as it was an environmental one" (Way 2006:507).

Stoddard's patchwork (also called primitive) agriculture meme has had great staying power. Today we know it is a sufficient but not a necessary condition for dense populations of bobwhites (Guthery et al. 2001). For example, in the mid-1800s Wisconsin bobwhites irrupted and achieved exceptional densities before agriculture arrived (Schorger 1946). Rangeland areas lacking any type of agriculture also can carry exceptional densities of bobwhites.

Defects in the Legacy

Any large body of information on any topic inevitably has strengths and weaknesses and *The Bobwhite Quail* is no exception. One error Stoddard committed was passing off as fact after-the-fact explanations of the cause of an event (this is called retroduction). For example, "many broomsedge [bluestem] fields are frequented by quail for nesting, roosting, and feeding that would by shunned by them but for the activities of hogs" (1931:355). This statement is plausible because of rooting and trailing by hogs (*Sus scrofa*). However, it is based on speculation and some other cause, such as some property of broomsedge fields that attracts both hogs and quail, might be the true cause. Or perhaps hogs are attracted to broomsedge fields to eat quail nests. Such cases of retroduction continue to inject false information in the guise of knowledge into wildlife science (Romesburg 1981).

A second boner he committed owed to the process of *invention*, or the confusing of plausibility and fact—retroduction on fantasy. "Weak chicks . . . normally are left behind very quickly by the brood, for the pace through the cover is regulated by the strong. . . ." (Stoddard 1931:197). That assertion certainly is plausible. However, its empirical confirmation involves seeing a brood (not easy), observing that one or more of its members are weak (how?), and following to document that the weaklings are left behind (not easy). How would you identify a weak chick versus one that simply got lost?

Here is another example of invention: "Although loss of developing chicks by drowning appears likely to be of little consequence in the rolling types of country, and is largely confined to the very young chicks lost in ditches, ravines, and gullies. . . ." (Stoddard 1931:202). The dependent clause beginning with 'although' certainly is plausible but whether it is empirically true was not known by Stoddard. The phrase containing 'is largely confined' is an assertion of fact that 'very young chicks' drowned in ditches and gullies. I would be surprised if Stoddard observed this because a collection of very young chicks that drowned (i.e., water in lungs) is quite implausible. Inventions such as this take on the aura of truth over the decades because they are birthed by an expert and frequently repeated. Humans have a tendency to soften skepticism when told statements are being made by experts (Freedman 2010).

Consider the following as a further example of invention: "If satisfactory sport and a safeguarded breeding stock are desired on the same ground year after year, the number of birds shot or otherwise harvested by man must be offset by control of natural enemies, improvement of coverts, or restocking" (Stoddard 1931:226). Stoddard is saying sustained yield harvest is impossible unless you reduce mortality or add to the standing crop. This notion may be rejected without recourse to experiment because predators have been taking a sustained yield of bobwhites for millennia. A quail dead of shotgun blast is no deader than one dead of talon. However, Stoddard's arguments are plausible, although wrong at the superficial level.

Lest you think I am unmercifully picking on Stoddard let me say that a lot of 'knowledge' about natural resources is based on invention. I have used (or committed) it myself. I provided information (Guthery 1986) on where supplemental water was needed based on annual rainfall. My arguments sounded good but they were based on nothing stronger than their melodious appeal to primitive logic.

Stoddard's book is and will remain a classic. Much of the natural history information, e.g., nesting, foods, movements, habitat requirements, and internal and external enemies, was sound for the times and valid today except insofar as times have changed.

Herbert L. Stoddard died with a copy of Aldo Leopold's *A Sand County Almanac* in his hands on 15 November 1968 (Gromme 1973).

ERRINGTON AND THE DOOMED SURPLUS

Convalescence and Creativity

Paul L. Errington's youth was characterized by debilitating illnesses and self-motivated, sometimes grueling, recoveries. An attack of polio in the summer of his eighth year led to prolonged incapacitation (Errington 1973). Likewise, he contracted rheumatic fever, an after effect of strep throat that may weaken heart valves, the last semester of his senior year in high school. This malady also resulted in a long recovery. Errington pressed himself physically with excursions in the outdoors to recover from these illnesses. Undoubtedly, these bouts provided him the opportunity to observe and participate in nature at nature's pace, and to mentally focus on same without having to commit much mind-time to the work-a-day world.

It is interesting that Aldo Leopold and Herbert L. Stoddard also had extended infirmities in their younger days. Leopold contracted Bright's disease (nephritis) in 1913 and remained incapacitated for 16.5 months (Meine 1988:131). Stoddard (1969:104) accidentally chopped his left leg with an ax and this wound and complications restricted his field activities from summer 1911 to summer 1912. These slow periods permit thoughts to foment and thereby foster the emergence of ideas because there is more time to think than during the conduct of normal activities. Convalescence seems to benefit creative thinking.

Errington was born 14 June 1902 on a farm near Bruce on the banks of the Big Sioux River in east-central South Dakota. Bruce had 272 residents in the 2000 census. The low human population, plus the nearby availability of farm, marsh, lake, and riverine habitat undoubtedly provided the young Errington with a cornucopia of wildlife and fish. Indeed, he was an avid hunter, trapper, and fisherman in his youth (Errington 1973).

The biographical information I have been able to retrieve on Errington makes little mention of his parents or family life. In his posthumous autobiography (*The Red Gods Call*) he mentions some activities of his mother and stepfather in a most general sense; names are not given. His stepfather, a proprietor of an ice cream parlor, gave the 11-year-old Errington a .22 rifle (Kohler 2011). His maternal grandparents (Johnson) had a farm on Lake Tetonkaha a short distance west of Bruce. Young Errington camped, fished, and hunted on the lake. His maternal uncle, Aaron Johnson, was a professor at the University of Wisconsin for awhile (Kohler 2011).

Wisconsin Studies

Early in his professional career, Errington became associated with Aldo Leopold and Herbert L. Stoddard. Stoddard and Leopold met in 1928 to select recipients of fellowships to conduct studies on important upland gamebirds in America (Stoddard 1969). The Sporting Arms and Ammunition Manufacturers Institute financially supported the fellowships. "A likely student for [a] fellowship, one with a favorable woodsman-trapper background, was available in the person of Paul Errington," Stoddard wrote (1969:220). Stoddard (1969:221) introduced Errington and Leopold to "key men and favorable terrain in the Prairie du Sac region," where Errington began research on bobwhites as part of graduate study at the University of Wisconsin, which he started in July 1929; the fellowship supported his work for 3 years (Errington 1948). He received his Ph.D. in 1932 and went to work for Iowa State University, where he remained for the balance of his career.

Compensation

Errington, in the general realm of ecology, probably is better known for his work with predator-prey relationships than for his great ideas regarding bobwhites, although these ideas overlap. Long before Errington the prevailing attitude on predators, for those who cared to have an attitude, was that predators kill and therefore take bounty from humankind. Errington (1967:225) took a deeper look:

> *In the case of Iowa muskrats [Ondatra zibethicus], the predation is centered upon overproduced young; upon the restless, the strangers, and those physically handicapped by injuries or weakness; upon animals evicted by droughts, floods, or social tensions; in general upon what is identifiable as the more biologically expendable parts of the population.*

Errington (1967:228) also recognized that life as a tangle of predators and prey, plants and sunlight, food webs and energy pyramids is replete with *compensation*. This tendency to compensate is "one of the prime upsetters of both theoretical and 'common sense' calculations as to how Nature's equations work."

Errington's recognition of compensatory mechanisms in nature was a stroke of genius. It involved (1) perceiving patterns hidden in complex relations, (2) dealing with the non-linearities that bedevil our as-the-crow-flies minds, and (3) having the fortitude to reject the so-called common knowledge of the tribe. These are intellectually deep and painful exercises that go somewhat contrary to human spirit. Perhaps they can be best explained by observing that in nature, what you see often is not what you get. The concepts will become clearer as I proceed through Errington's great ideas for quail.

Threshold of Security

The first great idea is that there exists a *Threshold of Security*, an imaginary construct that explains quail dynamics from fall to spring and provides a rationale for harvest management. Starting with his work at Prairie du Sac and continuing in Iowa, Errington observed a "rather constant year to year maximum" survival (Errington and Hamerstrom 1936:309). In other words, carrying capacity, "the *upper limit* of survival possible in a given covey territory as it exists under the most favorable conditions" (Errington and Hamerstrom 1936:308; emphasis in original) appeared constant through the years. Put in yet different words, barring weather emergencies such as blizzards, the number of breeders at the start of spring tended to constancy, at least in Errington's early results.

Errington (1945) called this number the Threshold of Security. Based on his field observations and data, when population abundance exceeded the threshold number, individuals were *vulnerable to* all forms of loss: egress (leaving the area), disease, predation, harvest, and other losses. Conversely, populations at or below the threshold were *resistant to* all forms of loss. Birds in excess of the threshold number were members of a *doomed surplus* (Errington and Hamerstrom 1936).

The threshold and doomed surplus concepts have direct relevance to harvest management: the shooting of a member of the doomed surplus has no effect on the population. The death of such an individual is fully compensatory—none lost from the breeding population for each bird bagged. Harvest, therefore, is inconsequential to bobwhite populations unless it involves taking birds from a population at or below the threshold level.

Inversity

I will show flaws in the threshold concept but first I discuss Errington's second great idea. It goes back to the compensation in nature that he recognized.

"Summer gains, as shown by numerical differences between spring and fall populations…, look highly variable; but … *they reveal certain patterns* (Errington 1945:13; emphasis added). "By the fall of 1932, it had been noted that summer gains tended to be in *inverse ratio* to spring densities…. For such years, we may ordinarily expect Prairie du Sac spring densities of 40 birds [this is really population size] to be followed by fall densities of about 140; spring densities of about 100, by fall densities of about 325; spring densities of 200, by fall densities of about 400; spring densities approaching 340, by fall densities approaching 440."

The above numbers show that as density of breeding birds goes up, productivity per pair goes down (inversity). Errington (1945:13) observed of spring pairs at Prairie du Sac, that 20 produced 5 young/pair in the fall, 50 produced >4 young/pair, 100 produced 2 young/pair, and 170 produced one-half young/pair. Errington observed that productivity as a function of spring density followed a reverse sigmoid curve. (I have accurately relayed what Errington reported, but I suspect he was reporting young/adult, not young/pair).

This Principle of Inversity is not only "one of the prime upsetters" (Errington 1967:228) of both theory and common sense but also a remarkable finding that holds approximately across wild vertebrates ranging from reptiles to mammals. Inversity is also called *density dependent productivity*. Density dependence is a mechanism which reduces the annual volatility of wildlife populations—a sort of population shock absorber that stimulates low populations and inhibits high populations. Errington discovered a truly great idea in the Principle of Inversity.

Contradiction

Just because the Threshold of Security and the Principle of Inversity are great ideas does not necessarily imply that they are without flaw. For example, the 2 concepts contradict each other. The threshold concept entails some constancy in breeding populations yet the inversity concept cannot be observed unless breeding populations are variable.

Regarding harvest management of bobwhites, the doomed or annual surplus model has been called into question. The model cannot possibly reflect nature in the case of variable thresholds (Romesburg 1981), which Errington (1945) posited. The additive model of harvest mortality (Roseberry and Klimstra 1984, Guthery 2002) seems to better explain the few empirical data available. However, for populations with low annual survival rates, the doomed surplus and additive models of harvest predict similar dynamics for bobwhites.

Scott (1963) considered Errington a deep thinker; I personally regard him as the deepest thinker of the Big Three. He took quailology beyond simple description and generalization into the realm of theoretical constructs (e.g., the Threshold of Security). Such concepts are key properties of elegant science (Guthery 2008).

Errington died in his sleep on 5 November 1962 (Schorger 1966) at the age of 60. One wonders whether his childhood bout of rheumatic fever might have hastened his death.

OTHER GREAT IDEAS

Leopold, Stoddard, and Errington are not the only biologists who have made important contributions to our understanding of bobwhites. Robert J. Robel and his students at Kansas State University have done superb work on foods and energetics. One particular paper, '*Bioenergetics of the bobwhite,*' (Case and Robel 1974), is a classic that explains a great deal about how bobwhites process calories and deal with ambient temperatures. Recourse to the information in this paper lays to rest many a phony notion about the thermal ecology of bobwhites.

John L. Roseberry and his students and colleagues at Southern Illinois University further developed the theory and practice of harvest management from the pristine speculations of Errington. '*Bobwhite population responses to exploitation: real and simulated'* (Roseberry 1979) is another classic. It is the type of paper so chock full of useful information that almost every sentence warrants highlighting. *Population Ecology of the Bobwhite* (Roseberry and Klimstra 1984) is a classic, underappreciated book.

Of course, in recent decades there have been a few hundred refereed articles on the management and biology of bobwhites, and research continues in the United States. This work is of variable importance. No doubt in time some of it will influence 'the vocabulary of everyone's thought' to the same extent as the work of Leopold, Stoddard, and Errington.

A final observation: a common property of the Big Three was extensive field observation coupled with analytical thinking on the mental information thus accrued. We appreciate them for observing *and* thinking. They rode to great heights on the back of natural history, without recourse to statistical folderol.

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LITERATURE CITED

Adler, M. J. 1981. Six great ideas. Touchstone, New York, USA.

Brennan, L. A., ed. 2007. Texas quails: ecology and management. Texas A&M University Press, College Station, USA.

Case, R. M., and R. J. Robel. 1974. Bioenergetics of the bobwhite. Journal of Wildlife Management 38:638–652.

Errington, P. L. 1945. Some contributions of a fifteen-year study of the northern bobwhite to a knowledge of population phenomena. Ecological Monographs 15:1–34.

Errington, P. L. 1948. In appreciation of Aldo Leopold. Journal of Wildlife Management 12:341–350.

Errington, P. L. 1967. Of predation and life. Iowa State University Press, Ames, USA.

Errington, P. L. 1973. The red gods call. Iowa State University Press, Ames, USA.

Errington, P. L., and F. M. Hamerstrom Jr. 1936. The northern bob-white's winter territory. Research Bulletin 201. Agricultural Experiment Station, Iowa State University, Ames, USA.

Fleischner, T. L. 2005. Natural history and the deep roots of resource management. Natural Resources Journal 45:1–13.

Freedman, D. H. 2010. Wrong. Little, Brown and Company, New York, USA.

Gromme, O. J. 1973. In memoriam: Herbert Lee Stoddard. Auk 90:870–876.

Guthery, F. S. 1986. Beef, brush and bobwhites. Caesar Kleberg Institute Press, Texas A&I University, Kingsville, USA.

Guthery, F. S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 61:291–301.

Guthery, F. S. 1999. Slack in the configuration of habitat patches for northern bobwhites. Journal of Wildlife Management 63:245–250.

Guthery, F. S. 2002. The technology of bobwhite management: the theory behind the practice. Iowa State University Press, Ames, USA.

Guthery, F. S. 2008. A primer on natural resource science. Texas A&M University Press, College Station, USA.

Guthery, F. S., and R. L. Bingham. 1992. On Leopold's principle of edge. Wildlife Society Bulletin 20:340–344.

Guthery, F. S., M. C. Green, R. E. Masters, S. J. DeMaso, H. M. Wilson, and F. B. Steubing. 2001. Land cover and bobwhite abundance on Oklahoma farms and ranches. Journal of Wildlife Management 65:838–849.

Kohler, R. E. 2011. Paul Errington, Aldo Leopold, and wildlife ecology: residential science. Historical Studies in Natural Science 41:216–254.

Leopold, A. 1933. Game management. Charles Scribner's Sons, New York, USA.

Leopold, A. 1948. Why and how research? Transactions of the North American Wildlife Conference 13:44–48.

Leopold, A. 1949. A sand county almanac. Oxford University Press, New York, USA.

McCullough, D. R. Not Dated. Of paradigms and philosophies: Aldo Leopold and the search for a sustainable future. Unpublished manuscript. Department of Environmental Science, Policy, and Management; University of California, Berkeley, USA.

Meine, C. 1988. Aldo Leopold: his life and work. University of Wisconsin Press, Madison, USA.

Romesburg, H. C. 1981. Wildlife science: gaining reliable knowledge. Journal of Wildlife Management 45:293–313.

Roseberry, J. L. 1979. Bobwhite population responses to exploitation: real and simulated. Journal of Wildlife Management 43:285–305.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, USA.

Schorger, A. W. 1946. The quail in early Wisconsin. Transactions of the Wisconsin Academy of Sciences, Arts, and Letters 36:77–103.

Schorger, A. W. 1966. In memoriam: Paul Lester Errington. Auk 83:52–65.

Scott, T. G. 1963. Paul L. Errington, 1902–1962. Journal of Wildlife Management 27:321–324.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. Charles Scribner's Sons, New York, USA.

Stoddard, H. L. 1969. Memoirs of a naturalist. University of Oklahoma Press, Norman, USA.

Way, A. G. 2006. Burned to be wild: Herbert Stoddard and the roots of ecological conservation in the southern longleaf pine forest. Environmental History 11:500–528.

ONE HUNDRED YEARS OF QUAIL MANAGEMENT IN ARIZONA

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ABSTRACT

Populations of Gambel's (*Callipepla gambelii*), scaled (*C. squamata*), and Montezuma (*Cyrtornyx montezumae*) quail in Arizona have fluctuated greatly in the 100 years since statehood as have regulations governing their take. The greatest fluctuations in numbers have been annual, but there is some evidence for a long-term decline in the numbers of all species. Quail hunt success has declined significantly since 1962 according to both check station information ($r^2 = 0.27$; $P<0.0001$) and hunt questionnaire data ($r^2 = 0.35$; $P<0.001$). Past attempts to improve or stabilize quail populations through bag limit and season adjustments have failed to impact quail numbers. Research investigating the influence of harvest on quail numbers showed that subsequent year population sizes fluctuated independent of harvest and that hunting had little effect on population size. Thus, season lengths increased over the years with late winter hunting opportunities becoming increasingly popular after 1979. Studies comparing hunted and non-hunted areas have not been conducted since late season hunting was initiated, and are needed to convince the public that quail populations in areas closed to late season hunting remain similar to those in areas open to late season hunting. Habitat conditions have also changed, deteriorating generally but improving on certain federal lands. Quail management efforts to improve hunt success by providing rainwater catchments and other habitat manipulations have not been effective at increasing population size, and water developments for livestock have resulted in long-term range deterioration. Decreasing population sizes and quail hunt success during the last 50 years, if due to environmental changes, cannot be addressed by regulation changes.

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INTRODUCTION

Quail hunting was an important sport in Arizona Territory along with taking quail for subsistence and commercial purposes. The sport involved in taking Arizona's quail was recognized as early as January 1864, when mining engineer J. Ross Browne wrote:

> "*Quail were very abundant as we drew near our first camping place on the Gila. I killed about two dozen on the wing; that is to say that I was on the wing myself when I shot, but the quail were on the ground. . .*"
> J. Ross Browne, 1869:76

The arrival of the railroads in Arizona in the 1880s opened markets on the Pacific Coast, and the commercial hunting of quail and doves became conspicuous, if not pervasive. Fearing their sport might be in jeopardy, sportsman's organizations such as the Tucson Gun Club prevailed on the territorial legislature to amend the game code in 1893 to extend the sport hunting of quail and other small game through March, and to outlaw the sale and shipping of wildlife during the closed season (Brown 1989).

Gambel's quail appear to have generally persisted in good numbers despite the droughts and landscape changes attendant with, and succeeding, the turn of the 20th century. This was due to the species' natural adaptability to shrub-dominated habitats rather than grassland and the expansion of grain cultivation after 1900 (Brown 1989). Some chroniclers such as Herbert Brown (1900) and Will Barnes (*in* Gorsuch 1934) described Gambel's quail populations as being larger prior to the droughts of the 1890s than later. The evidence is clear, however, that the more grassland-oriented species—scaled quail and Massena (Montezuma, locally known as fool or Mearns') quail declined in both distribution and abundance. Another grass-forb obligate quail, the masked bobwhite (*Colinus virginianus ridgwayi*) was extirpated from the state by 1900 (Brown 1904).

There was still good quail hunting to be had in Arizona after 1900 in spite of game laws often being ignored. An abundance of river bottom vegetation and wheat farming gave Arizona a reputation for quail hunting par excellence (O'Connor 1939). It was also recognized at an early date that Gambel's quail hatching success and population size was influenced by the amount of rainfall during the previous winter (Brown 2009). As today, quail hunting had its ups and downs, and some banner years were reported:

> *Yesterday was the opening day of the quail season, and many local nimrods tried their luck with the gun. The little brown birds at one time bid fair to be an unknown quantity in Arizona, but of late years a wise law for his protection has been in operation and his call can now be heard on all the hills and in all the valleys. At one time trappers captured the quail by the thousands and shipped them by the car load to the markets of*

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> *California. The sportsmen became alarmed at the rapid extermination and the legislature did the rest. Quail are now plentiful all over the country.*
> *Arizona Daily Star*, 16 October 1903

MANAGEMENT

The advent of cities and commerce meant that sport hunting had come to stay and, in 1905, the sale of game was outlawed entirely. The legislature in 1909 limited quail hunting to an open season of 16 October through 31 January, and this season remained in effect in the first state game code passed in 1912 along with a bag limit of 25 quail.

Little information is available on the vagaries of quail hunting between 1913 and passage of a 'new game code' in 1929. Quail management consisted primarily of trapping and transplanting quail to uninhabited or depleted areas, passing an Initiative in 1916 to close the season on 31 December and lower the daily bag limit to 20 'Gambel or Valley Quail,' and establish refuges closed to hunting (Brown 2012). Quail numbers must have been thought in need of improvement in 1929, as the season was again shortened, this time to 1 November through 31 December and the following year the newly appointed Arizona Game and Fish Commission reduced the bag limit to 15 quail per day. No season on Massena (Mearns') quail was authorized.

The conventional wisdom for game restoration in the 1920s called for strictly enforced closed seasons, additional refuges closed to hunting, and vigorous predator control. Quail and other small game species were subject to the same prescriptions as big game except restocking with pen-reared and exotic game birds was much in vogue. These concepts were later found to be simplistic, if not outright erroneous, but this thinking would dominate quail management in the Southwest for 30 years. More than 60 game refuges had been established by the 1930s—several specifically for species of quail (Fig. 1).

Probably the most significant management action in the 1930s was publication of Gorsuch's (1934) life-history study and conclusion that Gambel's quail could best be increased by preserving and rehabilitating their habitat—primarily through elimination of overgrazing. Gorsuch also recommended controlling the quail's natural enemies, better sportsmanship by hunters, the enforcement of reasonable game laws, and continued study by qualified biologists. It was not until 1939, however, when Arizona agreed to participate in the Pittman-Robertson Act that these recommendations could be implemented.

The first efforts to manage Arizona's premier game bird were for deputy wardens and Federal Aid biologists to make summer brood counts to appraise the commission of the year's quail hunt expectations, and to trap quail from farming areas where depredation complaints had been received. Quail hunt regulations fluctuated with the vagaries of supposed population levels: the bag limit was reduced from 15 to 10 in 1934, increased to 12 in 1937, and reduced to 10 again in 1939.

Arizona's first Federal Aid quail study focused on Cochise County, where the objective was to develop a satisfactory management plan and hunt regulations for Gambel's and scaled quail (Griner 1940b). Probably because of Gorsuch's influences, overgrazing and depredations by kangaroo rats (*Dipodomys* spp.) and ants were considered the most deleterious influences in need of investigation (Griner 1940e). Small 'inviolate' refuges near water sources were established, and it was recommended the county be divided into 4 management units, one to be closed to hunting each year on a rotating basis. The reasoning behind this recommendation, which was not implemented, was to reduce hunt pressure on the same coveys year after year.

Other quail investigations in 1940 concentrated on visiting well-known quail locales, reporting on quail conditions, and making recommendations for refuges and water developments (Griner 1940c, d, e; Kimball 1940a, b, c; Lawson 1940a, b). Drought, overgrazing, and overhunting were considered the primary factors limiting quail numbers, although Griner (1940b) recognized the value of green growth to reproductive success—a phenomenon he attributed to the production of Vitamin B-1. Other quail related activities consisted mostly of responding to requests to trap and disperse quail feeding on crops in the Safford, lower Gila River Valley, and Yuma areas (Griner 1940a, Lawson 1940c).

The winter of 1940–41 was abnormally wet, and much needed. The hunt recommendation was conservative despite an excellent hatch, and only a 15-day season was authorized. Kimball (1941a, b, c) thought that drought and heavy grazing had taken too great a toll of the breeding stock during the previous years. The planned implementation of deferred grazing systems, then being promoted by range conservationists, was also thought to be potentially ruinous to quail as all pastures would be grazed 3 years out of 4. A series of small enclosures were recommended as quail refugia to compensate for an increase in grazing duration

The winter of 1941–42 was not so generous. Summer surveys showed a decline in young to adult ratio, even though the successful hatch of 1941 had boosted the number of quail seen on surveys to a new high (Fig. 2). Kimball (1942b, c) unsuccessfully recommended shortening the month-long November season that had already been approved by the commission because of low recruitment.

The most substantial accomplishment in quail management in the early 1940s was the acquisition by the Arizona Game and Fish Department of tax delinquent lands along the lower Gila River for quail habitat. Similar plans for a management complex near Tucson were thwarted when the land was acquired for Davis-Monthan Air Force Base. One important achievement was the first mailing of a small-game hunt questionnaire to monitor the importance of quail to the state's license purchasers—an effort that with modifications would be implemented in the early 1960s (Brown 2012).

The summer surveys in 1943 indicated a disastrous hatch and an extremely low quail population (Fig. 2), and it was reasoned the high harvest enjoyed in 1942 had been

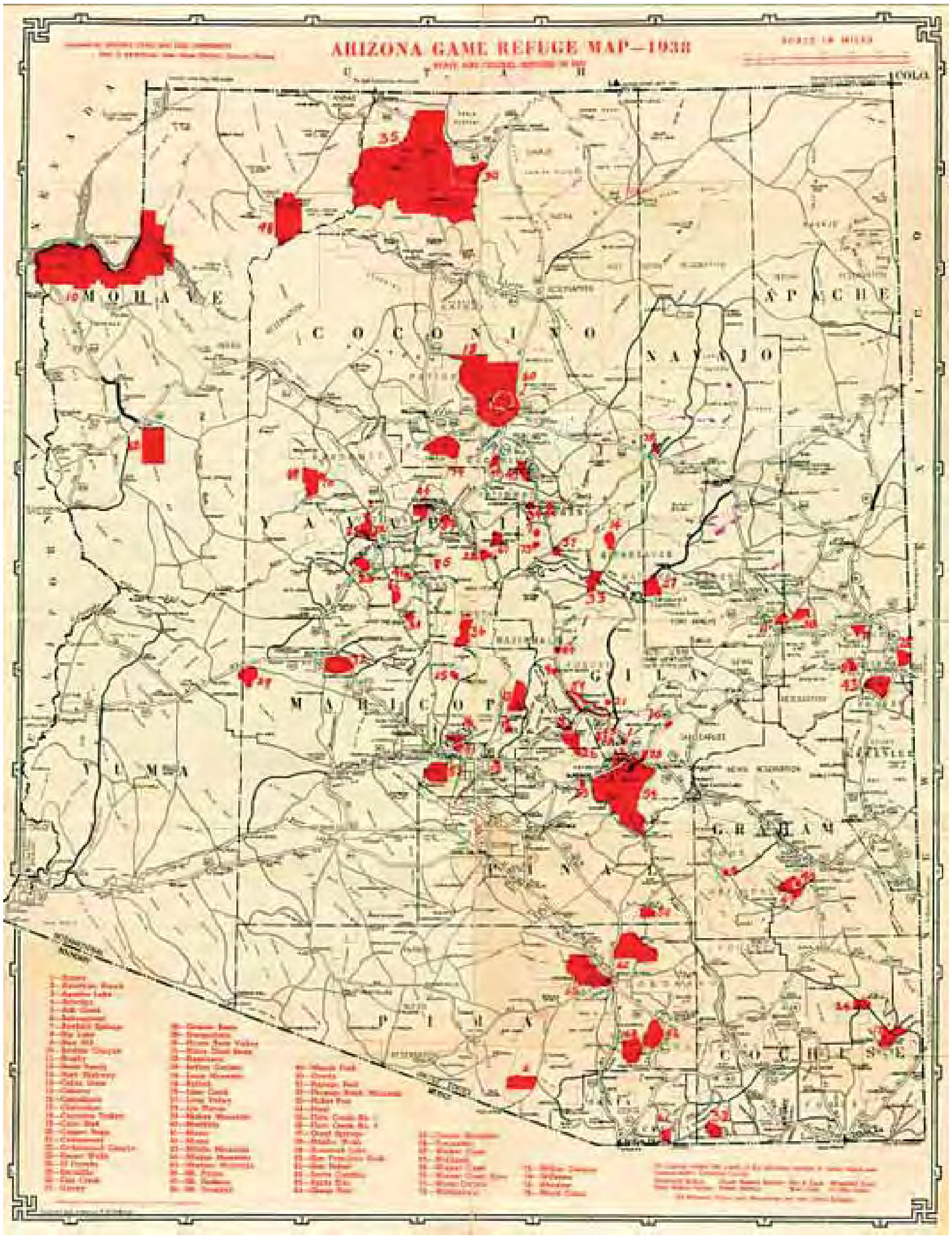
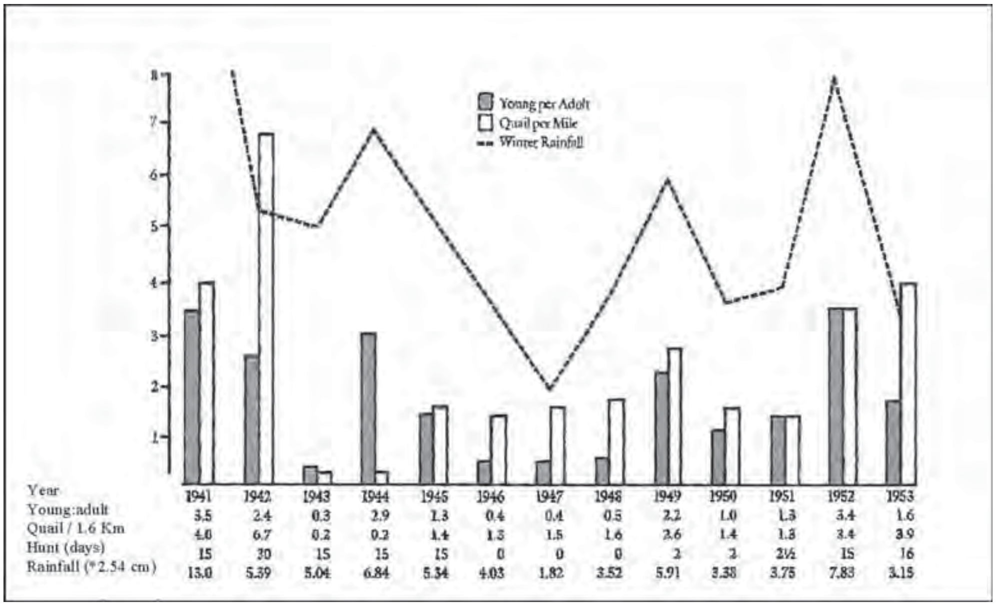


Fig. 1. Arizona State Game Refuges in 1938.

a debilitating factor. That the percentage of young in the 1942 check station bags was considerably lower than observed on July surveys was additional cause for concern. Much of the annual crop had been lost before the season began, and there was a fear the hunt had reduced brood-stock needed for the coming year. The length of the 1943 season was halved to 15 days.

Low quail numbers persisted through the mid-1940s. Some quail restoration plots in Cochise County showed improvement in range conditions, but little if any increase in quail numbers was discernable (Kimball 1942a; Eicher 1943, 1944). Quail management focused on expanding and standardizing summer brood counts, trapping and transplanting excess birds from agricultural areas (e.g., Arrington 1942, Kimball 1943), and implementing conservative hunt regulations. Water developments were given new impetus by Glading's (1943) 'gallinaceous guzzlers' in California, and water catchments specifically constructed to benefit quail were constructed in the Superstition Mountains, Paradise Valley, and other quail hunt areas (Fig. 3, Kimball 1946a).

Midsummer quail surveys in 1945 showed another year of poor quail production, and some populations were deemed the lowest in recorded history (Kimball 1946b).



Year	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953
Young:adult	3.5	2.4	0.3	2.9	1.3	0.4	0.4	0.5	2.2	1.0	1.3	3.4	1.6
Quail / 1.6 Km	4.0	6.7	0.2	0.2	1.4	1.3	1.5	1.6	2.6	1.4	1.3	3.4	3.9
Hunt (days)	15	30	15	15	15	0	0	0	2	2	2½	15	16
Rainfall (*2.54 cm)	13.0	5.39	5.04	6.84	5.34	4.03	1.82	3.52	5.91	3.38	3.75	7.83	3.15

Fig. 2. Standardized Gambel's quail survey and rainfall information in Arizona, 1941–53.

Even the Yuma area, the perennial source of crop depredation complaints and the source for quail stocking attempts, showed a marked decline. Hunting was thought to be additive to natural mortality, and Kimball (1946a) calculated that a ratio of 2.1 young to one adult was needed to justify a hunt. This number was based on Emlen and Glading's (1945) mean annual monthly mortality rate for California quail (*Callipepla californica*), and on past survey and check station data for Gambel's quail in Arizona. Summers having ratios of young to adults above 2.1:1 (1940, 1941, 1944) had been followed by fair to good quail seasons; those years when the young-to-adult ratio was < 2.1:1 were succeeded by poor or decreased hunt success. The statewide young-to-adult ratio observed in 1945 was 0.4:1; there would be no quail season in 1946, 1947, and 1948 (Fig. 2, Table 1; Brown 1989).

A 7-year drought broke in January 1949. Summer quail counts that year showed a statewide young-to-adult ratio of 2.16:1, and a 2-day season was authorized in 2 areas of southwest and east-central Arizona where ratios exceeded the 2.1 minimum (Lawson 1949). The bag and possession limit was 5 quail. The return to quail hunting was short-lived, however. Midsummer surveys in 1950 showed a Gambel's quail young-to-adult ratio of only 1.04:1 and the number of quail seen per 1.6 km of survey reached a new low.

Another miserable quail year followed in 1951, but Kimball's 2.1 young-to-adult criterion was now being scrutinized more closely. Gallizioli (1951a), on the basis of past survey and hunt data, questioned the rationale for closing the season in poor years. Most of the variation in quail hunt success appeared solely due to reproductive performance, population levels showed little relationship to previous hunt regulations and harvests. Sportsmen were also questioning the validity of brood counts, contending the surveys missed counting many young of the year. Additional surveys were conducted at their request, and substantial increases in young quail were noted on many of the routes. Short, local hunts of 2 ½ days each were then authorized in several areas. Survey route procedures were revised and the number of routes expanded (Gallizioli 1951a). Most importantly, a research study was instituted to examine the actual effects of hunting on quail populations (Gallizioli 1951b, 1952, 1953, 1954; Webb 1953).

QUAIL RESEARCH AND MANAGEMENT

Quail were abundant in 1952. Statewide young-to-adult ratios increased from 1:3.1 in 1951 to 3.4:1 – within 0.1 of the 1941 high. A 1–14 December season was approved with a bag limit of 8 quail. The data generated from this and the 1951 hunt, coupled with preliminary research findings, showed how overly conservative past hunt recommendations had been. Swank and Gallizioli (1953, 1954) were now able to show quail populations were heavily dependent on winter precipitation and the success of the hatch. Hunting had little if any effect. The 2-week hunt in late fall with an 8-bird bag limit was continued (with local exceptions). Previous management practices were questioned and either eliminated or modified. Trapping and transplanting practically ceased, refuges were abolished, and the value of water catchments was investigated.

Summer survey routes were modified in 1956, and a test made of a new call-count survey technique pioneered by Senteny (1957) and Gallizioli (1957a). A November-December season was recommended in 1957 as banding studies had shown that no more than 25% of the population would be removed by hunting, the percentage of quail removed was proportional to the density of birds,

Fig. 3. Tom Kimball showing one of the first quail water catchments in the Superstition Mountains, Arizona, ~ 1946. The apron of this ‘gallinaceous guzzler” is of asphalt and the water capacity of the catchment is limited to a few hundred liters.

and that hunting mortality was compensatory to natural mortality (Gallizioli 1957b).

Banding studies by Griner et al. (1941) and Swank and Gallizioli (1953) had shown a high loss of young quail between the midsummer brood count and late fall hunting seasons; thus a split 40-day season from mid-to late October and from mid-December through early January was adopted in 1958 to harvest those juveniles ‘that were going to die anyway’. The daily bag limit was increased to 10. Management efforts now concentrated on improving survey techniques, developing an annual statewide harvest estimate, and establishing a standardized season.

Harvest questionnaires were providing reliable hunt success estimates by 1965 on a statewide basis and a split quail season during the month of October and from 1 December through the end of January was in effect. The closed season during the month of November was to allow cattle growers to conduct round-ups without interference. A 15-bird bag-limit was established as the norm. A major change in survey procedures occurred in 1962 when call-count surveys proved able to predict fall population levels as measured by hunt success with 97% accuracy (Kufeld 1962, 1964, 1965; Smith and Gallizioli 1965; Fig. 4).

November was included in the quail season in 1971 without objection from stockmen and, in 1979, the season was extended to mid-February to coincide with closing of the increasingly popular Montezuma quail season. A standard small-game season opening on the second Friday in October was adopted that year, and this generous season of ~125 days remained in effect to the present time.

MANAGEMENT PRACTICES

Water Development

The practical aspects of water developments on quail populations were resolved by a Department study in the Paradise Valley-Pinnacle Peak area north of Phoenix that began in 1958 and concluded in 1962. Nine rainwater catchments were sealed from use in the study area from January 1961 through the end of the 1962 quail season, effectively drying up 81,000 ha of quail habitat with the exception of one intermittent stock tank. Despite the fact that 1961 was a drier than average year, quail call-counts and hunt success during the 1961 and 1962 seasons was slightly higher in the study area than in the adjacent control area where several rainwater catchments supplied quail with water throughout the spring and summer. It thus appeared water developments served to concentrate birds within certain portions of a covey’s range but had little effect on quail numbers and overall distribution (Gallizioli 1961, 1965).

Effects of Grazing

Gorsuch (1934), Griner et al. (1941), Kimball (1946a), and others considered heavy grazing to have a deleterious effect on Gambel’s quail. They reasoned the resulting reduction in forage and ground cover contributed to an increased mortality of adults and chicks and was an important cause of low quail numbers. These early suppositions were somewhat discredited by the knowledge that Gambel’s quail numbers fluctuated as markedly on grazed ranges as on ungrazed allotments, but the influence of livestock grazing on population carryover remained a concern.

Two similar areas were compared in an attempt to obtain some insights into the impact of grazing on Gambel’s quail populations: the Three-Bar Wildlife Area and a Tonto Basin study area. The former area had not been grazed since ~1944 whereas Tonto Basin was heavily grazed. Both areas were good quail habitat, about the same size, and possessed precipitation stations. Call-count and hunter collection data showed no significant differences in the percentage of young quail in the bag between the 2 areas for the 5 years from 1977 through 1981, even though the call-count index was higher on the non-grazed Three-Bar in all years but one, and hunt success was greater on the Three-Bar (Brown 1989). Hunters averaged almost a bird more per day on the Three-Bar than on Tonto Basin despite the same hatching success in both areas. It could be argued that quail hold better when more ground cover is present, and are thus more susceptible to the gun, but the fact that the call-count index was higher on the non-grazed area 4 of 5 years suggests population carryover was also usually greater on the Three-Bar than in Tonto Basin.

Virtually no field studies of Gambel’s quail have been done since 1981, the species of concern having switched to Montezuma quail and, to a lesser extent, scaled quail, both of which were shown to be impacted by livestock grazing and plant succession.

Table 1. Quail hunt information from statewide hunt questionnaires and Oracle Junction check station, 1940–2010.

Year	No. Quail Harvested	Quail/trip	Quail @ check sta.	Quail/trip check sta.
1940			3,858	6.7
1941			6,794	5.9
1942			8,497	5.0
1943			1,529	3.9
1944			no check sta.	
1945			no check sta.	
1946			no hunt	no hunt
1947			no hunt	no hunt
1948			no hunt	no hunt
1949			no hunt	no hunt
1950			no hunt	no hunt
1951			3,234	2.0
1952			4,303	3.9
1953			4,997	3.3
1954			6,658	3.3
1955			3,365	2.5
1956			1,407	1.7
1957			1,767	2.0
1958				2.6
1959			3,567	2.5
1960			10,395	5.9
1961	303,980	3.2	1,916	2.6
1962	320,865	2.6	9,358	6.0
1963	557,327	4.3	6,928	4.9
1964	711,826	4.1	1,421	2.9
1965	715,007	4.7	5,600	4.9
1966	1,223,243	5.8	3,467	4.3
1967	1,006,519	4.0	885	3.1
1968	1,541,978	5.3	2,115	4.6
1969	1,351,429	4.2	896	3.3
1970	1,026,276	3.3	580	4.3
1971	551,289	2.7	1,017	1.7
1972	468,347	2.5	1,888	2.9
1973	1,108,330	3.8	5,623	4.5
1974	969,270	2.8	1,221	2.0
1975	1,334,195	3.6	2,435	3.7
1976	1,233,308	3.2	1,574	2.1
1977	872,471	2.8	782	2.0
1978	1,580,309	4.2	2,590	4.4
1979	2,903,804	5.0	6,021	6.7
1980	1,987,103	4.5	3,756	5.8
1981	1,317,406	3.1	1,518	3.4
1982	1,303,570	3.4	2,141	3.5
1983	1,459,580	3.6	1,894	3.3
1984	1,181,450	3.1	1,133	2.3
1985	1,357,998	3.2	921	2.1
1986	1,540,736	3.5	372	2.0
1987	996,517	2.9	822	2.4
1988	707,252	2.7	348	1.2
1989	443,111	2.0	139	0.6
1990	342,952	1.6	278	1.1
1991	728,038	2.9	1,084	3.5
1992	1,121,746	3.5	1,802	3.3
1993	1,463,669	3.4	1,556	3.4
1994	1,031,285	2.7	1,511	2.9
1995	1,389,639	3.1	1,394	2.6
1996	833,780	2.1	474	1.2
1997	554,832	2.0	373	1.3
1998	840,258	2.9	1,113	3.0
1999	794,230	2.5	921	2.6
2000	537,202	2.2	365	1.1
2001	814,559	2.8	1,383	3.1
2002	383,453	2.1	256	1.2
2003	759,889	2.7	569	2.1
2004	654,977	2.5	393	2.0
2005	1,566,849	3.9	614	2.9
2006	778,798	2.9	219	0.9
2007	618,982	2.0	162	1.0
2008	362,306	2.4	270	2.1
2009	442,102	2.3	264	1.8
2010			371	2.7

WERE QUAIL MORE ABUNDANT IN THE PAST?

Gorsuch (1934), Leopold (1977), and Brown (1989) speculated that quail numbers, although fluctuating in response to the vagaries of winter precipitation and the hatch, were greater in the 19th century than in the 20th. The historic accounts on which these assumptions are based are too numerous and too detailed to be dismissed out of hand. The argument that this decline is based on long-term habitat alterations is persuasive and cannot be ignored. Mesquite (*Prosopis* spp.) bosques and other riparian habitats in particular have been much altered and Gambel's quail have undoubtedly suffered from years of grazing during times of drought, cessation of wheat farming, onset of industrialized agriculture, and the invasion of saltcedar (*Tamarix* spp.) and other exotic vegetation (Brown 1989).

The big question is whether this decline continues to occur and, if so, what are the actual causes, and, if identifiable, can anything be done to remedy the situation? Check station records show quail hunters at Oracle Junction in 1940, a dry year following prolonged drought, averaged 6.6 quail per hunter day—a success rate not attained now even in the best years. It would appear that quail hunting is less productive now than in the 1940s and 1950s unless one accepts the premise that hunters were formerly more dedicated. Fortunately, due to the monitoring programs implemented in the 1950s and 1960s, we now have the means to track quail hunt success, and fall population levels for the past half century.

The earliest of these monitoring methods were check stations and wing boxes (Brown 1989; Table 1). Provided one accepts the dictum that number of birds bagged per hunter trip is a function of population density, the trend at Oracle Junction, one of the state's premier quail hunting locales, indicates a population decline from 1940 through 2010 ($r^2 = 0.27$; $P < 0.0001$; Table 1, Fig. 5).

A more representative picture for Arizona can be obtained by examining the numbers of quail claimed and bagged per hunter trip as measured by small game hunt

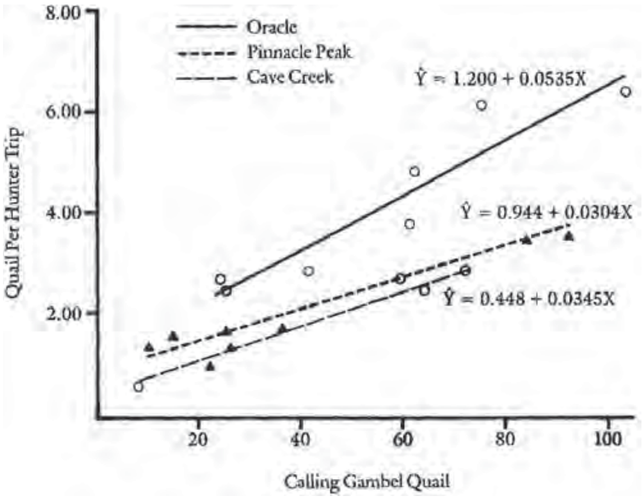


Fig. 4. Quail call count and hunt success information in 3 areas in Arizona. Data from Smith and Gallizioli (1965).

questionnaires. These data, while showing no significant change ($P < 0.10$) in numbers of quail claimed, show that hunt success has also declined since 1962 when questionnaire surveys were initiated ($r^2 = 0.35$; $P < 0.001$; Table 1, Fig. 6).

So, what is happening? Are quail hunters less avid in their pursuit of quail or are quail numbers in long term decline? One argument confounding the later conclusion is that Christmas Bird Count data collected by the Audubon Society in Arizona, while showing large annual fluctuations, show no long-term change in Gambel's quail populations between 1962 and 2010 (Fig. 6: $r^2 = 0.01$: n.s; http//audubon2.org/cbcist/Fig. 7). Thus, the phenomenon of declining quail hunt success may only apply to those public lands open to quail hunting. There are several hypotheses to possibly explain a long-term decline in hunt success.

1. *Quail hunters are less dedicated to their sport than formerly; do not exert themselves as much and quit hunting earlier in the day.*

This assumption is difficult to test and there is little reason at present to assume its validity. Personal observation shows that quail hunters appear as dedicated to their sport as formerly, and more likely to use bird dogs. Nor is there any evidence of an increase in the percentage of novice quail hunters, nor any data to support a decrease in hunter interest or hours spent afield. One must accept the premise that either a higher commitment to hunt success existed in the past or quail are now less easy to obtain, unless further exploration into this phenomenon is forthcoming.

2. *Hunter intensity has increased and more late winter hunting has resulted in increased mortality rates and fewer birds available to breed and nest the following spring.*

This hypothesis, although rejected by most game managers (e.g., Guthery et al. 2004), is testable and needs investigation if for no other reason than to assure the public that prolonged hunting is not depleting breeding stock. Most studies in Arizona and elsewhere have shown hunt mortality in small game populations is compensatory, but there may be situations where intense, prolonged hunting pressure impacts quail numbers—at least locally (e.g., Williams et al. 2004, Rolland et al. 2010). The extension of quail hunting seasons from January to mid-February in Arizona was instituted *after* studies had shown hunting did not result in additive mortality and

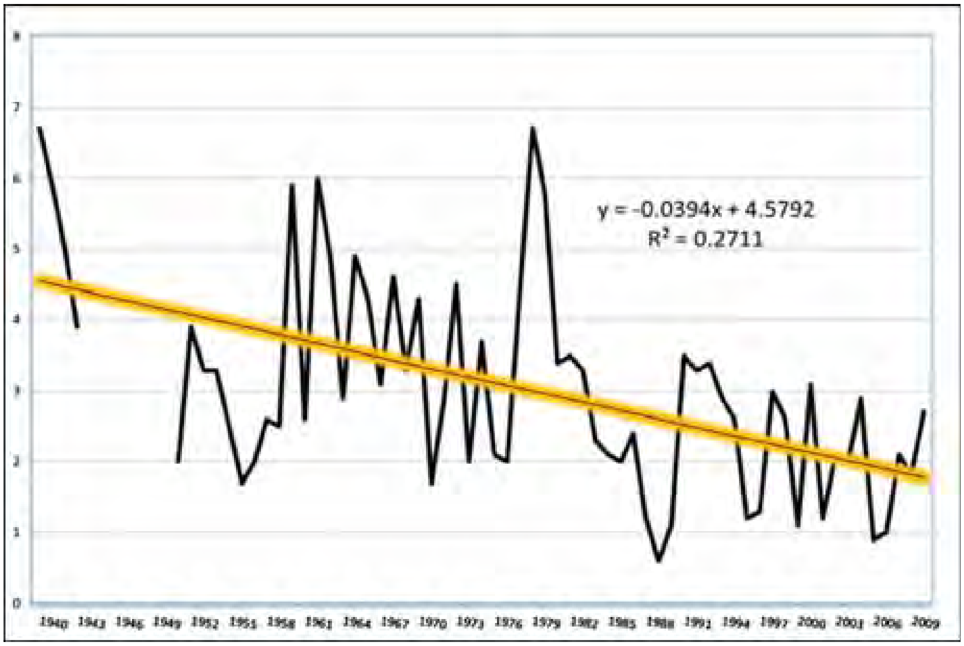


Fig. 5. Quail/hunter trip at Oracle Junction, Arizona check station, 1940–2010.

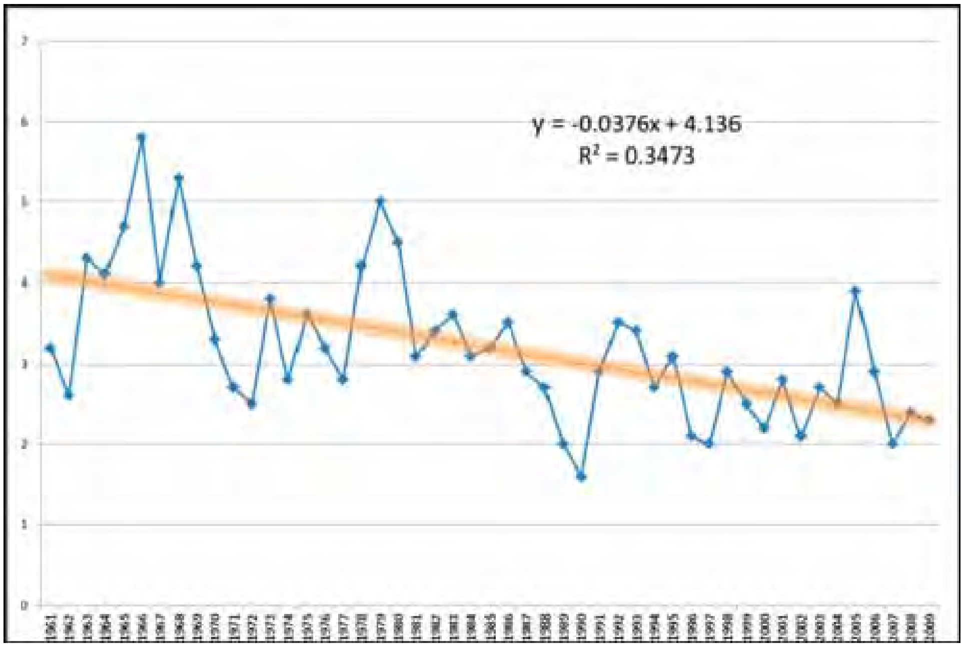


Fig. 6. Quail/hunter trip from mail questionnaires, Arizona, 1961–2009.

subsequent reduced quail population levels. Even though the large expanses and nature of quail habitats in Arizona make an additive mortality hypothesis unlikely, such a situation in local areas could reduce hunt success over time. Whatever the reason, this hypothesis can be tested by comparing quail populations in areas closed to late season quail hunting with those in similar or adjacent areas open to such hunting.

3. *Precipitation totals are in a long-term decline and/or rainfall patterns have changed.*

Most biologists and some hunters are prone to subscribe to this rationale as the reason for a decline in quail numbers despite a lack of statistical documentation. The problem with this explanation is there is little or no evidence to show a long-term decline in either winter or summer rainfall amounts in Arizona's quail habitats after 1960 (Turner et al. 2003). There appears to have been instead an increase in precipitation albeit of a higher variability (McClaran 2003). There has also been an increase in minimum temperatures since 1962, attendant with a continued increase in woody vegetation of tropic-subtropic origin (McClaran 2003, Turner et al. 2003). It is thus possible the overall increase in shrubby vegetation has reduced hunt success, however slight. If so, such a time-sensitive change would be difficult to measure.

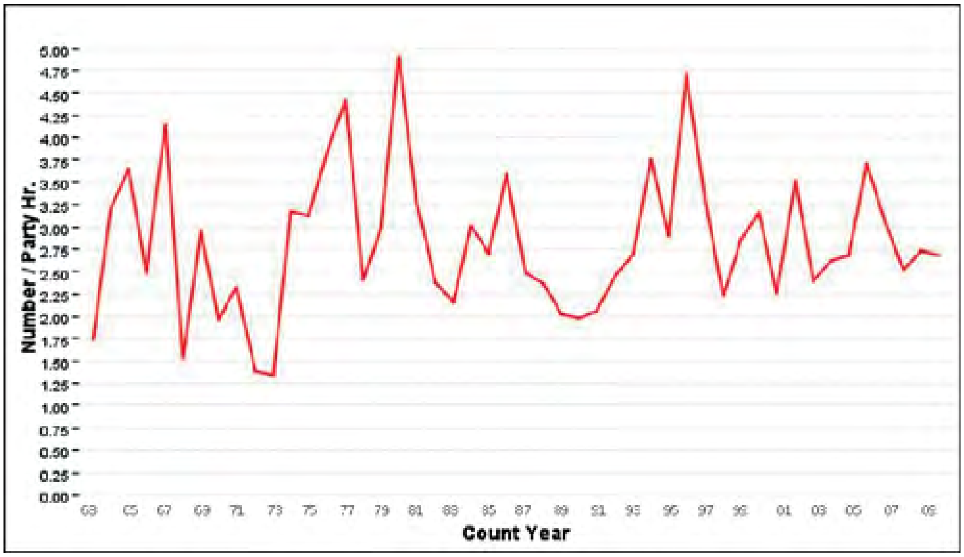


Fig. 7. Number of Gambel's quail seen/party/hr in Arizona on Audubon Christmas Bird Counts, 1962–2010.

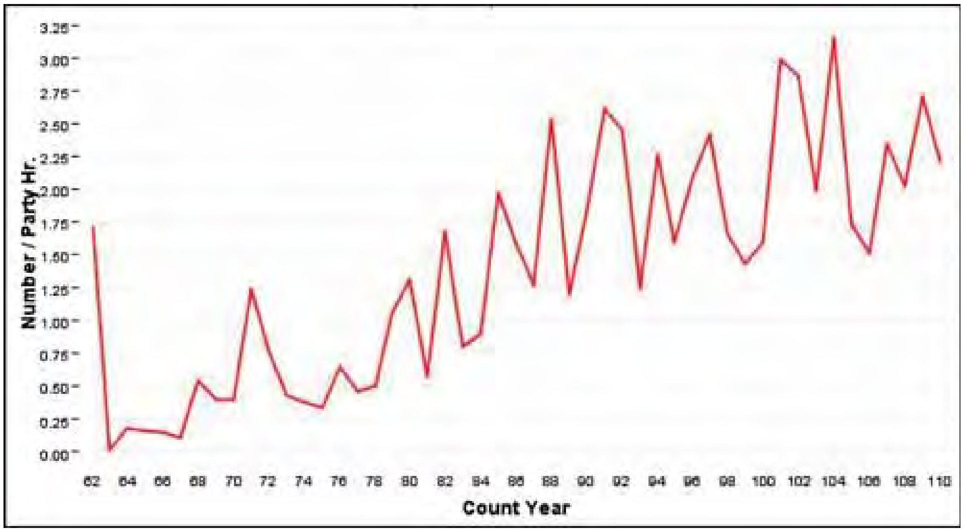


Fig. 8. Number of ravens seen/party/hr on Audubon Christmas Bird Counts, Arizona, 1962—2010.

4. *Habitat conditions have continued to gradually deteriorate due to inappropriate grazing and other land uses.*

This rationale is another favorite explanation for declining quail numbers and appears to have merit. Studies by McAullife and Van Devender (1995) and McAullife 1998) have shown the construction of stock tanks and other improvements concentrate livestock and result in long-term vegetation changes and desertification on public lands. The resulting increased evapotranspiration rates facilitate wind and sheet erosion that results in lower soil productivity. The corresponding changes in vegetation from semi-desert grassland and other vegetation communities of high value to quail populations are gradually replaced by desert-scrub communities with depauperate understories that lower quail numbers and hunt success. This hypothesis can be tested using paired areas, one of which is closed to livestock grazing, over a set period of time.

5. *Predation rates have increased due to increased water developments, more road kills and other ecological changes.*

A major cause of concern by earlier wildlife biologists (e.g., Ligon 1927), predation has long been considered a factor in game bird population dynamics (e.g., Gorsuch 1934, Potts 1986). Even now, some sportsmen continue to relate predation to quail population declines—a hypothesis rejected by most wildlife managers (e.g., J. R. Heffelfinger, personal communication 2012). There are, however, no studies indicating an increase in predation despite a curtailment in the use of predacides and evidence of increases in small carnivore populations and egg predators such as the common raven (*Corvus corax*) after 1972 (Fig. 8; $r^2 = 0.813$; $P<0.001$; Audubon Christmas Bird Count (http//audubon2.org/cbchist/graph.html). Hunt success on coyotes (*Canis latrans*) and foxes (*Urocyon cinereoargenteus* and *Vulpes velox*) in Arizona has also increased since 1991 with a reduction in fur prices and a ban on leg-hold traps (e.g., Arizona Game and Fish Department 2011). It thus appears, at least to some, that increased predation on breeding birds and their eggs could possibly explain a decrease in quail hunt success. Either way, no remedial measures should be taken unless further investigation demonstrates these concerns are justified.

Of the above 5 possible explanation for the decline in quail hunt success, only #'s 2, 3, 4, and 5 can be developed into testable hypotheses and only # 2 can be addressed by regulation changes. However, comparative studies need to examine if late hunt mortality is a factor in decreasing hunt success before any hunter restrictions are made. If # 3 is the cause, nothing can be done and the decline in hunt success will continue. If issues 4 or 5 are involved, only major management changes, difficult to implement, would stop the progression toward lower hunt success.

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LITERATURE CITED

Arizona Game and Fish Department. 2011. Hunt Arizona, 2011. Arizona Game and Fish Department, Phoenix, USA.

Arrington, O. N. 1942. A report on a land inspection survey of proposed Gambel quail release areas in the vicinity of Prescott, Arizona. Federal Aid Project 11-D. Arizona Game and Fish Commission, Phoenix, USA.

Brown, D. E. 1989. Arizona game birds. University of Arizona Press, Tucson, and Arizona Game and Fish Department, Phoenix, USA.

Brown, D. E. 2009. Arizona wildlife: the territorial years–1863–1912. Arizona Game and Fish Department, Phoenix, USA.

Brown, D. E. 2012. Bringing back the game: wildlife restoration in Arizona, 1912–1962. Arizona Game and Fish Department, Phoenix, USA.

Brown, H. 1900. Conditions governing bird life in Arizona. Auk 17:31–34.

Brown, H. 1904. Masked bobwhite (*Colinus ridgwayi*). Auk 21:209–213.

Browne, J. R. 1869. Adventures in the Apache country. Harper Brothers, New York, USA.

Eicher Jr., G. J. 1943. Annual mid-summer statewide Gambel quail survey, 1943. Federal Aid Project 9-R: Quail. Arizona Game and Fish Commission, Phoenix, USA.

Eicher Jr., G. J. 1944. Ecological study of Cochise County quail headquarters areas. Federal Aid Project 9-R, Special Report: quail. Arizona Game and Fish Commission, Phoenix, USA.

Emlen Jr., J. T., and B. Glading. 1945. Increasing valley quail in California. University of California Agricultural Experiment Station Bulletin 695.

Gallizioli, S. 1951a. Annual midsummer quail survey. Federal Aid Project 53-R-2. Arizona Game and Fish Commission, Phoenix, USA.

Gallizioli, S. 1951b. Sectional quail hunts. Federal Aid Project 53, R-2. Special Report. Arizona Game and Fish Commission, Phoenix, USA.

Gallizioli, S. 1952. Pre-season and post-season survey of the Oracle Junction area quail range. Federal Aid Project 53-R-2 Completion Report. Arizona Game and Fish Commission, Phoenix, USA.

Gallizioli, S. 1953. Annual quail survey and investigations. Federal Aid Project W-53-R-3 Completion Report. Arizona Game and Fish Commission, Phoenix, USA.

Gallizioli, S. 1954. Quail hunt information. Federal Aid Project W-53-R-4 Completion Report. Arizona Game and Fish Commission, Phoenix, USA.

Gallizioli, S. 1957a. Gambel's quail population trend technique. Federal Aid Project W-78-R. Arizona Game and Fish Department, Phoenix, USA.

Gallizioli, S. 1957b. The influence of hunting upon Gambel's quail populations. Federal Aid Project W-78-R. Arizona Game and Fish Department, Phoenix, USA.

Gallzioli, S. 1961. Water and Gambel quail. Arizona Game and Fish Department Bulletin. Phoenix, USA.

Gallzioli, S. 1965. Quail research in Arizona. Federal Aid Project W-78-R Special Bulletin. Arizona Game and Fish Department, Phoenix, USA.

Glading, B. 1943. A self-filling quail watering device. California Fish and Game 29:151–164.

Gorsuch, D. M. 1934. Life history of the Gambel quail in Arizona. University of Arizona Bulletin 2:1–89.

Griner, L. A. 1940a. Investigations of quail problems in Yuma Valley, May 8-11, 1940. Federal Aid Project 4-D: quail. Arizona Game and Fish Commission, Phoenix, USA.

Griner, L. A. 1940b. Proposed quail management plan for Cochise County, Arizona. Federal Aid Project 9-R. Arizona Game and Fish Commission, Phoenix, USA.

Griner, L. A. 1940c. Proposed quail refuge area in Pinal County, June 12–17, 1940. Federal Aid Project 4-D: quail. Arizona Game and Fish Commission, Phoenix, USA.

Griner, L. A. 1940d. Quail investigations of Wickenburg-Congress Junction area. Federal Aid Project 4-D: quail. Arizona Game and Fish Commission, Phoenix, USA.

Griner, L. A. 1940e. Report of field trip to Cochise and Santa Cruz counties, May 15-25, 1940. Federal Aid Report 4-D: quail. Arizona Game and Fish Commission, Phoenix, USA.

Griner, L. A. 1941. Quail survey of the Verde Valley. Federal Aid Project 9R. Arizona Game and Fish Commission, Phoenix, USA.

Griner, L. A., T. L. Kimball, and A. A. Nichol. 1941. Gambel quail in Arizona: a preliminary report. Federal Aid Project 9-R: quail. Arizona Game and Fish Commission, Phoenix, USA.

Guthery, F. S., M. J. Peterson, J. J. Lusk, M. J. Rabe, S. J. DeMaso, M. Sams, R. D. Applegate, and T. V. Dailey. 2004. Multistate analysis of fixed, liberal regulations in quail harvest management. Journal of Wildlife Management 68:1104–1113.

Kimball, T. L. 1940a. Quail survey of the Congress Junction-Date Creek area, June 22-30, 1940. Federal Aid Project 9-R: quail. Arizona Game and Fish Commission, Phoenix, USA.

Kimball, T. L. 1940b. Quail survey of the Gila River Valley. Federal Aid Report 9-R. Arizona Game and Fish Commission, Phoenix, USA.

Kimball, T. L. 1940c. Quail survey of the Queen Creek-Superstition Mountain area. Federal Aid Report 9-R. Arizona Game and Fish Commission, Phoenix, USA.

Kimball, T. L. 1941a. Maricopa County quail program. Part I. Paradise Valley Area. Federal Aid Project Arizona 9-R: quail. Arizona Game and Fish Commission, Phoenix, USA.

Kimball, T. L. 1941b. Restoration reconnaissance in Cochise County. Part I. Federal Aid Project 9-R: quail. Arizona Game and Fish Commission, Phoenix, USA.

Kimball, T. L. 1941c. Supplementary survey of the Congress Junction-Date Creek area—July 6, 1941. Federal Aid Report 9-R: quail. Arizona Game and Fish Commission, Phoenix, USA.

Kimball, T. L. 1942a. Ecological study of quail headquarter areas in Cochise County. Federal Aid Project 9-R. Special Report: quail. Arizona Game and Fish Commission, Phoenix, USA.

Kimball, T. L. 1942b. 1942 midsummer survey to determine the current production of quail. Federal Aid Project 9-R Special Report: quail. Arizona Game and Fish Commission, Phoenix, USA.

Kimball, T. L. 1942c. Quail survey of Maricopa County. Federal Aid Report 9-R: quail. Arizona Game and Fish Commission, Phoenix, USA.

Kimball, T. L. 1943. A standardized method of conducting the annual midsummer quail survey. Federal Aid Project 9-R Special Report: quail. Arizona Game and Fish Commission, Phoenix, USA.

Kimball, T. L. 1946a. Experimental quail watering devices, February-March, 1946. Federal Aid Project 9-R Special Report: quail. Arizona Game and Fish Commission, Phoenix, USA.

Kimball, T. L. 1946b. 1946 midsummer survey to determine the current production of quail. Federal Aid Report 9-R Special Report: quail. Arizona Game and Fish Commission, Phoenix, USA.

Kufeld, R. C. 1962. Quail survey and hunt information. Federal Aid Project W-53-R. Arizona Game and Fish Department, Phoenix, USA.

Kufeld, R. C. 1964. Quail survey and hunt information. Federal Aid Project W-53-R. Arizona Game and Fish Department, Phoenix, USA.

Kufeld, R. C. 1965. Quail survey and hunt information. Federal Aid Project W-53-R. Arizona Game and Fish Department, Phoenix, USA.

Lawson, L. L. 1940a. Quail survey of the Camelback Refuge. Federal Aid Project 4-D: quail. Arizona Game and Fish Commission, Phoenix, USA.

Lawson, L. L. 1940b. Quail survey of the Desert Wells Refuge. Federal Aid Project 4-D: quail. Arizona Game and Fish Commission, Phoenix, USA.

Lawson, L. L. 1940c. Reports on quail damage in Lower Gila River Valley, Yuma County, Federal Aid Project 4-D: quail. Arizona Game and Fish Commission, Phoenix, USA.

Lawson, L. L. 1949. Annual midsummer quail survey. Federal Aid Project 40-R. Arizona Game and Fish Commission, Phoenix, USA.

Leopold, A. S. 1977. The California quail. University of California Press, Berkeley, USA.

Ligon, J. S. 1927. Wildlife of New Mexico: its conservation and management. New Mexico State Game Commission, Santa Fe.

McAuliffe, J. R. 1998. Rangeland water developments: conservation solution or illusion? Pages 310–35 *in* Proceedings of a symposium on environment, economics, and legal issues related to rangeland water developments, November 13–18, 1997. The Center for the Study of Law, Science and Technology, Arizona State University, Phoenix, USA.

McAuliffe, J. R., and T. R. Van Devender. 1995. Landscape evolution, soil formation, and Arizona's desert grasslands. Pages 100–129 *in* M. P. McClaran and T. R. Van Devender, eds. The desert grassland. Univeristy of Arizona Press, Tucson, USA.

McClaran, M. P. 2003. A century of vegetation change on the Santa Rita Experimental Range: 100 years (1903–2003) of accomplishments and contributions. U. S. Department of Agriculture, Conference Proceedings, Tucson, Arizona, USA.

O'Connor, J. 1939. Game in the desert. Derrydale Press, New York, USA.

Potts, G. R. 1986. The partridge; pesticides, predation and conservation. William Collins and Sons Ltd., London, United Kingdom.

Rolland, V. J., A. Hostetler, T. C. Hines, H. F. Percival, and M. K. Oli. 2010. Impact of harvest on survival of a heavily hunted game bird population. Wildlife Research 37: 392–400.

Senteney, P. F. 1957. Factors affecting the nesting of Gambel quail in southern Arizona. Thesis. University of Arizona, Tucson, USA.

Smith, R. H., and S. Gallizioli. 1965. Predicting hunter success by means of a spring quail count of Gambel quail. Journal Wildlife Management 29:806–13.

Swank, W. G., and S. Gallizioli. 1953. The influence of hunting and of rainfall upon Gambel's quail. Arizona Game and Fish Department Special Report. Phoenix, USA.

Swank, W. G., and S. Gallizioli. 1954. The influence of hunting and of rainfall upon Gambel's quail populations. Transactions of the North American Wildlife Conference 19:283–296.

Turner, R. M., R. H. Webb, J. E. Bowers, and J. R. Hastings. 2003. The changing mile revisited: an ecological study of vegetation change with time in the lower mile of an arid and semiarid region. University of Arizona Press, Tucson, USA.

Webb, P. M. 1953. Trapping, tagging, and releasing quail on the Three Bar area. Federal Aid Project W-11-D. Arizona Game and Fish Commission, Phoenix, USA.

Williams, C. K., R. S. Lutz, and R. D. Applegate. 2004. Winter survival and additive harvest in northern bobwhite coveys in Kansas. Journal Wildlife Management 68: 94–100.

ADAPTIVE MANAGEMENT AND STRUCTURED DECISION MAKING: IS IT REALLY THAT EASY?

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ABSTRACT

The terms adaptive management and structured decision making are now commonplace in the field of wildlife management. The essential elements of each include unambiguous, measurable objectives, management alternatives for achieving those objectives, and at least a conceptual model for predicting the consequences of enacting each alternative. Many self-proclaimed practitioners do not understand the complete and correct application of these decision making tools, and many of the most likely beneficiaries are fearful of attempting to use them for similar reasons. The most common misconception is that these approaches equate to modeling or decision making by trial and error. The next most common misconception is that large amounts of data and complex simulation models are required before starting either process. Obviously, more information leads to more informed decisions, but frequently starting with a structured process leads to gathering more of the right information to inform decision making. Developing and applying adaptive management and structured decision making, done correctly, requires multiple participants representing analysts, researchers, managers, and beneficiaries, each of whom bring different essential skills to the process. However, none of the participants must possess all of those skills. When representatives from each of these groups work within their own skill sets, the rest is comparatively easy and requires only that all parties share a basic understanding of the process, a commitment to a shared set of wildlife conservation objectives, and transparent, open communication regarding the essential elements. Adaptive management also requires a commitment to monitoring to inform future decisions. The steps used to develop these decision support tools for conservation and wildlife management are the same for problems that range from site-level decisions to apply specific management actions, landscape-level decisions to prioritize areas for acquisition and management, and policy decisions that affect conservation at continental scales. Many of these problems do not require full application of adaptive management unless iterative decision making is required, and there is uncertainty with regard to the mechanisms leading to the consequences of management. Adaptive management can provide a means of learning more about those mechanisms while maximizing the likelihood of success. It is relatively easy to understand the development and implementation of these powerful management tools. The difficulty lies in obtaining the commitment necessary for their implementation.

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THE WESTERN QUAIL MANAGEMENT PLAN

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ABSTRACT

The Western Quail initiative was first proposed at Quail III in 1993. The reasons for creating this group were to improve management of western quail, assess populations range-wide, identify current threats, improve habitat, and identify research needs. The Western Association of Fish and Wildlife Agencies (WAFWA) approved creation of the Western Quail Working Group (WQWG) in July 2009. The purpose of the group is to implement the habitat objectives and management recommendations outlined in the Western Quail Management Plan, published by the Wildlife Management Institute in January 2010. Membership in the WQWG includes representatives from state and federal wildlife agencies and non-governmental organizations involved in wildlife habitat improvement. The first meeting of the group was at the January 2011 meeting of WAFWA in Tucson, Arizona where Memoranda of Understandings (MOUs) among the states and federal land management agencies were crafted and then signed by WAFWA states and Federal agencies at the July 2011 WAFWA meeting. The WQWG is poised to re-energize habitat restoration, research, and management of species of western quail throughout the Western United States. We welcome all partners who wish to be a part of this effort.

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QUAIL VII, A DIRECTOR'S PERSPECTIVE

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Key words: adaptive resource management, *Colinus virginianus,* NBCI, northern bobwhite, Southeastern Quail Study Group

Welcome to the 7th National Quail Symposium! I am Jon Gassett, Commissioner of the Kentucky Department of Fish and Wildlife Resources, and Chairman of the NBCI Management Board. I would also like to extend the welcome of Nick Wiley, my co-chair, and Executive Director of the Florida Fish and Wildlfe Conservation Commission. I see a lot of friends in the audience, and quite a few new faces as well, and on behalf of the Board, I want to thank you all for the heart and soul that you each put forth for the sake of the northern bobwhite.

THE PAST

As some of you may know, I grew up in Georgia and spent my earliest hunting years following behind some of the best bird dogs known to mankind...those raised by my grandfather – or at least I thought so as a seasoned 8-year old hunter.

That was a time when birds were still relatively plentiful, and if you were lucky enough to have a granddad that sold Ford trucks to the farming communities south of the fall line in Georgia, you had plenty of farms to hunt on. But as is inevitable, times have changed.

Land use patterns, farming practices, private leases, and competition for life needs have resulted in a long protracted slide in quail numbers as well as the people that pursued them. The 40-year decline of this prince of game birds was already apparent even before the passing of my last bird dog and of my grandfather whose footsteps I used to walk in.

This story is the same for many of the state fish and wildlife directors throughout this country. Growing up hunting small game with family and friends - dreaming of finding a way to make a career of spending time outdoors every day – going to college to major in Wildlife Biology, of all things – landing that first job as a wildlife biologist and working in the field – then getting promoted to your level of incompetence until you are forced to stay inside, ride a desk, push paper, and manage personnel and budgets and to run an agency instead of being outside with the critters.

State agency directors have long held an interest in the restoration and recovery of the native fish and wildlife species of their respective states. White-tailed deer, wild turkey, elk, waterfowl, black bears, furbearers, eagles, and many others all have their place among our long history of successes.

However, few, if any, have held the intrigue, or generated the frustration levels comparable to that of the iconic northern bobwhite. This species, which has tormented and delighted professionals and laypersons alike, has rightfully taken its place among state agencies as the Holy Grail – the prince of game birds - a highly desirable and lofty, yet sometimes, seemingly unattainable recovery goal.

Where the recovery and restoration of other species are shining examples of what we are all capable of, few demanded sweeping landscape level changes to succeed. Most were simply the case of having adequate preexisting habitat conditions and simply moving critters around to fit our needs.

Northern bobwhite recovery has always presented a unique challenge – that being, to change the attitudes of people to affect wholesale landscape level changes to habitat that are essential to their recovery.

A decade ago, the Northern Bobwhite Conservation Initiative had, as its genesis, a collective group of southeastern state directors acting on the good advice and recommendations of the Southeast Quail Study Group.

The thought of bobwhites once again taking to the sky behind one's hunting dog whetted the appetites of several of those directors, and we asked, then begged and finally arm-twisted each participating state to carve out baseline funding to get the Initiative off the ground.

However, the task was daunting. . .the restoration of a species that has succumbed to decades of habitat loss or conversion was comparable only to the recovery of our nation's migratory waterfowl populations, but without the federal authority, protection, and funding, through the Duck Stamp and the North American Wetlands Conservation Act, to help us move the needle toward success.

It was the idea of a range-wide recovery approach, garnering support at the State, Federal, NGO, and private sector level, rather than a piecemeal state-by-state approach, that sparked the interest of those southeastern directors, generating support, both financially and politically, and leading to the birth of regional recovery strategy that soon evolved into the full blown, range-wide effort of which we are all now a part.

With a foundation steeped in science and sound policy, and with guiding principles that contain language like: Heritage, Stewardship, Landscape, Working Lands, Habitat, Partnerships, Adaptive Management, and Col-

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laboration, the NBCI is well developed to be THE road to recovery for the northern bobwhite.

THE PRESENT

So I would like to provide one Director's perspective of the first 10 years of the NBCI. To do this, we might ask ourselves, "How have we done over the past 10 years?" "Are there measures of success from Generation One of the NBCI plan?" "Has NBCI met directors' expectations?" or are we just proving the definition of insanity - doing the same thing over and over again, while expecting a different result?

I won't speak for the other state directors, those types being the fickle, opinionated and contrary folks that they can be…but I will say that my interactions with them indicate that many of us share similar feelings on the NBCI and its work over the past decade.

We have laid a fantastic framework from which to stage the recovery of this most challenging species. Scientists, managers, and policy makers have come together to develop, nurture, support, and even fund our first efforts. And we have had successes.

Across the range of the bobwhite, individual success stories of farmers and landowners are cropping up like weeds. The public is beginning to re-engage on the quail issue, and this is critical to driving the plan forward into Generation Two.

More broadly, we are seeing regions within states take on the issue with bobwhite focus areas –intensively managed multi-county areas with local and state level buy-in. And nationally, we are engaging in negotiations with Farm Bill lawmakers, NRCS, and FSA at levels that we formerly only dreamed.

With the revision of the NBCI plan late last year, we are poised to take the next step. By painting the picture that northern bobwhites are a keystone species for grassland ecosystems, the new plan revision has the potential to generate support from a much larger conservation community.

Incorporation of the latest GIS and data management tools into a Conservation Planning Tool give us the ability to focus on both broad scale recovery efforts as well as more localized approaches – all from the same data source.

The Adaptive Resource Management approach incorporated into the new revision allows us to use a structured decision-making process that will indicate where we are hitting our mark and where we are falling short.

"The State of the Bobwhite: Grassland Conservation at a Crossroads"- our review of the status of the species – was sobering. It would have some asking if the bobwhite has a place on the Endangered Species List rather than on a covey rise in front of a good pointing dog, or next to the potatoes, biscuits, and gravy.

However, as alarming as this report appeared, there is a positive side. Most great conservation efforts started with a threat, sometimes of extinction, that led to a call to arms. When wetlands were being drained at an alarmingly reckless rate, we secured the federal duck stamp for their protection under the National Wildlife Refuge System, and later secured further protections for private wetlands in the swampbuster provisions in the Federal farm bill.

When waterfowl reached historic lows in many areas, we implemented Adaptive Harvest Management Techniques, developed the North American Waterfowl Management Plan (NAWMP), and its funding source, the North American Wetlands Conservation Act.

We can draw a number of comparisons between the North American Waterfowl Management Plan and the Northern Bobwhite Conservation Initiative. Both are science-based approaches. Both focus on landscape level habitat needs. Both are responsive to long-term declines in population numbers. Both focus on significant, but obtainable recovery goals. Both go through a periodic comprehensive review that is the cornerstone of adaptive management. Both have ties to the Joint Ventures. And both have extensive involvement and buy-in from state fish and wildlife leadership.

From its genesis in 2002 through its revision in 2011, State Directors have never flinched from the concept that the NBCI is a long-term approach to conservation. We didn't get here overnight, and we won't see recovery happen that quickly either.

But success takes funding. From the development of NAWMP in 1986 and its subsequent updates, we have seen significant recovery of waterfowl populations. We have also seen a cash infusion of around 6 billion dollars through the joint ventures – a number that dwarfs the restoration price tag of any other species of which I am aware. NBCI's next major goal, should be to work towards that level of funding for our Initiative.

THE FUTURE

So what about the future? What's next? What should we expect from the state directors and the NBCI Management Board, specifically? And more broadly, where is the NBCI headed?

The battlefield for bobwhite recovery is mapped out by the good science that you do, and you managers out there are our infantry. But battles are won by moving troops and resources across that field in a strategic manner. This is the area where state directors, generally, and NBCI board members, specifically, should be making their living.

The scientists and managers have their part to play, but if the commanders of the battle, the policy makers, have lost sight or interest in success, then we will all fail. The job of the NBCI Management Board is to make sure that our state fish and wildlife directors don't lose sight of the NBCI goals and don't lose their interest in success. We will make sure this doesn't happen.

This can be a difficult challenge, as you might imagine. State agency leaders tend to be very accomplishment-oriented. In times of increasing budgetary constraints, conflicting demands on time and resources, and difficult, sometimes hostile political pressures, directors want results, and results, and more results!

We need results that are not just those of the scientific variety. Science is a critically important aspect of wildlife management, and a place where quail coordinators and biologists play well, but we need results on many different fronts. Public opinion, changes in behavior, shifts in public policy, anything that results in increasing awareness and importance will, by its nature, assist in providing the support and funding necessary to carry out our task.

Remember that science can explain how the internal combustion engine in your car works, but ultimately somebody still has to put gas in the tank to make it go.

Success on the ground is the litmus test of the success of the NBCI, but it takes results at all levels to accomplish our mission. We have good science and will continue to develop more.

But the ultimate battle for success, which you can read as the battle for funding and public support, will be determined by how successfully we can use that science in the halls of Congress, in our State Legislatures, and with our public.

So how do we continue to build upon an already successful Initiative? As a part of the NBCI, should we all become advocates for quail recovery? What about the conflict between science and advocacy?

The short answer is: yes, we should. The longer version was best put into words by the great conservationist, President Theodore Roosevelt. In one of his greatest speeches, he stated:

> *"It is not the critic who counts; not the man who points out how the strong man stumbles, or where the doer of deeds could have done them better. The credit belongs to the man who is actually in the arena, whose face is marred by dust and sweat and blood, who strives valiantly; who errs and comes up short again and again; because there is not effort without error and shortcomings; but who does actually strive to do the deed; who knows the great enthusiasm, the great devotion, who spends himself in a worthy cause, who at the best knows in the end the triumph of high achievement and who at worst, if he fails, at least he fails while daring greatly. So that his place shall never be with those cold and timid souls who know neither victory nor defeat."*

Scientists are cautioned from their first research experience about straying into the nefarious world of advocacy. Their job, they are told, is to simply develop hypotheses, collect data, make analyses, draw conclusions based on the previous 3 steps, and repeat.

Taking a position for or against something because it's the right thing to do is simply not the sandbox that scientists are supposed to play in, or so they are taught.

Folks, we don't have time for that kind of nonsense. As leaders, we expect you do good science, and produce valid, reproducible results. As managers, we expect you to apply to the ground what science indicates are the best practices.

But if you stop at that, and sit around waiting for the advocates to ride in with bags of money and convince the unwashed masses that restoring bobwhites is the right thing to do for conservation, then we have already lost the war.

As an example, I would like to spend a second talking about a recent wildlife threat that I have been intimately involved with that I think will demonstrate my point.

White-nosed syndrome is a fatal disease that is ravaging the populations of our cave dwelling bats. It appears to have a fatality rate approaching 100%, but the science isn't there yet. It appears to be spread by human and bat movement between caves, but the science isn't there yet. The one thing is does do is kill bats - millions of bats. And some, I suspect, have sat on their hands, content to simply document the decline of the bats, and fail to manage, for fear that active management may cause more harm. And others, I suspect, have sat on their research – not releasing it until it is published for fear of getting scooped – while the managers sit waiting for the scientists to tell them the right thing to do.

Meanwhile, the bats will be decimated, and many species will likely go extinct, because we lack the intestinal fortitude to do something. . .to dare greatly.

So there are those that watch things happen and those that make things happen. Restoration success stories are written by those that make things happen. Critics have the luxury of sitting on the sidelines, watching things happen, and pointing out our missteps and mistakes, but those types seldom make history.

There is a time and place for science, for management, for advocacy, and for action. We know a lot about bobwhites, but there will always be more we want to know. We also know that their recovery is a one of the greatest challenges we will face, but it will also be one of our greatest successes, and we don't need science to tell us that.

It is time now for our state and federal agencies, our NGOs, private partners, and our scientists and managers, under the umbrella of NBCI, to do for northern bobwhites what we have done for the ducks. To fight for what we know is the right thing to do. We have to get into that arena, get sweaty and dusty and bloody, and we have to win. We all have to get in the arena and dare to do great things!

Thank you for having me here today and thanks for all that you do for the NBCI and for bobwhite conservation!

IMPACTS OF INVASIVE, EXOTIC GRASSES ON QUAIL OF SOUTHWESTERN RANGELANDS: A DECADE OF PROGRESS?

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ABSTRACT

Exotic grass invasions are a serious concern for State and Federal agencies, non-government organizations, and private landowners engaged in quail conservation and management. Quail biologists recognized the potential negative impacts of exotic grass invasion on North American quail populations 2 decades ago. This issue was addressed in a review paper published in the Proceedings of the 5th National Quail Symposium in 2002. That paper reported the state of our knowledge on impacts of exotic grass invasions on 5 quail species inhabiting southwestern rangelands. Our objective is to update the progress of exotic grass-quail research on southwestern rangelands during the past decade by reviewing studies that provide specific results about the impacts of exotic grass invasions on southwestern quail populations. Results of studies that have quantified the impacts of exotic grass on quail habitat use are summarized and discussed along with studies that describe how exotic grasses impact important components of quail habitat such as diversity and abundance native herbaceous plants and arthropods. Management of exotic grasses is also discussed.

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Key words: exotic, fire, grass, herbicide, invasion, management, quail, range, southwest

INTRODUCTION

The status of quail populations on rangelands of the southwestern United States continues to be of concern to Federal, State, and private land natural resource managers, upland bird hunters, and bird watchers. Populations of the 6 native quail species in North America have not increased despite recognition that western quail species needed prompt attention from quail biologists during the

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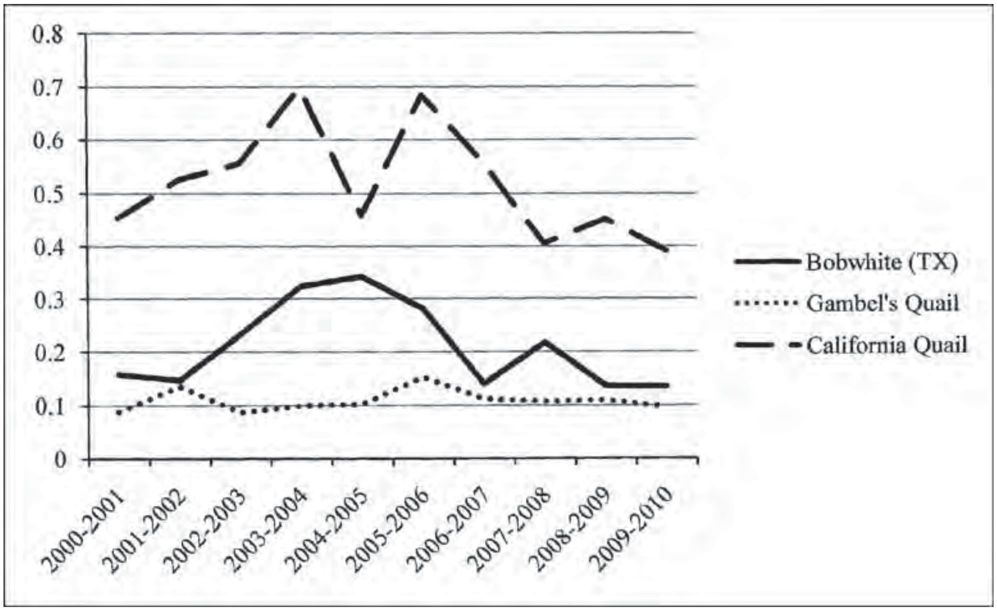

Fig. 1. National Audubon Society Christmas Bird Count population trends in number of birds per hour for northern bobwhites from Texas, and Gambel's and California quail from the United States between 2000 and 2010.

Quail III (Robel 1993) and Quail V (Brennan 2002) symposia. The National Audubon Society's Christmas Bird Count (CBC) data from 2000 to 2010 (National Audubon Society 2010) indicate Gambel's (*Callipepla gambellii*), scaled (*C. squamata*), and Montezuma (*Cytronyx montezumae*) quail populations remained stable over the past decade (Figs. 1, 2). Montezuma quail numbers remain extremely low and Gambel's and scaled quail populations have trended downward over the past 3 years (2007–2010). The status of northern bobwhites (*Colinus virginianus*) (data restricted to Texas), mountain quail (*Oreortyx pictus*), and California quail (*C. californica*) are even more worrisome because CBC data indicate that populations continued to decline over the past decade.

There are myriad reasons for declines of native quail species in the southwestern U.S; however, habitat loss continues to be one of the primary concerns among quail biologists (Brennan 2002, Zornes 2009). Factors commonly observed that involve loss of quail habitat that are immediate and noticeable include urban and suburban development, livestock overuse of rangelands, and an increase in modern farming activities. The invasion of southwestern quail habitats by exotic plant species represents a more subtle and less immediate form of habitat loss that has been occurring for decades. This was

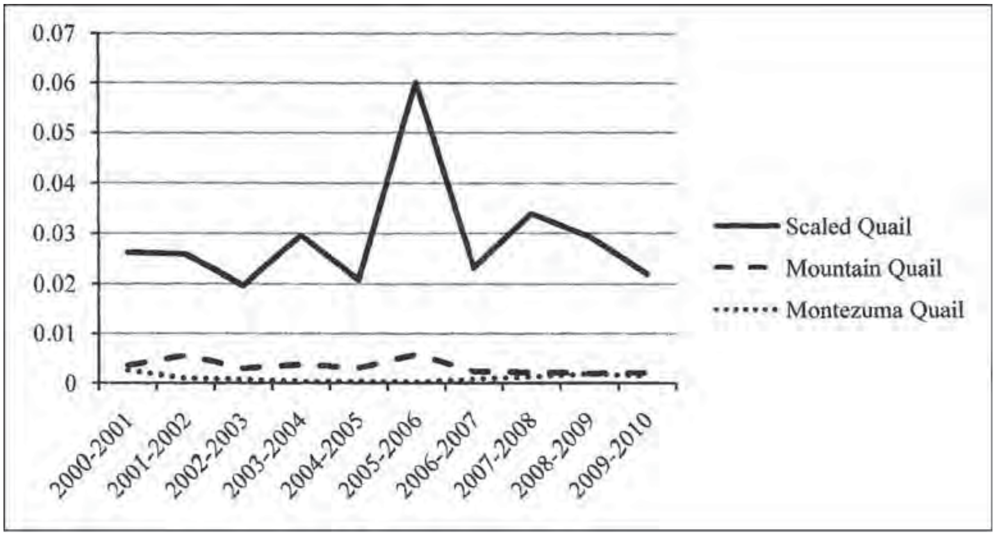

Fig. 2. National Audubon Society Christmas Bird Count population trends in number of birds per hour for scaled, mountain, and Montezuma quail from the United States between 2000 and 2010.

first detailed as a threat to quail populations by Engel-Wilson and Kuvlesky (2002) and Kuvlesky et al (2002). The potentially negative consequences that exotic grasses have on Gambel's, scaled, and Montezuma quail, and northern and masked bobwhites (*C. v. ridgwayi*) were reviewed by Kuvlesky et al. (2002) who noted the need for research on the quail/invasive exotic grass issue was desperately needed to better manage the potential threat to quail populations.

Our objective is to review research addressing the invasive exotic grass-quail issue that has been accomplished during the decade since Quail V. Most of the research that has been accomplished during the past 10 years has been on northern bobwhites, and that section is limited to bobwhites. We believe understanding how invasive exotic plants impact quail is important and this paper provides updated reviews of (1): how exotic grass invasions impact rangeland vegetation communities used by quail; (2): how exotic grass invasions impact arthropod communities, which are important quail food; (3) how exotic grass communities impact quail and (4): potential strategies to manage invasive exotic grasses to benefit rangeland quail populations.

EFFECTS OF INVASIVE PLANTS ON NATIVE RANGELAND COMMUNITIES

Invasive exotic plants are an unfortunate reality in the United States. Most introductions were made with the intention of improving food and fiber production or to improve aesthetics (ornamental plants). Most of the estimated 5,000 species of exotic plants that have become established in native ecosystems have significantly altered these ecosystems by displacing native plant species (Pimental et al. 2005). Displacement of native plant species by introduced plants often has a cascading negative impact on the invertebrate and vertebrate organisms that also co-inhabit the invaded ecosystems. Many exotic grasses from southern Africa, Mediterranean regions, and Eurasia were first introduced to the overgrazed rangelands of the southwest U.S. to stabilize soil surfaces and provide forage for cattle with the hope these introductions would improve the economics of livestock production. Certain introduced grasses have economically benefited livestock producers in specific locations, such as buffelgrass (*Pennisetum ciliare*) in southern Texas. Others have become costly weeds that are difficult for livestock producers to control (e.g., invasion of Old World bluestems in coastal bermudagrass [*Cynodon dactylon*] pastures).

The impact of these exotic grasses on ecosystem processes and dynamics at the time of introduction was not part of the discussion. For example, Pimental et al. (2005) estimated the cost associated with exotic plant invasions (e.g., loss of livestock forage, costs of herbicides) on pastures in the United States is 6 billion dollars; they also indicated that numerous threatened and endangered species that occur on pasturelands are at risk due to competition from invading exotic plants.

The impacts of exotic plant invasions continue to be a major concern for natural resource managers. This is because exotic plant invasion on millions of hectares of southwestern rangelands continues unabated today and may be getting worse. Gori and Enquist (2003), for example, estimated non-native grasslands comprise 22.6% of current U.S. grasslands in southeastern Arizona alone: Boer lovegrass (*Eragrostis chloromelas*) and Lehmann lovegrass (*E. lehmanniana*) are common and/or are the dominant grass species on > 556,560 ha. Additionally, cheatgrass (*Bromus tectorum*) has invaded 5 million ha in Utah and Idaho since it was introduced to North America, and has diminished the flora and fauna of the ecological communities it has invaded (Pimental et al. 2005).

Ingress of exotic plants into native plant communities is a continuing process, resulting in dominance of increasingly large tracts of land by more exotic plants. Bowers et al. (2006) examined trends of abundance of exotic plants on a Sonoran Desert site and found that between 1982 and 2005 the number of exotic species increased from 34 in 1982 to 44 in 2005. The percentage of casual, naturalized, and invasive categories of exotic plant species increased by 44, 40, and 15%, respectively. These findings led the authors to conclude the longer a species persists, the more likely it is to overcome barriers to naturalization and invasion; ultimately the proportion of exotic plant species on their Sonoran Desert study area will continue to increase over time. Unfortunately, little has been accomplished since 2002 to reduce exotic grass invasions and the detrimental impacts invasive exotic grasses have on native plant communities. These intentional and unintentional introductions of exotic grasses to southwestern rangelands continue to damage native plant communities.

Buffelgrass

Buffelgrass is one of the most damaging of exotic grasses to southwestern native plant communities. Buffelgrass is a native of South Africa that was introduced to Texas in the early part of the 20th century in an effort to improve forage production for cattle on native rangelands. It had become naturalized by the end of the 1950s over most of South Texas (Hanselka 1988). It has adapted so well to the rangelands of Texas that over 20 years ago Hanselka (1988) described buffelgrass as 'South Texas Wonder Grass.' It was the most important grass in South Texas from a cattleman's perspective because it was an adaptable and drought tolerant plant, and increased livestock carrying capacity almost threefold (Hanselka 1985). However, buffelgrass can pose significant problems for native plant communities once it is established and becomes the dominant plant species. For example, Flanders et al. (2006) found that native forb and grass diversity, and abundance in South Texas was significantly lower on sites dominated by buffelgrass, along with Lehmann lovegrass, than on sites dominated by native plants. Sands et al. (2009) studied the impacts of buffelgrass invasions on native herbaceous plant communities in the western Rio Grande Plains of Texas for 2 years and found that in plots with > 25% buffelgrass the native forb canopy was reduced by > 70%, native forb species richness was reduced by > 60%, and forb stem density was reduced by > 70% compared to plots with < 5% buffelgrass. Olsson et al. (2011) reported that portions of the Sonoran Desert invaded by buffelgrass were characterized by lower native perennial plant cover and species richness, and that cover and richness declined as time increased post-invasion indicating an ongoing transformation from a rich perennial shrub community to exotic plant community was occurring. Rogstad et al. (2009) indicated the biological diversity of the Sonoran Desert was threatened, in part, by the invasion of exotic grasses and indicated buffelgrass is particularly harmful because it readily suppresses annual and perennial plants, and forms dense stands in a desert that initially supported low densities of perennial grasses. Buffelgrass is a tenacious invader and supremely well adapted to rangelands from coastal southern Texas to the Sonoran Desert in southern California; it represents a significant threat to the biodiversity of millions of hectares of the southwestern U.S.

Additional Exotic Grasses

Invasions by other exotic grass species also negatively impact native vegetation communities. For example, Rogstad et al. (2009) indicated that red brome (*Bromus madritensis*) invasion posed a significant threat to the biodiversity of the Sonoran Desert because it gradually excluded native annual and perennial plants. Gabbard and Fowler (2007) examined the ecological amplitude of King Ranch bluestem (*Bothriochloa ischaemum*) on the Edwards Plateau of Texas and found this African exotic grass displayed little habitat preference because it was found in virtually every habitat type sampled. Moreover, in the plots where King Ranch bluestem was dominant, native plant species richness and diversity were lower than in plots with no King Ranch bluestem. Similarly, in another study conducted on the blackland prairies of central Texas, Wilsey et al. (2009) reported that herbaceous plant species diversity in exotic plant communities that included King Ranch bluestem and Johnsongrass (*Sorghum halepense*), decreased linearly with an increase in biomass produced by the exotic vegetation communities. Sands et al. (2009) found that Lehmann lovegrass contributed to the negative relationship between exotic grass cover, and total grass cover and the richness, coverage, and density of forbs on their South Texas study area. Thus, while buffelgrass is major exotic invader on rangelands throughout the southwestern U.S., numerous additional exotic grasses, including red brome, King Ranch bluestem, Johnsongrass, and Lehmann lovegrass pose additional threats to rangeland biodiversity over extensive areas.

Kuvlesky et al. (2002) suggested invasive exotic grasses negatively impact the rangeland communities they invade because they eventually become the dominant herbaceous species by replacing native plant species. Research conducted since 2002 confirms Kuvlesky et al. (2002) who suggested exotic grass invasions of rangeland quail habitat simplify native plant communities and reduce their value for quail. A reduction in important food plants via a decrease in forb species diversity reduces the value of any habitat for quail.

EFFECTS OF INVASIVE PLANTS ON ARTHROPOD COMMUNITIES

The impact of exotic grass invasions on arthropod communities vary. Rangelands in southeastern Arizona invaded by Lehmann lovegrass had an abundance of arthropods including Hymenoptera (ants, bees, wasps) and Hemiptera (true bugs) indicating these arthropods may not have been negatively impacted by exotic grass invasion (Litt and Steidl 2010). McIntyre and Thompson (2003) noted that in the southern High Plains of Texas, arthropod richness and abundance did not differ between Conservation Reserve Program (CRP) fields planted to weeping lovegrass (*E. curvula*) and Old World Bluestem (OWB) (*Bothriochloa ischaemum*) versus fields planted to a mix of native grass species.

Recent arthropod-exotic grass research indicates exotic grass invasions are detrimental to rangeland arthropod communities. Tallamy (2004) suspected that exotic plants negatively affect native phytophagous arthropods because native arthropods share no evolutionary history with exotic plants and, consequently, are unable to use exotic plants as a source of food. Most of the work published recently seems to support what Tallamy suspected. For instance, McIntyre and Thompson (2003) compared the abundance and diversity of arthropods between fields of weeping lovegrass, OWB, mixed native grasses with buffalograss (*Buchloe dactyloides*), mixed native grass without buffalograss, and native shortgrass prairie in the Texas Panhandle. Native prairie supported higher arthropod diversity and abundance than CRP fields, which was a reflection of differences in the structure and diversity of the vegetation between native prairie and CRP fields. Hickman et al. (2006) reported significantly less arthropod biomass in OWB fields compared to pastures with native herbaceous vegetation and attributed this to the general absence of forbs in OWB fields. Flanders et al. (2006) reported arthropod abundance on their South Texas study area was 60% greater on native grass sites than on sites dominated by buffelgrass and Lehmann lovegrass. Spiders, beetles, and ants were 42–83% more abundant on native grass sites and this was attributed to the greater niche diversity and abundance the native herbaceous vegetation provided arthropods.

Simao et al. (2009) also reported reductions in plant species richness on plots planted with Japanese stiltgrass (*Microstegium vimineum*) as well as a 39% reduction in arthropod abundance and 19% reduction in species richness compared to control plots. Litt and Steidl (2010) quantified the effects of invasion of rangelands in southeastern Arizona by Lehmann lovegrass on arthropod assemblages and reported that richness of arthropod families, richness of morphospecies, and overall abundance of arthropods decreased as Lehmann lovegrass dominance of rangelands increased. Some arthropod families responded favorably to Lehmann lovegrass invasions, but most families responded negatively. This was attributed to a variety of factors that potentially made exotic grass-dominated areas inhospitable to arthropods including a reduction in vegetation patchiness and structural heterogeneity, altered microclimates, and reduced palatability of Lehmann lovegrass. Cord (2011) found areas dominated by native grasses on her South Texas study area had 32–55% more arthropods per sampling plot than areas dominated by the invasive grasses Kleberg bluestem (*Dicanthium annulatum*), which is an exotic plant, and tanglehead (*Heteropogon contortus*), which is a native plant with invasive characteristics. Cord (2011) also reported differences in specific arthropod Orders because native grass-dominated areas supported significantly more plant-feeding arthropods, spiders (Araneae), grasshoppers/crickets, and beetles than areas dominated by invasive grasses. She attributed the greater abundance of arthropods in native grasses to better arthropod habitat conditions because native grass communities had greater forb cover and higher plant species diversity than exotic-grass dominated areas.

Thus, some arthropod Orders do not appear to be impacted by exotic grass invasions of rangelands, but the simplification of the vegetation community via reduction in native forb and grass diversity clearly seems to reduce the number of habitat niches required by a variety of arthropods. This results in a simplified arthropod community inhabiting rangelands dominated by invasive exotic grasses. Arthropods are important part of quail diets and a reduction in arthropod diversity and abundance would likely be detrimental to quail populations inhabiting rangelands where exotic grass invasions have negatively impacted arthropod communities.

INVASIVE GRASSES AND QUAIL

Quail populations require food, cover, and useable space in sufficient quantities throughout the year to be self-sustaining. Kuvlesky et al. (2002) suggested exotic grass invasions of quail habitat should be a major conservation concern because these invasions have the potential to severely limit the essential food and cover resources quail require to survive. They also indicated that, in the absence of extensive exotic grass-quail research, they could not discount the possibility that exotic invasive grasses may benefit quail populations under certain conditions. The authors (2002) provided nothing more than educated guesses and speculation, which prompted them to challenge quail biologists to conduct research designed to specifically focus on the impacts of exotic grass invasions on quail populations, particularly on rangelands

The responses of quail to exotic grass invasions are not necessarily negative. Some recent quail-exotic grass studies have revealed that, depending on conditions, quail response to exotic grass invasions can be positive or neutral. For example, a case study on masked bobwhite recovery in southern Arizona and northern Sonora, Mexico concluded the presence of low to moderate infestations of buffelgrass and Lehmann lovegrass on rangelands occupied by masked bobwhites provided suitable habitat (Hernandez et al. 2006). Buffelgrass, under drought conditions, can be almost the only herbaceous cover available to masked bobwhites in Sonora (Kuvlesky et al. 2002). Sands (2007) reported that bobwhites on his western Rio Grande Plains study area in South Texas used buffelgrass as a nesting substrate, and Tjemeland (2007) also reported that bobwhites on his South Texas study area readily used buffelgrass-dominated fields for nesting and roosting. Doxon and Carroll (2007) examined arthropod and vegetation characteristics of several CRP fields in western Kansas relative to gamebird habitat suitability and found most fields, including those with an alfalfa component, and non-herbicide treated wheat fields had adequate arthropod-prey availability. These fields were deemed suitable habitat for ring-necked pheasant (*Phasianus colchicus*) and bobwhite chicks. Buelow (2009) evaluated the impacts of tanglehead on bobwhite habitat use in South Texas and reported bobwhites exhibited a neutral response to this native invasive plant as they nested in tanglehead stands, but did not select or avoid them. Moore (2010) found that guineagrass (*Urochloa maxima*) invasion did not reduce usable space for bobwhites on her South Texas study area. Bobwhites, at the macrohabitat scale, seemed to prefer guineagrass for loafing cover.

Recent research has documented positive responses of bobwhites to exotic grass invasions, but bobwhites may also respond negatively to exotic grass invasions depending on the circumstances. For example, Flanders et al. (2006) reported bobwhite abundance on native grass-dominated sites of their South Texas study area was twice as high compared to buffelgrass and/or Lehmann lovegrass-dominated sites. They attributed the greater abundance of bobwhites to the higher diversity and abundance of native herbaceous food-bearing species, and the more abundant and diverse arthropod prey present on the native-dominated sites. Sands (2007) found that bobwhites use stands of buffelgrass for nesting cover, but avoided buffelgrass after nesting. Avoidance of buffelgrass after nesting probably resulted because of the lower abundance of arthropods that occur in buffelgrass stands and because it impedes chick mobility making it poor brooding habitat. Sands (2007) added that he believed areas with extensive exotic grass cover reduced foraging habitat space for bobwhites. Buelow (2009) documented that bobwhites nested in tanglehead stands on his South Texas study area, but believed the invasions of this native grass ultimately provided poor brooding and foraging cover due to lack of food-producing forbs, increased litter depths, and lower amounts of bare ground.

MANAGEMENT OF EXOTIC GRASSES FOR QUAIL: IS IT POSSIBLE?

Ten years ago, scientists assumed exotic grass invasions of western rangelands posed a significant threat to quail populations (Kuvlesky et al. 2002). Subsequently, research has indicated that exotic grass invasions can represent a loss of quail habitat in the southwestern U.S. An important question is: can these invaded landscapes be managed to improve quail habitat; or can the rate of exotic grass invasion be sufficiently slowed to maintain existing quail habitat? The answer is probably yes. However, it is important to realize that complete eradication of invasive grasses is not possible for most exotic species of grass that are invading rangelands in the southwestern U.S. Either we do not know how to effectively manage invasions or we are in the early stages of research that is revealing how specific species might be managed. Success can probably be achieved in certain situations and for specific quail species. This will likely vary depending on the species of exotic grass targeted for management, the ecosystem being invaded, the extent of invasion, and past and current land management histories. We discuss several promising management techniques that have been developed to manage exotic grass invasions and strategies that will likely improve management of exotic grass invasions.

Management of Exotic Grasses

Managing exotic grass invasions in an effort to restore quail habitat on southwestern rangelands is possible but depends on the extent to which an ecosystem has been invaded, the extent of invasion on the area targeted for management and, most importantly, the exotic grass species targeted for management. Ecosystems in the early stages of invasion are generally easier to manage because exotic grasses can be removed when they first begin colonizing a site, allowing more options and techniques to be used. However, land managers must exercise continued vigilance to remove exotic grasses in the early stages of invasion. Invasive plants that have already become established in concert with native herbaceous species cannot realistically be managed by targeting individual plants. They must be managed by reducing exotic grass populations. Planning horizons must be implemented that schedule treatments over successive years to continuously combat recurring invasions. Managing exotic grass invasions where an exotic grass is the dominant species on a landscape scale that covers millions of hectares is often impractical and unrealistic because of the complex logistics and expense that would be required to achieve uncertain success. Application of specific herbicides and prescribed fire, along with manipulating soil chemistry and establishing potential competitors, have been demonstrated to effectively manage exotic grass invasions at least over the short term.

Herbicides.—Several studies have recently indicated herbicides can be used to reduce populations of specific exotic grass species if applied at appropriate rates and appropriate time of year when exotic plants are vulnerable. For example, Simmons et al. (2007) reported they reduced King Ranch bluestem abundance in the Texas Hill Country using glyphosate applied at 0.89 kg/ha during June and September. Tjemeland et al. (2008) found that tebuthiuron applied at 2.24 kg/ha during early fall after successive rainfall events induced new vegetative growth on their South Texas study area significantly reduced buffelgrass canopy cover, and increased native grass cover 2 years post-treatment. Steers and Allen (2010) applied the post-emergent, grass-specific herbicide Fusilade II at a rate of 15 ml/64 m^2 during 2 successive January treatments to desert shrubland in California following a fire and almost eliminated invasive grasses (*Bromus* spp. and *Schismus* spp.) while achieving native annual plant dominance and increased density of native perennial plants. Elseroad and Rudd (2011) reported aerially applying imazapic at a rate of 70 g ai/ha in October on northcentral Oregon grasslands significantly reduced cheatgrass frequencies for 3–4 years post-treatment, although they had limited success increasing native perennial species on treated areas.

The use of herbicides to manage other exotic grass species is often unsuccessful despite these reports of success because herbicides can have a negative impact on members of the native plant community. Rinella et al. (2009) reported aerial application of picloram at a rate of 1.1 kg/ha to a grassland in Montana resulted in increased abundance of targeted exotic herbaceous species because of the decrease in native herbaceous plant abundance that occurred. Mittelhauser et al. (2011) pretreated a blackland prairie site in Texas with glyphosate at a rate of 1.84 kg/ha and then aerially applied imazapic at 3 different rates (0.07, 0.092, 0.138 kg/ha) to reduce abundance of exotic bluestems and failed to have any significant impact on these invasive plants. Overall, it appears certain exotic grass species can be managed with particular herbicides under certain situations, particularly when their phenological status makes them vulnerable. However, it is also evident this will not work for all exotic grass species and or with other herbicides. Reducing the abundance of an exotic grass species should be the primary goal, but herbicides should not be used if they threaten the native plant community. Selectively reducing exotic grasses is desirable, but the issue is complicated as invading plants may share physiological and phenological characteristics with native species occupying the native ecosystem being invaded. Treatments may often pose a threat to the native plants that are targets of restoration (Simmons et al. 2007).

Prescribed Fire.—Fire, although it generally facilitates invasion, may be used to manage exotic grass invasions under certain conditions. Vermeire and Rinella (2009) discussed the use of fire to kill the seeds of Japanese brome (*Bromus japonicus*) and its potential for managing invasions of annual invasive grasses. Abella et al. (2009) reported that red brome live and dead cover averaged 9 to 10 times lower on burned areas than unburned areas 2 years following an intense wildfire in a desert shrubland on the outskirts of Las Vegas, Nevada. Red brome seed densities on the soil surface were 4 times lower on burned areas compared to unburned areas. Brooks (2002) reported that increased fire temperatures recorded under creosote (*Larrea tridentata*) plants in the Mojave Desert resulted in 4 years of reduced annual plant biomass and species diversity.

Perennial exotic grasses may also be vulnerable to fire under certain conditions. For example, Daehler and Goergen (2005) were able to restore a native Hawaiian grass to plots formerly occupied by buffelgrass by subjecting the plots to prescribed fire and low water supplementation for 4 years, suggesting buffelgrass plants can be suppressed via seed mortality as a result of burning under dry conditions. Ramierz-Yanez (2005) found that guineagrass populations were reduced when plants were subjected to intense prescribed fire followed by intensive cattle grazing. Native herbaceous species richness increased on burned areas 1 year post-fire. It appears there are opportunities to use prescribed fire to manage certain species of exotics if burning disrupts life cycles or otherwise occurs when species are vulnerable to fire. However, Brooks and Chambers (2011) indicated effective management of native perennial shrublands requires an understanding of their ecological resistance to invasion from exotic grass species and their resilience to fire. Further research to gain a thorough understanding of the ecological interaction among specific exotic grass species, fire, and native plant communities is needed.

Native Seeding.—Managing exotic grasses in a manner that effectively reduces their populations is the first objective of restoring a native plant community. What should be done when dispersing exotic seeds threaten managed areas or when an exotic grass has thoroughly dominated an area for so long that native plants have long been suppressed? Salo (2004) suggested opportunities for red brome management exist immediately following drought because red brome does not establish a seed bank; thus, persistence in the Sonoran and Mojave deserts depends on uniform seed germination during cool moist winters. Populations are decimated when drought occurs, due to a lack of seed production. Native herbaceous plants use these winter drought opportunities to re-establish during subsequent wet periods in spring and summer on areas formerly dominated by red brome (Salo 2004). These established natives provide competitors that compete with red brome seedlings that later attempt to colonize these areas. Corbin and D'Antonio (2004) conducted an experiment on the coastal prairie of California providing evidence that established native perennials limit exotic annual grass invasions by limiting the availability of space and light.

Seeding native herbaceous plant species after winter drought may help suppress future red brome invasion in invaded areas and other areas invaded by exotic grasses where native seed banks are depleted. McLaughlin and Bowers (2007) studied the effects of exotic grasses on soil seed banks on a grassland study site of southeastern Arizona following a wildfire. They found the soil seed bank on their burned plots contained only exotic grass seed, prompting them to conclude that even when exotic grass management is successful, restoration of native grassland will require reseeding of native herbaceous plants. Abella et al. (2007) were able to restore native herbaceous vegetation on a burned site by carefully selecting a native seed mixture from plants that had a history of being productive on their Sonoran Desert study site. Similarly, Mittelhauser et al. (2011) improved densities of 4 warm season native grass species they established via post-treatment herbicide seeding on blackland prairie invaded by exotic bluestem.

Policy.—Effective management of exotic grass invasions can probably be accomplished most effectively by initiating a policy whereby experts from multiple disciplines relevant to invasive plants science and management have an opportunity to collaborate in an effort to develop coordinated management strategies. Rogstad et al. (2009) recommended the formation of an interagency invasive species team that would provide leadership including coordinating information, identify and pursue funding opportunities, developing treatment options, and rehabilitation prior to, during, and after fires.

MANAGEMENT IMPLICATIONS

A few research projects focused on the exotic grass-quail issue have been completed on Texas rangelands since Quail V. This research has revealed that invading exotic grasses, such as buffelgrass and Lehman lovegrass, probably negatively impact quail populations because bobwhite abundance is lower on areas dominated by exotic grasses compared to areas dominated by native grasses and forbs. However, in situations where an important habitat component is limited, some exotic grasses can supplement the limiting component making habitat conditions suitable for bobwhites. Overall, the reduction in native plant and arthropod species diversity and abundance that generally follows exotic grass invasions reduces habitat quality for not only bobwhites but other quail species that inhabit southwestern rangelands.

Recent research has revealed that certain exotic grasses can be managed with specific herbicides, prescribed fire, and using native plant seedings to serve as competitors. Thus, it may be possible to restore quail habitat on southwestern rangelands by exploiting the vulnerabilities of exotic grass species. However, exotic grass management requires repeated treatments for an extended period. Thus, an organized and comprehensive plan that establishes clear objectives and prioritizes management actions should be developed prior to implementing active management.

Concerns about the role exotic grass invasions are having on western quail species are legitimate because exotic grass invasions likely contribute to one of the primary reasons quail populations have been declining, i.e., habitat loss. Results of the research that has been accomplished since Quail V clearly indicate that exotic grass invasions of South Texas rangelands are impacting bobwhite populations and their habitat but these impacts are not always negative. Scaled, Gambel's, Montezuma, California, and mountain quail may be responding to exotic grass invasions of their habitats in a similar manner, but this remains speculation until research focusing on each of these western quail species is completed.

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LITERATURE CITED

Abella, S. R., E. C. Engel, C. L. Lund, and J. E. Spencer. 2009. Early post-fire establishment on a Mojave Desert burn. Madrono 56:137–148.

Abella, S. R., J. L. Gunn, M. L. Daniels, J. D. Springer, and S. E. Nyoka. 2007. Using a diverse seed mix to establish native plants on a Sonoran Desert burn. Native Plants 10:21–30.

Bowers, J. E., T. M. Bean, and R. M. Turner. 2006. Two decades of change in distribution of exotic plants at the desert laboratory, Tucson, Arizona. Madrono 53:252–263.

Brennan, L. A. 2002. A decade of progress: a decade of frustration. Proceedings of the National Quail Symposium 5: 230–232.

Brooks, M. L. 2002. Peak fire temperatures and effects on annual plants in the Mojave Desert. Ecological applications 4:1088–1104.

Brooks, M. L., and J. C. Chambers. 2011. Resistance to invasion and resilience to fire in desert shrublands of North America. Rangeland Ecology and Management 64:431–438.

Buelow, M. C. 2009. Effects of tanglehead on northern bobwhite habitat use. Thesis. Texas A&M University-Kingsville, USA.

Corbin, J. D., and C. M. D'Antonio. 2004. Competition between native perennial and exotic annual grasses: implications for an historic invasion. Ecology 85:1273–1283.

Cord, E. E. 2011. Changes in arthropod abundance and diversity with invasive grasses. Thesis. Texas A&M University-Kingsville, USA.

Daehler, C. C., and E. M. Goergen. 2005. Experimental restoration of an indigenous Hawaiian grassland after invasion by buffelgrass (*Cenchrus ciliaris*). Restoration Ecology 13:380–389.

Doxon, E. D., and J. P. Carroll. 2007. Feeding ecology of ring-necked pheasant and northern bobwhite chicks in Conservation Reserve Program fields. Journal of Wildlife Management 74:249–256.

Elseroad, A. C., and N. T. Rudd. 2011. Can imazapic increase native species abundance in cheatgrass (*Bromus tectorum*) invaded native plant communities? Rangeland Ecology and Management 64: 641–648.

Engel-Wilson, R., and W. P. Kuvlesky Jr. 2002. Arizona quail: species in jeopardy? Proceedings of the National Quail Symposium 5:1–7.

Flanders, A. A., W. P. Kuvlesky Jr., D. C. Ruthven III, R. E. Zaiglin, R. L. Bingham, F. Hernandez, and L. A. Brennan. 2006. Effects of invasive exotic grasses on South Texas rangeland breeding birds. Auk 123:171–182.

Gabbert, B. L., and N. L. Fowler. 2007. Wide ecological amplitude of a diversity-reducing invasive grass. Biological Invasions 9:149–160.

Gori, D. F., and C. A. F. Enquist. 2003. An assessment of the spatial extent and condition of grasslands in central and southern Arizona, southwestern New Mexico and northern Mexico. The Nature Conservancy, Arizona Chapter, Tucson, USA.

Hanselka, C. W. 1985. Grazing management strategies for buffelgrass. Pages 53–64 *in* Symposium on buffelgrass: adaptation, management and forage quality (E. C. A. Runge and J. L. Schuster, eds.). Texas Agriculture Experiment Station MP-1575. College Station, USA

Hanselka, C. W. 1988. Buffelgrass–South Texas wonder grass. Rangelands 10: 279–281.

Hernandez, F., W. P. Kuvlesky Jr., R. W. DeYoung, L. A. Brennan, and S. A. Gall. 2006. Recovery of rare species: case study of the masked bobwhite. Journal of Wildlife Management 70: 617–631.

Hickman, K. R., G. H. Farley, R. Channel, and J. E. Steier. 2006. Effects of Old World bluestem (*Bothriochloa ischaemum*) on food availability and avian community composition within the mixed-grass prairie. Southwestern Naturalist 51:524–530.

Kuvlesky Jr., W. P., T. E. Fulbright, and R. Engel-Wilson. 2002. The impact of invasive exotic grasses on quail in the southwestern United States. Proceedings of the National Quail Symposium 5: 118–128.

Litt, A. R., and R. J. Steidl. 2010. Arthropod assemblages change along a gradient of invasion by a nonnative grass. Biological Invasions 12:3449–3463.

McIntyre, N. E., and T. R. Thompson. 2003. A comparison of Conservation Reserve Program habitat plantings with respect to arthropod prey for grassland birds. American Midland Naturalist 150: 291–301.

McLaughlin, S. P., and J. E. Bowers. 2007. Effects of exotic grasses on soil seed banks in southeastern Arizona grasslands. Western North American Naturalist 67:206–218.

Mittelhauser, J. R., P. W. Barnes, and T. G. Barnes. 2011. The effect of herbicide on the re-establishment of native grasses in the blackland prairie. Natural Areas Journal 31:226–233.

Moore, S. F. 2010. Effects of guineagrass on northern bobwhite habitat use. Thesis. Texas A&M University-Kingsville, USA.

National Audubon Society. 2010. The Christmas Bird Count historical results. National Audubon Society, New York, USA. www.christmasbirdcount.org

Olsson, A. D., J. Betancourt, M. P. McClaran, and S. E. Marsh. 2011. Sonoran Desert ecosystem transformation by a C4 grass without the grass/fire cycle. Diversity and Distributions 18:10–21.

Pimental, D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52:273–288.

Ramirez-Yanez, L. E. 2005. Prescribed fire and intensive grazing to control invasive guinea grass on native pastures in South Texas. Thesis. Texas A&M University-Kingsville, USA.

Rinella, M. J., B. D. Maxwell, P. K. Fay, T. Weaver, and R. L. Sheley. 2009. Control effort exacerbates invasive-species problem. Ecological Applications 19:155–162.

Robel, R. J. 1993. Symposium wrap-up: what is missing? Proceedings of the National Quail Symposium 3: 156–159.

Rogstad, A., T. M. Bean, A. Olsson, and G. M. Casady. 2009. Fire and invasive species management in hot deserts: resources, strategies, tactics and response. Rangelands 31:6–13.

Salo, L. F. 2004. Population dynamics of red brome (*Bromus madritensis* subsp. *rubens*): times for concern, opportunities for management. Journal of Arid Environments 57:291–296.

Sands, J. P. 2007. The impacts of invasive exotic grasses on northern bobwhite habitat use and selection in South Texas. Thesis. Texas A&M University-Kingsville, USA.

Sands, J. P., L. A. Brennan, F. Hernández, W. P. Kuvlesky Jr., J. F. Gallagher, D. C. Ruthven III, and J. E. Pittman III. 2009. Impacts of buffelgrass (*Pennisetum ciliare*) on a forb community in South Texas. Invasive Plant Science and Management 2:130–140.

Simao, M. C. M., S. L. Flory, and J. A. Rudgers. 2009. Experimental plant invasion reduces arthropod abundance and richness across multiple trophic levels. Oikos 119:1553–1562.

Simmons, M. T., S. Windhager, P. Power, J. Lott, R. K. Lyons, and C. Schwope. 2007. Selective and non-selective control of invasive plants: the short-term effects of growing-season prescribed fire, herbicide, and mowing in two Texas prairies. Restoration Ecology 15:662–669.

Steers, R. J., and E. B. Allen. 2010. Post-fire control of invasive plants promote native recovery in a burned desert shrubland. Restoration Ecology 18:334–343.

Tallamy, D. W. 2004. Do alien plants reduce arthropod biomass? Conservation Biology 18:1689–1692.

Tjemeland, A. D. 2007. Habitat restoration and northern bobwhite use of buffelgrass-dominated grasslands. Thesis. Texas A&M University-Kingsville, USA.

Tjemeland, A. D., T. E. Fulbright, and J. Lloyd-Reilley. 2008. Evaluation of herbicides for restoring native grasses in buffelgrass-dominated grasslands. Restoration Ecology 16:263–269.

Vermeire, L. T., and M. J. Rinella. 2009. Fire alters emergence of invasive plant species from soil surface-deposited seeds. Weed Science 57:304–310.

Wilsey, B. J., T. B. Teaschner, P. P. Daneshgar, and H. W. Polley. 2009. Biodiversity maintenance mechanisms differ between native and novel exotic-dominated communities. Ecology Letters 12:432–442.

Zornes, M. L. 2009. Managing quail in Arizona: meeting new challenges with old techniques. Gamebird 2006: Quail VI and Perdix XII: 370–378.

EFFECTS OF PATCH BURNING AND GRAZING EXOTIC-GRASS MONOCULTURES ON NORTHERN BOBWHITE HABITAT AND PRODUCTIVITY

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ABSTRACT

Buffelgrass (*Pennisetum ciliare*) is an invasive, exotic grass that threatens biodiversity and wildlife habitat throughout the southwest. This is especially true for northern bobwhites (*Colinus virginianus*). Bobwhite populations have decreased over the past century because of a loss in habitat and usable space. Use of exotic grass monocultures by quail tends to be limited to edges adjacent to woody plant communities. We evaluated if creating a mosaic of small prescribed burns followed by intense cattle grazing in exotic-grass monocultures will increase usable space for bobwhites and increase bobwhite abundance in La Salle County, Texas. We randomly assigned a patch burn-graze treatment to 2,200-ha pastures dominated by buffelgrass and randomly selected 2 experimental controls (grazing only) to 2,200-ha pastures. We burned patches totaling 25% of each pasture in January 2010 and allowed grazing after burned grass reached 15 cm in height. Grazing intensity (standing crop removal) was sampled in June and August 2010. Patch-burning and grazing resulted in more heterogeneity in standing crop of buffelgrass ($P < 0.001$). Bobwhites appeared to use exotic grass monocultures in burned patches with a greater abundance of native forbs and woody plants during the first year of study. Bobwhites avoided areas where there was no native vegetation, and their abundance was closely associated with brushy riparian areas ($P = 0.09$). There were no differences ($P > 0.05$) in bobwhite abundance between treatment and control pastures. Severe drought during the first year of study may have affected the results.

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Key words: buffelgrass, *Colinus virginianus,* northern bobwhites, *Pennisetum ciliare*, Texas

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QUAIL RESPONSE TO TWO LARGE-SCALE WILDFIRES IN THE TEXAS PANHANDLE

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ABSTRACT

Rangeland wildfires burned 275,805 ha in 2 large blocks in the Texas Panhandle in March 2006. We assessed the impact on northern bobwhite (*Colinus virginianus*) and scaled quail (*Callipepla squamata*) populations through use of spring call-counts at 6 study sites during summer 2006–2008. Call-counts were higher in 2006 on non-burned (control) sites combined than on burned sites combined. Two years post-burn call-counts were higher on 3 of the burned sites and on 3 of the control sites. Between year comparisons revealed a difference only in the 2006/2007 pairing with 2006 having lower counts on burned than on control sites. Vegetation regrowth and concomitant quail abundance was affected more by soil texture, topography, and precipitation than spatial relation to the burn perimeter. Sites comprised of coarse-textured soils responded more quickly and likely supported higher densities pre-burn than sites with more finely-textured soils. Shortgrass sites without a significant woody component probably had lower populations pre-burn, and recovered more slowly than mid-grass communities that had a greater woody component. Landscape relief appeared to mitigate the immediate impact of the burn, enhancing recovery by providing refugia (unburned patches) within the burn.

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Key words: *Callipepla squamata*, *Colinus virginianus*, fire, northern bobwhite, scaled quail, Texas Panhandle, wildfire

INTRODUCTION

Wildfires in the High Plains ecoregion of Texas have been recognized as a frequent occurrence since early settlement (Jackson 1965, Lehmann 1984:258, Schmidly 2002:382). The topography, climate, and vegetation are conducive to large prairie fires (Jackson 1965). Weather conditions in March 2006 in the Texas Panhandle presented ideal conditions for wildfires. The region had been in a drought for 11 months, and under critical drought conditions for 5 months (Zane et al. 2006), leading the National Weather Service Storm Protection Center to issue an *Extremely Critical Fire Danger* warning for 8, 10, 11, and 12 March. Rangeland wildfires burned 294,000 ha in the Texas Panhandle during 12–18 March 2006 (J. R. Harrell, USDA-Natural Resources Conservation Service, personal communication). The largest fires, initiated by downed power lines, were the Borger Fire (143,775 ha) and the Interstate 40 (I-40) Fire (132,030 ha). Extremely low relative humidity ($< 10\%$), unseasonably warm temperatures, and sustained 74 km/hr winds with gusts of 93 km/hr pushed the fires east across the region. Fire advanced 72 km in 9 hrs at one point, spreading at a rate of 8 km/hr with flame lengths of > 3 m.

Howard et al. (1959) discounted the risk of wild vertebrates dying during wildfires, but unknown numbers of various species of wildlife perished in these fires. Mortalities observed by the senior author included mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), North American porcupine (*Erethizon dorsatum*), northern raccoon (*Procyon lotor*), and quail (unknown spp.).

Quail populations, especially northern bobwhites, can benefit from prescribed fire (Stoddard 1931:413, Rosene 1969:63, Wilson and Crawford 1979, Lehmann 1984:258, Guthery 2000:71, Dabbert et al. 2007). Roseberry and Klimstra (1984:128) reported accidental fires on their Illinois study site prolonged the usefulness of nesting habitat in the face of natural succession in old fields. Jackson (1965:257) observed the impact of an "accidental grassfire" on quail in the High Plains and summarized that "prescribed burning might well be used to set plant succession back to provide habitat." Management strat-

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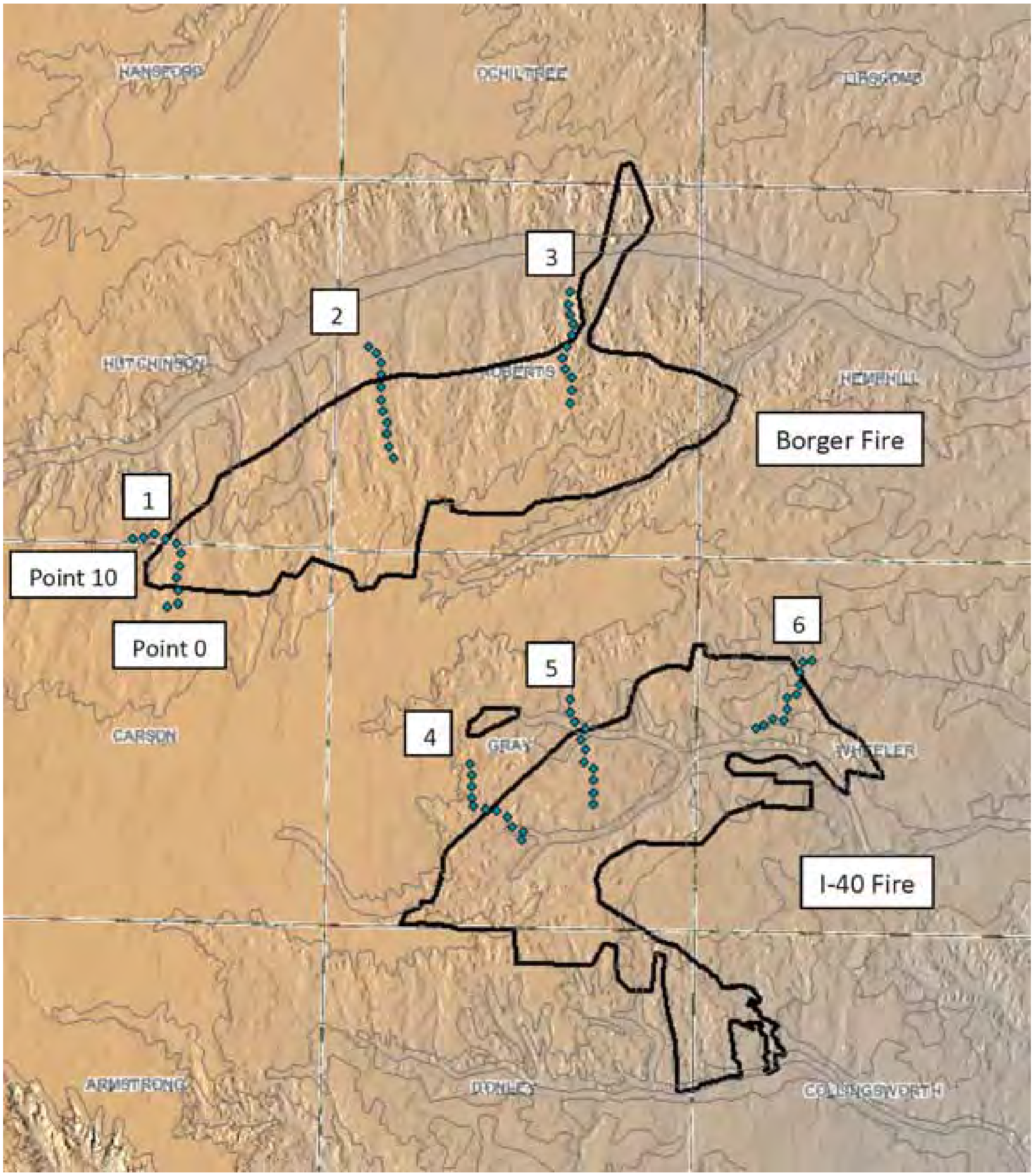

Fig. 1. Burn areas showing relief and corresponding distinct generalized vegetation communities, transect locations, and listening-point numbering scheme, northeast Texas Panhandle, 2006.

egies (including prescribed fire) that alter composition and structure of the plant community at the landscape scale increase useable space and may be effective in lessening winter quail mortality (Seckinger et al. 2008). Quail populations benefit most by burning in areas with > 75 cm average annual precipitation (Guthery 1986:75). Guthery (2000:71) contended that burning has limited applicability in more arid areas, but may be useful if applied infrequently.

Little is known about the effect of large-scale wildfires on quail populations. We initiated a study after the 2006 wildfires to assess their impact on short-term abundance of northern bobwhite and scaled quail. Our objective was to ascertain recovery rates of bobwhite and scaled quail, i.e., how quickly they became re-established at distances > 5 km from the perimeter of the wildfire-burned areas.

STUDY AREA

The Texas High Plains is a 8 million-ha subunit of the Great Plains. The region is a relatively high plateau fringed on the east and south by the Caprock Escarpment

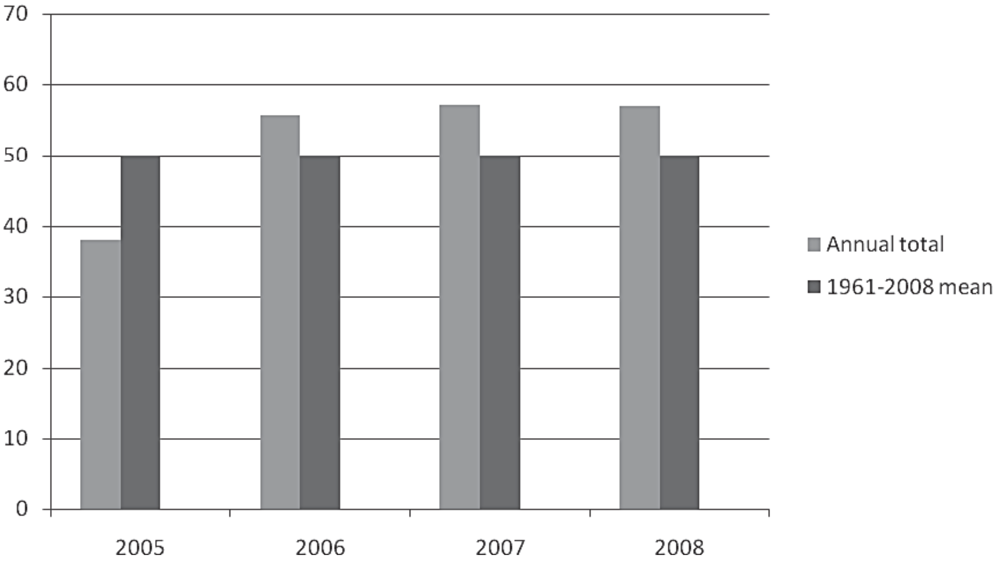

Fig. 2. Annual precipitation totals (cm) and long-term mean for Amarillo, Texas (U.S. Department of Commerce 2009).

with elevations of 915 to 1,375 m sloping gradually to the southeast (Gould 1975:13).

We established 6 study sites in Carson, Gray, Huthinson, Roberts, and Wheeler counties (Fig. 1) on private ranches in the wildfire-affected areas. The study area included portions of the High Plains (shortgrass prairie) and Rolling Plains (mid-grass-shrub) ecoregions. Annual precipitation for the region (recorded at Amarillo, Texas) was 38.1, 55.6, 57.1, and 57.0 cm for 2005, 2006, 2007, and 2008, respectively (U.S. Department of Commerce 2009) (Fig. 2). Soils ranged from fine sand to clay loam (USDA 2009). We chose study sites on the edge of burned blocks to accommodate sampling that incorporated both burned and non-burned areas.

Relative abundance of bobwhites was near the long-term mean for the High Plains and Rolling Plains ecoregions during the term of our study (Fig. 3).

METHODS

We established 3, 16-km sampling transects with listening points marked at 1.6-km intervals on each of the wildfire blocks (Fig. 1). Transects were oriented north-south, straddled the burned-non-burned interface with a minimum of 3 points inside and 3 outside the burned area, and were divided equally between the Borger and I-40 fires. Listening points were numbered 0–10, south to north.

We conducted spring cock call-counts during the peak breeding season (May–early Jul) 2006-08. Counts were initiated 30 min before official sunrise and continued for 2 hrs with 5 min actively listening at each point. Total number of calls heard and number of individual calling males heard were recorded for each listening point. Three counts were made at each point, each on different days spread over a 30-day counting period.

We used single factor ANOVA to test for differences in call counts at an *alpha* level of 0.05. We centered an 81-ha area of interest on each listening point and used soil survey data (USDA 2009) to characterize soils into broad categories, i.e., sand, loam, clay, and combinations as appropriate.

RESULTS

We heard scaled quail calling very infrequently during the study and did not include those data for this study. Bobwhite call-count data (Table 1) comprise the primary subject for analysis.

Call-count data from the Borger (Transects 1–3) and I-40 (Transects 4–6) burns by year and combined revealed a significant difference ($P \leq 0.05$) between counts on burned versus non-burned (control) sites in 2006 (Table 2). Call counts were higher on 2 of the control sites (transects 2 and 3) and lower on 1 (transect 6) 1 year post-burn. Call counts were higher on 3 of the burned sites (transects 1, 4, and 6) and on 3 of the control sites (transects 2, 3, and 5) 2 years post-burn. Between-year comparisons had a difference only in the 2006/2007 pairing with 2006 having lower call numbers on burned than on control sites.

The Borger burn versus control by-year comparison showed more quail calls on the control sites all 3 years on 2 transects. Only transect 1 in year 3 had higher numbers of calls on the burned sites. Fewer calling males were observed in 2006 at the burned listening points than at the control points. Between-year comparisons showed higher numbers in 2007 than 2008 on control sites on transect 1. More quail were heard in 2008 than either 2006 or 2007 on the burned sites on transect 3. Data by transect with all 3 years combined revealed higher numbers on control sites on transects 2 and 3.

Burned versus control listening-point data by-year comparisons for the I-40 block revealed fewer calling males on burned areas the year of the burn. Only 1 transect had higher numbers on burned sites 1 year post-

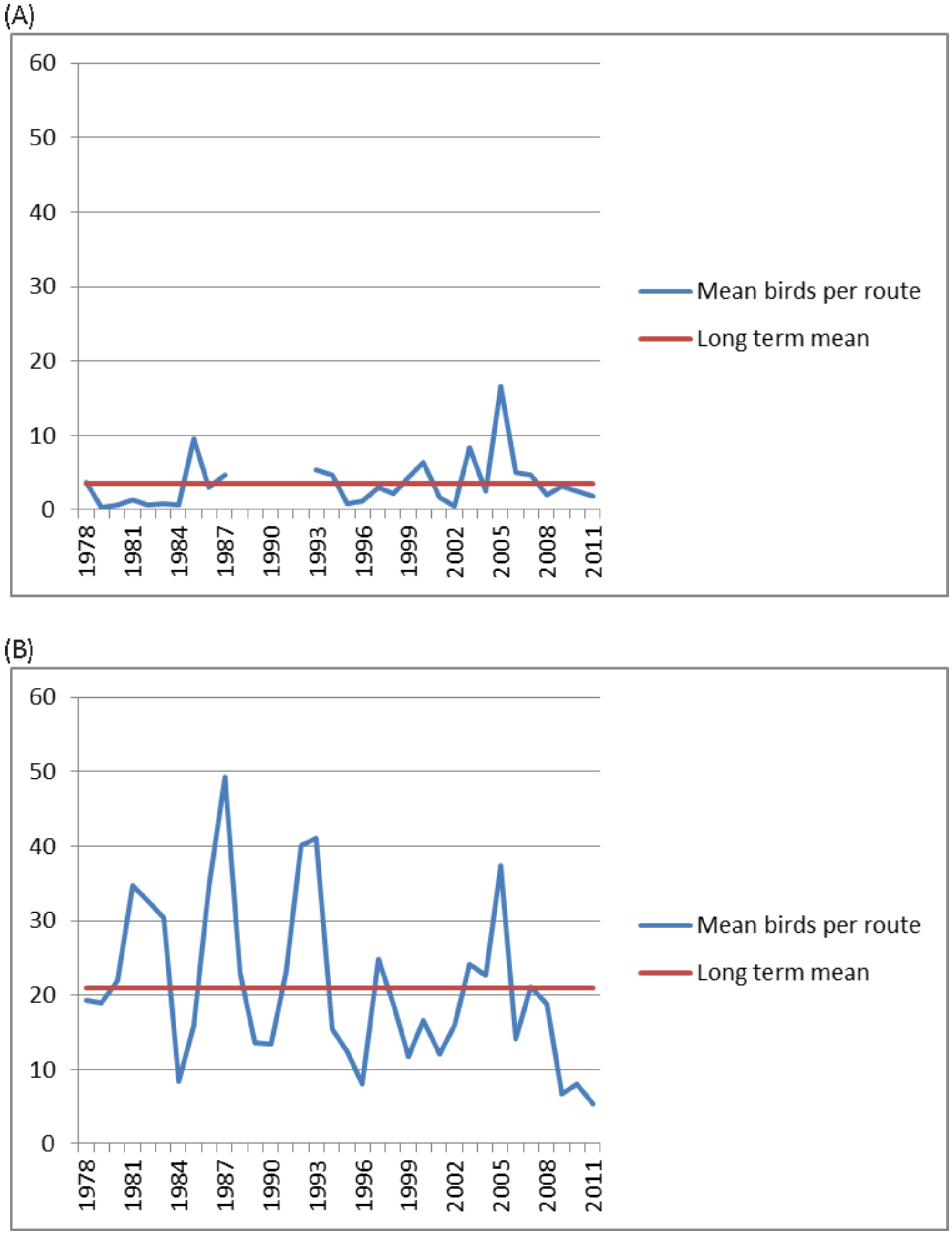

Fig. 3. Northern bobwhite abundance from 1978 to 2011 for the High Plains (A) and Rolling Plains (B) ecoregions as estimated by summer roadside counts (TPWD 2012).

burn. Two transects had more quail on the burned sites 2 years post-burn and 1 transect had higher numbers on the control sites (Table 2).

Three of the 6 individual transects had quail numbers on the burned areas less than or equal to those on the control areas for each of the 3 years post-burn. Four of the 6 transects in 2006 had significantly ($P \leq 0.05$) fewer calling males on the burned than on the control listening points (Table 2). Call counts varied according to soil texture (Table 3). Coarse-textured (i.e., sandier) sites (e.g., transect 6) responded more quickly than sites dominated by finer-textured soils (i.e., loams, clay-loams).

DISCUSSION

The impact of wildfire on birds has been studied to some extent (Jackson 1965), but the effect of shortgrass prairie wildfire on northern bobwhites is poorly understood. Wildfires are not planned (by definition), and pre-burn estimates of bobwhite abundance specific to the burned areas are unknown.

Shortgrass prairie (High Plains) portions of transects without a significant woody component would be expected to have lower bobwhite populations pre-burn than midgrass/shrub (Rolling Plains) transects possessing a significant woody component (TPWD 2012). Shortgrass

Table 1. Mean number of spring calls by bobwhite by transect (1–6), listening point (0–10), and year. Bold indicate listening points within the burned areas.

	Borger Fire									I-40 Fire								
	1			2			3			4			5			6		
	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
0	2.33	4.33	0.33	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.33**	**5.33**	**5.33**	**0.00**	**1.67**	**0.33**	**3.33**	**12.33**	**11.00**
1	0.00	0.67	0.00	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**2.67**	**3.67**	**3.67**	**0.33**	**3.00**	**1.33**	**3.67**	**12.33**	**11.33**
2	0.67	1.67	0.00	**1.00**	**1.33**	**0.67**	**0.00**	**0.00**	**0.00**	**1.67**	**2.00**	**2.00**	**0.33**	**6.67**	**3.33**	**3.33**	**8.00**	**14.67**
3	**0.33**	**0.67**	**0.33**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**1.67**	**1.67**	**0.33**	**3.00**	**3.67**	**5.33**	**7.00**	**10.67**
4	**7.00**	**1.33**	**1.33**	**0.33**	**3.00**	**0.33**	**0.00**	**0.00**	**0.33**	**0.00**	**1.33**	**1.33**	**0.00**	**3.67**	**6.00**	**4.67**	**10.67**	**13.67**
5	**3.33**	**3.00**	**1.67**	**1.67**	**0.33**	**1.33**	**0.00**	**0.00**	**0.67**	0.00	2.33	0.00	**0.67**	**3.00**	**7.67**	**3.67**	**9.33**	**12.33**
6	**2.67**	**2.33**	**2.00**	**1.00**	**3.67**	**3.67**	1.67	0.00	1.33	2.33	3.67	1.00	**2.33**	**5.33**	**8.33**	**4.00**	**3.33**	**9.33**
7	3.33	4.33	0.33	3.33	4.33	3.67	1.33	2.33	4.33	1.33	1.67	1.00	4.00	5.00	5.00	**5.67**	**6.67**	**8.00**
8	4.00	4.00	0.00	3.67	2.67	4.00	2.67	2.00	6.00	0.33	1.67	0.00	4.33	4.00	7.67	5.33	6.33	8.33
9	3.67	7.67	0.00	6.00	6.67	8.00	4.67	2.67	8.00	2.67	1.33	0.67	5.67	5.00	7.67	4.00	6.00	4.67
10	0.33	0.67	0.00	5.67	8.00	6.33	4.33	2.67	7.00	3.33	3.00	0.00	5.00	4.67	5.67	4.33	4.33	4.67

sites (mostly those on more western sites in our study) had little or no recovery during the period of study. Rough, broken topography (e.g., draws, riparian areas), which typically had more shrubs (e.g., skunkbush [*Rhus trilobata*]), appeared to mitigate the immediate impact of the burn at some sites, speeding recovery by providing refugia (non-burned patches) within the burn.

Shortgrass prairie (High Plains) plant communities are inherently less habitable by northern bobwhites than midgrass/shrub communities. Soils are predominately clay loams. Woody cover is sparse with yucca (*Yucca* spp.) providing virtually the only woody cover. The primary herbaceous species are buffalograss (*Buchloe dactyloides*) and blue grama (*Bouteloua gracilis*), neither of which provides substantial nesting or escape cover for bobwhites.

Scarcity of shrubs suitable for escape and loafing cover limits use of shortgrass sites (Dabbert et al. 2007). Species like lotebush (*Ziziphus obtusifolia*) provide desirable cover for northern bobwhite and scaled quail (Rollins 2007), but are top-killed by intense fires and can take $>$10 years to attain sufficient size to be used as cover again (Renwald et al. 1978). Thus, woody cover recovers more slowly on shortgrass sites.

Mid-grass (Rolling Plains) sites generally have a greater woody component that is largely resilient to the effects of fire and re-sprouts rapidly and profusely (e.g., skunkbush, sand shinnery oak [*Quercus havardii*]) (Holechek et al. 2004:514). The sandy soils on these sites provide superior quail habitat (Guthery 2000:18) and regrow more rapidly post-fire, given adequate precipitation (Scifres and Hamilton 1993:80). Sand shinnery oak, primarily found on sandier soils, responds quickly by re-sprouting (Scifres and Hamilton 1993:81), providing structure and useable space for quail (Guthery 1997). These sites likely supported higher pre-burn quail numbers than clay loam sites due to differences in their respective plant communities and inherent site potential.

Substantial rainfall occurred on the eastern-most, more sandy transects within several weeks of the wildfire and likely contributed to the rapid recovery of vegetation, and subsequent bobwhite abundance (Table 2).

Rangeland wildfire is not synonymous with prescribed burning. Prescribed burning is implemented under

Table 2. Average number of spring calls by bobwhite on transects 1–6 and combined, and by year and combined, Borger (Transects 1–3) and I-40 (Transects 4–6) wildfires, Texas Panhandle, 2006–2008. Significant difference ($P \leq 0.05$) indicated by differing superscript (year) or bold (treatment).

Transect #		2006	2007	2008	2006–2008
1	Burned	3.33	1.83	**1.33**	2.00
	Not burned	1.92^{a}	3.19^{a}	0.89^{b}	2.17
2	Burned	0.17^{a}	1.33^{ab}	0.86^{b}	0.97
	Not burned	**4.67**	**5.42**	**5.50**	**5.19**
3	Burned	0.00^{a}	0.00^{a}	0.17^{b}	0.55
	Not burned	**2.93**	**1.93**^{a}	**5.33**^{b}	**3.40**
4	Burned	1.13	2.80	**2.80**	2.24
	Not burned	1.67^{ab}	2.28^{a}	0.44^{b}	1.46
5	Burned	0.57^{a}	3.76^{b}	4.38^{ab}	2.90
	Not burned	**4.75**^{ab}	4.67^{a}	**6.50**^{b}	5.30
6	Burned	4.21^{a}	**8.71**^{b}	**11.37**^{b}	8.10
	Not burned	**4.56**	5.56	5.89	5.33
Combined	Burned	1.22^{a}	2.68^{b}	2.48^{ab}	
	Not burned	**3.11**	3.59	3.42	

Table 3. Transects 1–3 (Borger Fire) and 4–6 (I-40 Fire) with burn status assignment and soil characterization (USDA 2009).

Point	Burn status	Two most prominent soil textures
		Transect 1
0	no	loam/gravelly loam
1	no	fine sandy loam/clay loam
2	no	clay loam/fine sandy loam
3	yes	clay loam/gravelly loam
4	yes	loam/clay loam
5	yes	loamy fine sand/fine sand
6	yes	loamy fine sand/fine sand
7	no	loamy fine sand/fine sand
8	no	stony loam/loam
9	no	gravelly loam/fine sandy loam
10	no	clay loam/fine sandy loam
		Transect 2
0	yes	loam/clay loam
1	yes	loam/clay loam
2	yes	loam/clay loam
3	yes	fine sandy loam/loam
4	yes	fine sandy loam
5	yes	fine sandy loam
6	yes	fine sandy loam/loamy fine sand
7	no	fine sandy loam/fine sand
8	no	loamy fine sand/loam
9	no	loamy fine sand/fine sand
10	no	fine sand/fine sandy loam
		Transect 3
0	yes	fine sandy loam/clay loam
1	yes	clay loam/sandy loam
2	yes	loam/clay loam
3	yes	clay loam/loam
4	yes	clay loam/fine sandy loam
5	yes	loam/fine sandy loam
6	no	fine sandy loam/gravelly loam
7	no	gravelly loam/loam
8	no	gravelly loam/fine sandy loam
9	no	fine sandy loam/gravelly loam
10	no	fine sandy loam/loam
		Transect 4
0	yes	fine sandy loam/loamy fine sand
1	yes	loamy fine sand/fine sandy loam
2	yes	fine sandy loam/clay loam
3	yes	clay loam/fine sandy loam
4	yes	loam/clay loam
5	no	loam/sandy clay loam
6	no	gravelly loam/clay loam
7	no	loam/clay loam
8	no	loam/clay loam
9	no	gravelly loam/clay loam
10	no	clay loam/gravelly loam
		Transect 5
0	yes	loamy fine sand/fine sandy loam
1	yes	fine sandy loam/loamy fine sand
2	yes	loamy fine sand
3	yes	loamy fine sand/fine sand
4	yes	loamy fine sand/fine sandy loam
5	yes	gravelly sandy loam/fine sandy loam
6	yes	loamy fine sand/gravelly sandy loam
7	no	loamy fine sand/clay loam
8	no	loamy fine sand/fine sandy loam
9	no	loamy fine sand/fine sand
10	no	loamy fine sand/fine sandy loam
		Transect 6
0	yes	fine sandy loam/loamy fine sand
1	yes	fine sand/loamy fine sand
2	yes	fine sand
3	yes	loamy fine sand/fine sand
4	yes	loamy fine sand/fine sand
5	yes	loamy fine sand/fine sand
6	yes	loamy fine sand/fine sand
7	yes	loamy fine sand/fine sandy loam
8	no	loamy fine sand/fine sandy loam
9	no	fine sandy loam/loamy fine sand
10	no	fine sandy loam/loamy fine sand

conditions that are favorable to management objectives that may include: (1) invasive species control, (2) forage production enhancement, and (3) browse and/or forb quality improvement. Time of day, soil moisture, season, air temperature, and wind speed are among the parameters considered in planning a successful prescribed burn (Scifres and Hamilton 1993, Holechek et al. 2004). Wildfire is spontaneous, by definition unplanned, and may have few of the preferred conditions and advantages credited to prescribed burns driven by specific objectives.

MANAGEMENT IMPLICATIONS

The slow recovery of bobwhite populations in the wildfire-affected areas can likely be attributed to at least 3 factors. First, the amount and timing of post-burn rainfall produced disparate impacts within and among individual study transects. Second, soil texture and the concomitant plant response to rainfall post-burn likely contributed to the development of more habitable conditions for bobwhites on sites dominated by sandy soils. Last, recovery rates because of distance from burned edge, may have overwhelmed response of bobwhites to recolonize large landscapes, especially those devoid of woody cover.

Post-burn recovery of woody plants suitable for mid-day loafing and escape cover occurs slowly on clay-loam soils (Renwald et al 1978). Succession to a shrub overstory may take 10 years at this latitude. Extended grazing deferment, or light grazing pressure until a full growing season (or longer) has passed after substantial rainfall is received, could encourage earlier recovery post-burn.

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LITERATURE CITED

Dabbert, C. B., D. R. Lucia, and R. B. Mitchell. 2007. Quails on the High Plains. Pages 233–247 *in* L. A. Brennan, ed. Texas quails: ecology and management. Texas A&M University Press, College Station, USA.

Gould, F. W. 1975. Texas plants: a checklist and ecological summary. Publication MP-585. Texas Agricultural Experiment Station, College Station, USA.

Guthery, F. S. 1986. Beef, brush, and bobwhites: quail management in cattle country. Golden Banner Press, Corpus Christi, Texas, USA.

Guthery, F. S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 61:291–301.

Guthery, F. S. 2000. On bobwhites. Texas A&M University Press, College Station, USA.

Holechek, J. L., R. D. Piper, and C. H. Herbel. 2004. Range management principles and practice. Pearson Education Inc., Upper Saddle River, New Jersey, USA.

Howard, W. E., R. L. Fenner, and H. E. Childs Jr. 1959. Wildlife survival in brush burns. Journal of Range Management 12:230–234.

Jackson, A. S. 1965. Wildfires in the Great Plains grasslands. Proceedings of the Tall Timbers Fire Ecology Conference 4:241–259.

Lehmann, V. W. 1984. Bobwhites in the Rio Grande Plain of Texas. Texas A&M University Press, College Station, USA.

Renwald, J. D., H. A. Wright, and J. T. Flinders. 1978. Effect of prescribed fire on bobwhite quail habitat in the Rolling Plains of Texas. Journal of Range Management 31:65–69.

Rollins, D. 2007. Quails on the Rolling Plains. Pages 117–141 *in* L. A. Brennan, ed. Texas quails: ecology and management. Texas A&M University Press, College Station, USA.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale and Edwardsville, USA.

Rosene, W. 1969. The bobwhite quail: its life and management. Rutgers University Press, New Brunswick, New Jersey, USA.

Schmidly, D. J. 2002. Texas natural history: a century of change. Texas Tech University Press, Lubbock, USA.

Scifres, C. J., and W. T. Hamilton. 1993. Prescribed burning for brushland management. Texas A&M University Press, College Station, USA.

Seckinger, E. M., L. W. Burger Jr., R. Whittington, A. Houston, and R. Carlisle. 2008. Effects of landscape composition on winter survival of northern bobwhites. Journal of Wildlife Management 72:959–969.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner's Sons, New York, USA.

Texas Parks and Wildlife Department (TPWD). 2012. Quail survey data in major ecological regions. Texas Parks and Wildlife Department, Austin, USA. www.tpwd.state.tx.us/huntwild/hunt/planning/quail_forecast/forecast/

U.S. Department of Agriculture (USDA). 2009. Web Soil Survey. USDA, Natural Resources Conservation Service, Washington, D.C., USA. websoilsurvey.nrcs.usda.gov

U.S. Department of Commerce. 2009. Climate summary, Amarillo, Texas. National Oceanic and Atmospheric Administration, Baton Rouge, Louisiana, USA.www.noaa.gov/climate/local_-data.php?wfo=ama

Wilson, M. M., and J. A. Crawford. 1979. Response of bobwhites to controlled burning in south Texas. Wildlife Society Bulletin 7:53–56.

Zane, D., J. Henry, C. Lindley, P. W. Pendergrass, D. Galloway, T. Spencer, and M. Stanford. Surveillance of mortality during the Texas Panhandle wildfires (March 2006). Texas Department of State Health Services, Austin, USA.

DISTANCE–BASED HABITAT ASSOCIATIONS OF NORTHERN BOBWHITES IN A FESCUE-DOMINATED LANDSCAPE IN KANSAS

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ABSTRACT

Northern bobwhites (*Colinus virginianus*) have a wide distribution across North America which influences its' associations with habitats in a variety of landscapes. We used radio-marked bobwhites and Euclidean distance to characterize land cover associations of bobwhites at generalized level 1 and specific level 2 land cover classifications during the reproductive (15 Apr-14 Oct) and covey (15 Oct-14 Apr) periods in southeastern Kansas from 2003 to 2005. Habitat associations occurred during the reproductive (Wilkes' $\lambda = 0.04$, $F_{6,36} = 143.682$, $P < 0.001$) and covey (Wilkes' $\lambda = 0.056$, $F_{6,\ 29} = 81.99$, $P < 0.001$) periods. Ranking of the reproductive period habitats indicated bobwhites preferred locations in close proximity to fescue (*Festuca* spp.) over all other habitats. Coveys preferred locations in close proximity to woody cover. Bobwhites were found to associate with specific habitats at the level 2 land cover classification during the reproductive (Wilkes' $\lambda = 0.006$, $F_{16,\ 26} = 284.483$, $P < 0.001$) and covey (Wilkes' $\lambda = 0.004$, $F_{16,\ 19} = 276.037$, $P < 0.001$) periods. Bobwhites preferred locations in close proximity to fescue pastures and roads equally over all other habitats during the reproductive period. Coveys preferred locations in close proximity to roads and Conservation Reserve Program lands during the covey period. Fescue pastures may be avoided by bobwhites during the covey period, provided adequate cover is not provided, but bobwhites are strongly associated with them during the reproductive period because they meet nesting and brooding needs not met by other habitats.

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Key words: *Colinus virginianus*, Conservation Reserve Program, Euclidean distance, habitat associations, Kansas, northern bobwhite

INTRODUCTION

The decline of bobwhite populations has often been attributed to changes in land use, particularly changes in farming practices (Brennan 1991, Church and Taylor 1992, Brady et al. 1993, Peterson et al. 2002). The widespread shift to clean farming and removal of fencerows and idle land has made agricultural landscapes less favorable to bobwhites through fragmentation and loss of habitat (Brennan 1991, Roseberry 1993). Veech (2006) found that declining, and locally extinct bobwhite populations occur in landscapes that are different from those of increasing populations. He found that declining populations tend to occur in landscapes having more closed canopy woodland or forest than increasing populations.

The widespread use of cool-season grasses such as tall fescue (*Festuca arundinacea*) has been suggested as a factor in the decline of bobwhites. Little research has been conducted on the effects of exotic grasses on habitat use during the life cycle of bobwhites. Much of the limited research was in undisturbed areas (Burger et al. 1990, Barnes et al 1995). One of the reasons that fescue has been viewed as poor habitat for bobwhites is its limited diversity and lack of bare ground in stands that have not

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been mowed or grazed (Barnes et al. 1995). However, recent work by Labrum (2007) suggests fescue, while not providing optimum habitat for bobwhites, may supply structure and insects not available elsewhere in a landscape. Kuvlesky et al. (2002) indicated more research was needed to quantify the specific effects of fescue and other exotic grasses on bobwhites throughout their range.

The 'edge', ecotone, or transition where different plant communities blend together has been hypothesized to be an important habitat component for bobwhites (Stoddard 1931, Rosene 1984). Edge can take several forms. It can be a hard and distinct boundary (inherent edge) between habitat types, such as envisioned by Leopold (1933) or it can be a true ecological transition zone (induced edge) where two successional stages blend together such as described by Smith and Smith (2009). However, little information is available on the preference of bobwhites for different edge types or what constitutes an acceptable edge type and the scale of edge use (field vs. landscape). Roseberry and Sudkamp (1998) reported bobwhite in Illinois were associated with patchy landscapes that contained moderate amounts of row crops, grassland, and abundant woody edge, but we do not know the scale of patch use in their study.

Our objectives were to examine: (1) the effects of landscape configuration in a fescue- dominated agricultural system on bobwhite locations during the year using Euclidean distances, and (2) the effect of specific land cover types on bobwhite locations.

STUDY AREA

The 64.8-km^2 study area was in southwestern Bourbon County, Kansas, 3.2 km south of Uniontown (37° 46′ 58″ N, 94° 58′ 43″ W) (Fig. 1). This was also a demonstration area for the Southeastern Kansas Quail Initiative sponsored by the Kansas Department of Wildlife and Parks, and other partners. The vegetation was dominated by fescue pastures and hayfields intermixed with native prairie pastures and hayfields. Large tracts of cropland were within the floodplains of streams. Smaller tracts of cropland were scattered throughout the upland. There were narrow riparian forests interconnected with small woodlots and linear fencerows throughout the area. Many of the fencerows consisted of mature Osage orange (*Maclura pomifera*). Conservation Reserve Program (CRP) lands were scattered in the uplands and in small patches in the floodplains of streams. CRP consisted of a mix of native warm-season grasses including big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*).

The land cover of the study area consisted of a patchy landscape (Fig. 1). Fescue hayfields comprised 5.8%, fescue pasture 36.3%, fescue waterways 0.9%, farm ponds 0.5%, farmsteads 1.0%, idle land 1.2%, native prairie hayfields 1.6%, native prairie pasture 4.3%, native grass waterways 0.1%, roads 0.9%, woodlands 20.6%, and woody fencerows 1.6% of the study area. Most changes occurred in CRP and cropland (Table 1). Woodland patch size varied from 0.4 to 332.2 ha. Cropland patch size varied from 0.1 to 83.5 ha while fescue patch size varied from 0.3 to 282.2 ha. Native prairie patch size varied from 0.1 to 128.9 ha. The CRP tracts in the study area were isolated with patch sizes from 0.5 to 58 ha.

METHODS

Field Procedures

We trapped bobwhites from January through March 2003 through 2005 and October through December 2003 and 2004 using baited funnel traps on 8 0.64-km^2 areas. We classified captured birds to age and sex, and all were weighed. Individuals within each covey weighing $>$ 150 g were fitted with a necklace radio transmitter (AVM Instrument Company Ltd., Colfax, CA, USA) weighing $<$ 5 g. We released bobwhites immediately after processing at the capture location. We located bobwhites 3 to 7 times/week until mortality, loss of contact (radio failure or long distance movement), or end of study.

We located bobwhites with radio transmitters using a combination of hand-held 3-element yagi antennas and a 4-element null peak antenna mounted on a vehicle. We conducted homing with hand-held antennas. The null peak antenna was used to relocate bobwhites that moved long distances.

Locations of bobwhite were recorded on Universal Transverse Mercator (UTM) grids on aerial photographs. We used a global positioning system (GPS) to record the location where bobwhites were flushed. Vehicle telemetry consisted of 2 to 3 bearings taken rapidly within 10 min to triangulate the radio-marked bobwhite's location. Triangulation was used to locate bobwhites during the reproductive period. We used GPS to record the base stations for vehicle triangulation. Program LOAS (Ecological Software Solutions, Urnsach, Switzerland) was used to estimate locations of radio-marked bobwhite based on triangulation data.

We used on-screen digitizing in ArcView 3.3 (Environmental Systems Research Institute Inc., Redlands, CA, USA) to classify land cover based on digital images. We used 2002 Digital Orthophoto Quarter Quads (DOQQ) as well as 2003, 2004, and 2005 National Agricultural Inventory Program (NAIP) digital color aerial photographs as base maps for land cover analysis. We obtained DOQQs and NAIP digital color aerial photos from Kansas Data Access and Support Center (http://www.kansasgis.org/). Land cover was classified for 2003, 2004, and 2005. We classified land cover into a level 2 classification of farmsteads, roads, farm ponds, fescue hayfields, fescue pasture, fescue waterways, idle land, native prairie hayfields, native prairie rangeland, native prairie waterways, new CRP, burned CRP, and established CRP. New CRP was general sign-up and continuous sign-up $<$ 2 years of age. Burned CRP was those areas burned by landowners during March and April through the first growing season and up until mid-April of the following year. Established CRP had been established for a minimum of 3 years. The differentiation between CRP and native prairie was due to differences in

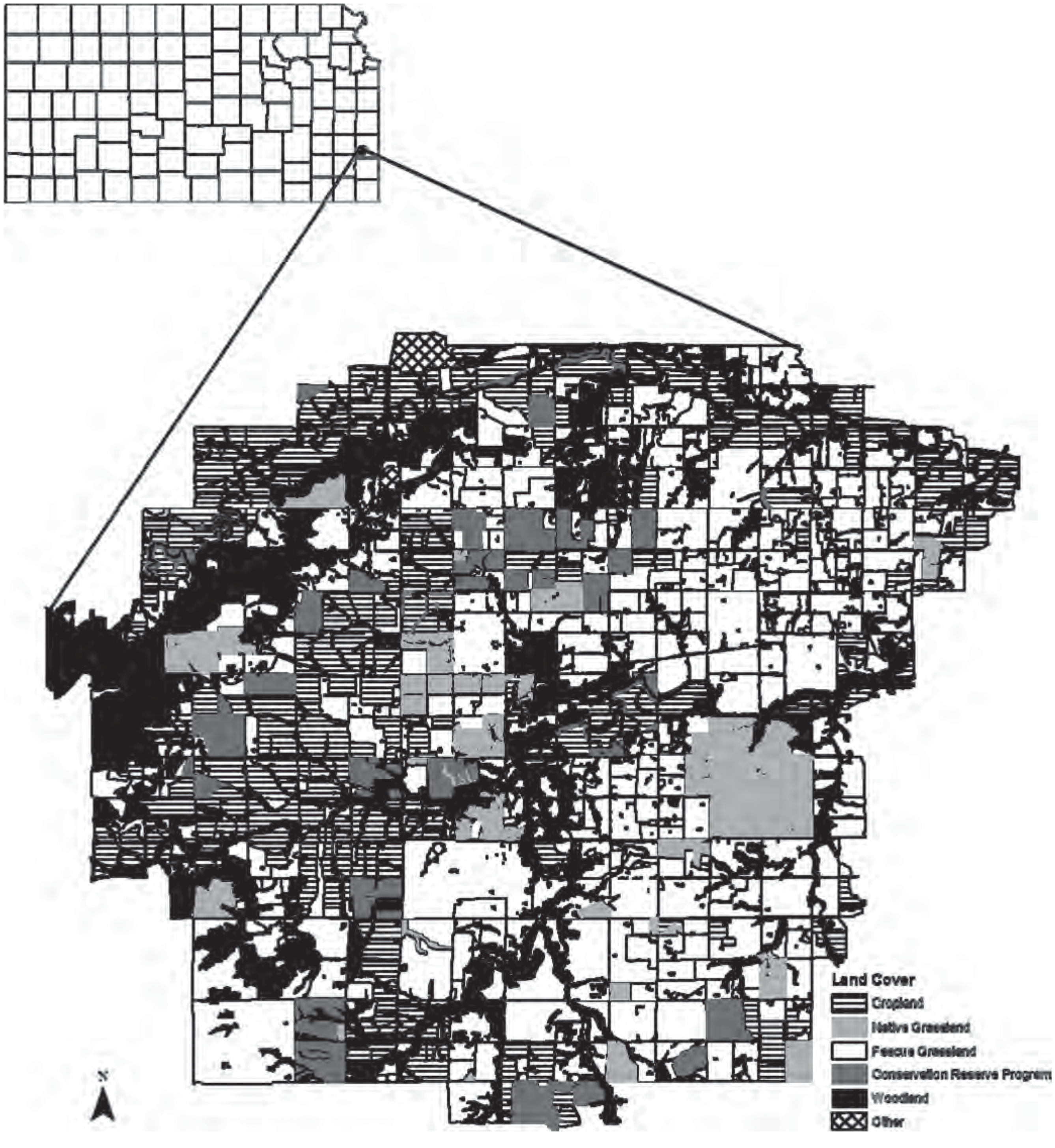

Fig. 1. Study area in Bourbon County, Kansas, USA with general land cover class distribution, 2003–2005.

management of those areas along with higher plant diversity that often occurred in prairie areas versus CRP. We analyzed habitat association of bobwhites and grouped land cover into level 1 generalized classification of other (farmsteads, urban, roads, and farm ponds), fescue grassland (fescue hayfield, fescue pasture, fescue waterway, and idle land), native prairie (native prairie hayfield, native prairie rangeland, and native prairie waterway), woodland (fencerows and woodlots), and CRP (new, burned, and established general sign-up CRP). We ground-truthed all areas each year to obtain an accurate map.

Habitat Association Analysis

We used Euclidean distance (Conner and Plowman 2001, Conner et al. 2003) to analyze habitat use by bobwhites during covey (15 Oct-14 Apr) and reproductive

(15 Apr-14 Oct) periods because of its advantages over other methods. Conner et al. (2003) found Euclidean distance identified edges as important habitat features and was not affected by location error. Bingham and Brennan (2004) reported this method did not inflate Type I error. Our Euclidean distance analysis was based on ratios of use versus expected distance to habitat. The observed-random ratio should equal 1.0 for each habitat type if use was nonrandom. The ratio suggested which habitat was associated more or less with bobwhite locations if the habitat was associated disproportionately. The observed-random ratio was < 1.0 if bobwhites were associated more with the habitat than expected. The observed-random ratio was > 1.0 if bobwhites were associated less with the habitat than expected.

We conducted home range analyses separately for covey and reproductive periods. We used the Animal Movement Extension (Hooge and Eichenlaub 2001) to calculate the 95% fixed-kernel home range for each covey (covey period) and individual (reproductive period). We used ArcView 3.3 to buffer each home range at 1,000 m. The 1,000-m buffer was used to generate a comparison of potential use to landscape availability around bobwhite home ranges. A 1,000-m buffer was used because bobwhites seldom moved $>$ 1,000 m beyond their home ranges during their lives. We used the Animal Movement Extension to generate 30 uniformly random points within each buffer for each home range. We separated habitats for 2003, 2004, and 2005 into different layers, and used the ArcView Nearest Neighbor extension (Weigel 2004) to estimate the distance for each random and bobwhite location for each habitat type and year. The Nearest Neighbor analysis was conducted at the initial general and detailed land-cover classes.

We calculated $\mathbf{r_j}$ which was the average distance for random locations for each bobwhite or covey to each land cover type (Conner and Plowman 2001) and $\mathbf{u_i}$ which was the average distance to each habitat for each bobwhite or covey (Conner and Plowman 2001). We created $\mathbf{d_i}$ which was a vector of ratios for each bobwhite or covey by dividing $\mathbf{u_i}$ by $\mathbf{r_j}$ (Conner and Plowman 2001). The expected value of each element in $\mathbf{d_i}$ is 1.0 under the null hypothesis of no selection (Conner and Plowman 2001). We used MANOVA to test for significance of $\mathbf{d_i}$ for sex and year. We used the mean of the $\mathbf{d_i}$ which was $\boldsymbol{\rho}$ and MANOVA to examine if $\boldsymbol{\rho}$ differed from a vector of ones (Conner and Plowman 2001).

We used the Wilkes' λ test statistic to indicate non-random resource selection (Conner and Plowman 2001). We tested each element of $\boldsymbol{\rho}$ for each habitat type against 1 using a paired t-test to examine which habitat types were used disproportionately (Conner and Plowman 2001). Bobwhites were associated less with the habitat if a statistically significant element of $\boldsymbol{\rho}$ was > 1 (Conner and Plowman 2001). Bobwhites were associated more with the habitat if a statistically significant element of $\boldsymbol{\rho}$ was < 1 (Conner and Plowman 2001). We also tested whether a particular habitat type was used more than other habitat types using a paired t-test. The pair-wise test provided a habitat ranking matrix similar to the compositional analysis approach of Aebischer et al. (1993). We conducted analyses at both levels 1 and 2 land cover classifications. We conducted statistical analyses with SPSS 12.0 (SPSS Inc., Chicago, IL, USA).

Table 1. Percent land cover class that changed in study area in southeastern, Kansas, USA, 2003–2005.

	2003	2004	2005
Burned CRP[a]	0.6	0.1	2.5
CRP[a]	3.2	3.8	1.4
Cropland	21.1	19.9	19.9
New CRP[a]	0.3	1.4	1.4

[a] Conservation Reserve Program lands.

RESULTS

We captured and radiomarked 275 northern bobwhites representing 42 coveys. We used 179 radio-marked bobwhites representing 35 coveys for analysis. Sample size was reduced because 7 coveys did not survive past the 14-day acclimation period. Ninety-four of the 179 remaining radio-marked bobwhites during the covey period were males and 85 were females. Forty-two radio-marked individuals were used for analysis during the reproductive period of which 25 were males and 17 were females.

There was no difference in habitat association by sex during the reproductive period (Wilkes' $\lambda = 0.885$, $F_{6,35} = 0.756$, $P = 0.609$). There was no detectable difference in habitat association between years for covey period (Wilkes' $\lambda = 0.523$, $F_{12,54} = 1.724$, $P = 0.087$). There was a difference in habitat association between years for the reproductive period (Wilkes' $\lambda = 0.516$, $F_{12,68} = 2.219$, $P = 0.02$). Covey period data were pooled by sex and year, and also for the reproductive period due to small sample sizes during individual years.

Analysis of habitat associations using Euclidean distance for the reproductive period at the generalized land cover classification indicated habitat selection occurred (Wilkes' $\lambda = 0.04$, $F_{6,36} = 143.682$, $P < 0.001$). Bobwhites were closer than expected during the reproductive period to woody cover ($t_{41} = -4.065$, $P < 0.001$), other ($t_{41} = -6.336$, $P < 0.001$), fescue grassland ($t_{41} = -8.872$, $P < 0.001$), and CRP ($t_{41} = -8.872$, $P < 0.001$). There was no detectable preference or avoidance of bobwhite locations in relation to native prairie ($t_{41} = -0.707$, $P = 0.483$) or cropland ($t_{41} = 0.848$, $P = 0.401$). Bobwhites had a greater preference for fescue during the reproductive period than other habitats (Table 2).

Habitat selection occurred for the covey period based on Euclidean distance (Wilkes' $\lambda = 0.056$, $F_{6,29} = 81.99$, $P < 0.001$). Coveys were closer than expected to woody cover ($t_{34} = -11.563$, $P < 0.001$), other ($t_{34} = -3.630$, $P = 0.001$), native prairie ($t_{34} = -2.658$, $P = 0.012$), CRP ($t_{34} = -5.642$, $P < 0.001$), and cropland ($t_{34} = -2.915$, $P = 0.006$). Coveys did not show a detectable proximity to fescue grassland ($t_{34} = -1.002$, $P = 0.323$) during the covey period. Coveys had an overall preference for locations closer to woody cover than other habitats during

Table 2. Pair-wise comparisons (*t*- and *p*-values and final land cover ranking; the higher the rank, the more preference for that land cover type) of distance/random ratios for habitats during the reproductive period with initial generalized land cover classifications (level 1) for bobwhites in southeastern Kansas, USA, 2003–2005.

	Cropland		CRP[a]		Fescue		Native prairie[b]		Other		Woodland		
	t	*P*	*t*	*P*	*t*	*P*	*t*	*P*	*t*	*P*	*t*	*P*	Rank
Cropland			−3.507	0.001	−5.709	0.001	−1.155	0.255	−3.931	0.001	−3.01	0.004	1
CRP[a]	3.507	0.001			−2.511	0.016	2.857	0.007	−0.91	0.368	−0.1	0.921	3
Fescue	5.709	0.001	2.511	0.016			6.088	0.001	2.567	0.014	2.462	0.018	6
Native prairie[b]	1.155	0.255	−2.857	0.007	−6.088	0.001			−4.219	0.001	−2.54	0.015	2
Other	3.931	0.001	0.91	0.368	−2.567	0.014	4.219	0.001			0.589	0.559	5
Woodland	3.01	0.004	0.1	0.921	−2.462	0.018	2.54	0.015	−0.589	0.559			4

[a] Conservation Reserve Program land.

[b] Mix of native grasses and forbs not established under CRP.

the covey period based on the pair-wise comparisons (Table 3).

Bobwhites exhibited habitat selection during the reproductive period (Wilkes' $\lambda = 0.006$, $F_{16,26} = 284.483$, $P < 0.001$). They were closer than expected to burned CRP ($t_{41} = -4.878$, $P < 0.001$), CRP ($t_{41} = -3.119$, $P = 0.003$), woody fencerows ($t_{41} = -2.910$, $P = 0.006$), fescue pasture ($t_{41} = -4.091$, $P < 0.001$), fescue waterways ($t_{41} = -2.224$, $P = 0.32$), native prairie hayfield ($t_{41} = -2.121$, $P = 0.40$), native prairie waterways ($t_{41} = -3.441$, $P = 0.001$), new CRP ($t_{41} = -3.526$, $P = 0.001$), ponds ($t_{41} = -3.667$, $P = 0.001$), and roads ($t_{41} = -4.772$, $P < 0.001$). Bobwhites did not show a detectable preference or avoidance for locations close to woodlots ($t_{41} = -1.884$, $P = 0.067$), cropland ($t_{41} = 0.803$, $P = 0.427$), farmsteads ($t_{41} = -0.424$, $P = 0.674$), fescue hayfield ($t_{41} = -0.377$, $P = 0.708$), idle land ($t_{41} = 0.449$, $P = 0.656$), and native prairie pasture ($t_{41} = -0.684$, $P = 0.498$). Bobwhites preferred locations during the reproductive period closer to fescue pastures and roads more than other habitats (Table 4).

Coveys exhibited habitat selection during the covey period at the level 2 land cover classification (Wilkes' $\lambda = 0.004$, $F_{16,19} = 276.037$, $P < 0.001$). Coveys were closer to woodlots ($t_{34} = -2.813$, $P = 0.008$), burned CRP ($t_{34} = -2.588$, $P = 0.14$), cropland ($t_{34} = -2.602$, $P = 0.014$), CRP ($t_{34} = -3.438$, $P = 0.002$), woody fencerows ($t_{34} = -2.322$, $P = 0.26$), idle land ($t_{34} = -3.031$, $P = 0.005$), native prairie pasture ($t_{34} = -2.309$, $P = 0.27$), native prairie waterways ($t_{34} = -3.346$, $P = 0.002$), new CRP ($t_{34} = -3.431$, $P = 0.002$), and roads ($t_{34} = -5.067$, $P < 0.001$). Coveys were farther from fescue pastures than expected ($t_{34} = 2.491$, $P = 0.018$). Coveys did not show a detectable preference or avoidance to farmsteads ($t_{34} = 0.348$, $P = 0.730$), fescue hayland ($t_{34} = -0.111$, $P = 0.912$), fescue waterway ($t_{34} = -1.284$, $P = 0.208$), native prairie hayland ($t_{34} = -1.351$, $P = 0.186$), or ponds ($t_{34} = -1.772$, $P = 0.085$). Coveys preferred locations that were in close proximity to roads and CRP (Table 5).

DISCUSSION

Bobwhite populations in Kansas have been relatively stable after declining from their highest recorded levels in the early 1970s (Applegate and Williams 1998). Bobwhite whistle-count data indicate populations in southeastern Kansas were relatively stable from 1998 through 2006 (Pitman 2006) but have since declined slightly due to weather conditions (Dahlgren 2011). This suggests current habitat conditions in the area are able to sustain populations although weather influences may periodically intervene. Understanding the influence of landscape configuration on bobwhite locations can greatly assist in managing bobwhite populations in other landscapes.

We used Euclidean distance to examine how bobwhite locations were influenced by their proximity to other land cover types or habitats within the landscape. Bingham et al. (2010) believed landscape configuration

Table 3. Pair-wise comparisons (*t*- and *p*-values for each pair-wise comparison along with final ranking); the higher the rank, the more preference for that land cover type of distance random ratios for habitats during the covey period with initial generalized land cover classifications (level 1) for bobwhites in southeastern Kansas, USA, 2003–2005.

	Cropland		CRP[a]		Fescue		Native prairie[b]		Other		Woodland		
	t	*P*	*t*	*P*	*t*	*P*	*t*	*P*	*t*	*P*	*t*	*P*	Rank
Cropland			−0.13	0.897	2.236	0.032	0.891	0.379	−0.13	0.897	−2.825	0.008	3
CRP[a]	1.121	0.270			3.98	0.001	1.97	0.057	1.341	0.189	−1.354	0.185	5
Fescue	−2.236	0.032	−3.98	0.001			−1.917	0.064	−3.308	0.002	−5.667	0.001	1
Native prairie[b]	−0.891	0.379	−1.97	0.057	1.917	0.064			−0.949	0.349	−4.485	0.001	2
Other	0.13	0.897	−1.341	0.189	3.308	0.002	0.949	0.349			−3.011	0.005	4
Woodland	2.825	0.008	1.354	0.185	5.667	0.001	4.485	0.001	3.011	0.005			6

[a] Conservation Reserve Program land.

[b] Mix of native grasses and forbs not established under CRP.

and juxtaposition of habitat patches would influence which habitats would be preferred and would vary depending on the landscape context. They recommended Euclidean distance not be used in resource selection until these problems could be corrected. We did not use Euclidean distance for resource selection such as compositional analysis, but used it to show the influence of landscapes on bobwhite locations.

Habitat associations of bobwhites in Bourbon County varied between the reproductive and covey periods, most likely due to changes in biological needs of bobwhites throughout their life cycle. Bobwhites tend to prefer areas of primarily dead vegetation that is denser than surrounding habitat for nesting (Rosene 1984, Taylor et al. 1999a). Bobwhites also tend to select vegetation that is an average of 50 cm in height in Illinois (Klimstra and Roseberry (1975) to 52 cm in Kansas (Taylor et al. 1999a) for nesting. Bobwhites during the brood-rearing period tend to select areas with relatively abundant bare ground and forb cover for brooding (Taylor and Guthery 1994, Taylor et al. 1999a). Labrum (2007) suggested bobwhites during the reproductive period may be selecting for habitats having a higher insect diversity. Winter roost sites during the covey period were in vegetation that had a mean height of 59 cm in Illinois (Klimstra and Ziccardi 1963), 68 cm in Oklahoma (Wiseman and Lewis 1981), and 91 to 106 cm in Missouri (Chamberlain et al. 2002). Habitat selection appears to be for habitat patches which allow predator avoidance, increased accessibility to food, and increased nesting and brood rearing success (Roseberry and Klimstra 1984, Rosene 1984).

Conner et al.'s (2003) distance analysis of bobwhite habitat association indicated greater use of edge or ecotone than expected. However, use of edge was only associated with some habitats. Our results indicated bobwhites preferred edges between woody cover, other (farmsteads and ponds), fescue, and CRP during the reproductive period. Bobwhites preferred edges between woody cover, other, native grassland, CRP, and cropland during the covey period.

There was a distinct shift in proximity of bobwhite locations between seasons. Bobwhites avoided fescue during the covey period, but associated strongly with it during the reproductive period. Avoidance of fescue during the covey period and its use during the reproductive period was probably due to changes in vegetation characteristics between the 2 periods as well as changes in the biological needs of bobwhites. Continuous grazing of fescue and changes in plant growth during the covey period resulted in extremely short vegetation. The change in vegetation height became most pronounced from December through early April. The short stature of the vegetation during this time period probably would not provide adequate thermal cover or protection from predators.

Reduction of vegetation height also can have a significant effect on habitat connectivity between suitable habitat patches by not providing sufficient cover during the covey period. Large areas of short fescue, mowed native grass, bare crop fields, or other short vegetation reduce movement of bobwhites between habitats and potentially reduce overall survival of individuals. It can also result in isolation of bobwhites into small patches where taller vegetation occurs. This results in small coveys being unable to increase to an optimum group size. Williams et al. (2003) reported bobwhites had an optimal group size of 10–11 individuals. Thus, as group size increased, survival decreased for individuals, movement increased, and individual body mass decreased. Small groups of 1 to 7 individuals also had lower group persistence, individual survival, and increased movement (Williams et al. 2003). Isolation of coveys in our study due to habitat fragmentation may have prevented small coveys from recruiting new members reducing overall fitness of these coveys.

Fescue pastures in the study area were typically grazed by cattle rotated among fields in spring which resulted in a mix of short grass and tall thick patches during the summer with a variety of intermixed short annual forbs. The strong association of bobwhites with fescue on our study area was probably because it was the only habitat that met bobwhite needs. Labrum (2007) also believed that although fescue pastures were not ideal habitat for bobwhites, they provided structure and insect diversity not available in other habitats. Osborne et al. (2012) reported fescue CRP fields which were disturbed had more bobwhite use during the reproductive period than fields that were not disturbed. The positive associations that we found with fescue differ from previous reports. Barnes et al. (1995) concluded that undisturbed tall fescue was not good bobwhite habitat because it lacked proper vegetation structure, floristic composition, and sufficient food. Sole (1995) reported bobwhites did not use fescue fields but used a field converted from fescue to native warm-season grasses. Klimstra and Roseberry (1975) indicated bobwhites used fescue pastures little during the breeding season, and used unimproved pastures more. Unimproved pastures were those that contained a mix of naturally occurring forbs, grasses, shrubs, and briars (*Rubus* spp.) (Klimstra and Roseberry 1975), a habitat commonly referred to as old field.

Woody cover generally was more preferred in the covey than the reproductive period, but woody fencerows were preferred during spring over other woody cover. Woody fencerows were linear areas throughout the study area composed of mature trees and/or a mix of shrubs, grasses, and forbs. Other woodlands were along riparian areas and as large patches of trees in cool-season grass pastures. This spatial distribution of woody vegetation over the landscape allowed bobwhites to feed and be close to woody cover for escape and thermal protection.

Williams et al. (2000) reported woody cover (treelines and wooded drainage ways) was the primary escape cover for bobwhites during the winter in east-central Kansas. Wiseman and Lewis (1981) indicated woody cover (tall shrubs, short shrubs, and woodland) was an important habitat throughout the year for bobwhites in tallgrass prairie of Oklahoma. Woody cover provided feeding, resting, and escape cover for quail throughout the year. Taylor and Burger (2000) reported bobwhites during the breeding season in Mississippi preferred woody areas

Table 4. Simplified ranking matrices based on pair-wise comparisons of distance/random ratios for each land cover class during the reproductive period using a detailed land cover classification (level 2) for bobwhites in southeastern Kansas, USA, 2003–2005. Each element in the matrix was replaced by its sign; a triple sign represents difference at $P < 0.05$ (+ = a positive association and – = a negative association). The higher the rank, the more preference for that land cover type.

	BCRP[a]	Cropland	CRP[b]	Farm[c]	Fence[d]	FH[e]	FP[f]	FW[g]	Idle	NPH [h]	NPP [i]	NPW [j]	New CRP	Pond	Road	Woodlot	Rank
BCRP[a]		+++	+	+++	+	+++	−	+	+++	+++	+++	+++	+++	+	−	+	13
Cropland	− − −		− − −	−	− − −	−	− − −	− − −	−	−	−	−	− − −	− − −	− − −	−	1
CRP[b]	−	+++		+	−	+	−	+	+++	+	+	+	+	−	−	−	9
Farm[c]	− − −	+	−		−	+	− − −	−	+	−	+	−	−	− − −	− − −	−	3
Fence[d]	−	+++	+	+		+	−	+	+++	+	+++	+	+	+	−	+	12
FH[e]	− − −	+	−	−	−		+++	−	+	−	−	−	−	− − −	− − −	−	3
FP[f]	+	+++	+	+++	+	− − −		+++	+++	+++	+++	+++	+++	+++	+	+	14
FW[g]	−	+++	−	+	−	+	− − −		+	+	+	+	−	−	− − −	−	7
Idle	− − −	+	− − −	−	− − −	−	− − −	−		−	−	−	− − −	− − −	− − −	−	2
NPH[h]	− − −	+	−	+	−	+	− − −	−	+		+	+	−	−	− − −	−	6
NPP[i]	− − −	+	−	+	− − −	+	− − −	−	+	−		−	− − −	− − −	− − −	−	4
NPW[j]	− − −	+	−	+	−	+	− − −	−	+	−	+		− − −	− − −	− − −	−	5
New CRP	− − −	+++	−	+	−	+	−	+	+++	+	+++	+++		−	− − −	−	8
Pond	− − −	+++	+	+++	+	+++	− − −	+	+++	+	+++	+++	+		−	+	11
Road	+	+++	+	+++	+	+++	+	+++	+++	+++	+++	+++	+++	−		+	14
Woodlot	−	+	+	+	−	+	−	+	+	+	+	+	+	−	−		10

[a] Burned Conservation Reserve Program land.

[b] Conservation Reserve Program land.

[c] Farmstead.

[d] Woody fencerow.

[e] Fescue hayland.

[f] Fescue pasture.

[g] Fescue grass waterway.

[h] Native prairie hayland.

[i] Native prairie pasture.

[j] Native prairie waterway.

Table 5. Simplified ranking matrices based on pair-wise comparisons of distance/random ratios for each land cover class during the covey period using a detailed land cover classification (level 2) for bobwhite in southeastern Kansas, USA, 2003–2005. Each element in the matrix was replaced by its sign; a triple sign represents difference at $P < 0.05$ (+ = a positive association and − = a negative association). The higher the rank, the more preference for that land cover type.

	BCRP[a]	Cropland	CRP[b]	Farm[c]	Fence[d]	FH[e]	FP[f]	FW[g]	Idle	NPH[h]	NPP[i]	NPW[j]	New CRP	Pond	Road	Woodlot	Rank
BCRP[a]		−	−	+	−	−	+++	+	−	+	+	+	−	+	− − −	−	9
Cropland	+		−	+	+	+++	+++	+	+	+	+	+	+	+	−	−	13
CRP[b]	+	+		+	+	+++	+++	+	+	+	+	+	+	+	−	+++	15
Farm[c]	−	−	− − −		− − −	−	+++	−	− − −	−	−	−	−	− − −	− − −	− − −	2
Fence[d]	+	−	−	+		+	+++	+	−	+	+	+	+	+	−	−	11
FH[e]	−	− − −	− − −	+	−		+++	−	−	−	−	−	−	− − −	− − −	− − −	3
FP[f]	− − −	− − −	− − −	− − −	− − −	− − −		− − −	− − −	− − −	− − −	− − −	− − −	−	− − −	− − −	1
FW[g]	−	−	−	+	−	+	+++		−	+	−	−	−	+	− − −	−	6
Idle	+	−	−	+++	+	+	+++	+		+	+	+	+	+	−	−	12
NPH[h]	−	−	−	+	−	+	+++	−	−		−	−	−	−	− − −	−	4
NPP[i]	−	−	−	+	−	+	+++	+	−	+		+	−	+	− − −	−	8
NPW[j]	−	−	−	+	−	+	+++	+	−	+	−		−	+	− − −	−	7
New CRP	+	−	−	+++	−	+++	+	+	−	+	+	+		+	− − −	−	10
Pond	−	−	−	+	−	+	+	−	−	+	−	−	−		− − −	−	5
Road	+++	+	+	+++	+	+++	+++	+++	+	+++	+++	+++	+++	−		+	16
Woodlot	−	−	−	+++	+	+++	+++	+	+	+	+	+	+	+	−		14

[a] Burned Conservation Reserve Program land.

[b] Conservation Reserve Program land.

[c] Farmstead.

[d] Woody fencerow.

[e] Fescue hayland.

[f] Fescue pasture.

[g] Fescue waterway.

[h] Native prairie hayland.

[i] Native prairie pasture.

[j] Native prairie waterway.

and old fields that were burned and disked. Sandercock et al. (2008) indicated winter survival was vital to population growth and increasing the availability of woody cover provided more protection from predators during this period.

Woody fencerows were often along boundaries of fescue pastures. Many fencerows associated with fescue were grazed and had reduced shrub cover and forbs compared to fencerows associated with road edges and CRP that were not grazed. Preference of bobwhites for locations in close proximity to woodlands during the covey period was probably due to the association of woodlands and CRP fields in our study area.

Bobwhites had a higher preference for CRP edge during the covey period than during the reproductive period. Williams et al. (2000) reported bobwhites preferred idle land which included CRP, grass waterways, and roadsides during the winter. Taylor et al. (1999b) also reported idle land, of which 62% consisted of CRP, was preferred habitat in Kansas during the breeding season in both cropland and rangeland areas.

Little other information on use of CRP by bobwhite is available. This lack of research has resulted in limited changes to CRP that might be beneficial to bobwhites. CRP edge was preferred over new or burned CRP during the covey period. CRP fields were areas that had at least 1 growing season since the last disturbance. New CRP was preferred to burned CRP as it contained minimal grass cover and was often covered with annual weeds. However, burned CRP edge was preferred over unburned or new CRP during the reproductive period. This difference may have been due to increased diversity of CRP, 1 year after disturbance. Burned CRP may have been preferred in the breeding season due to increased bare ground and shorter vegetation which made the areas more favorable for movement and feeding by broods.

Bobwhites favored locations near roads during the reproductive and covey periods over all other land cover classes. Association of bobwhites with roads during the reproductive period may also be due to proximity to fescue pastures. Roads may serve as dusting and foraging areas. Roadsides contained fencerows or scattered trees in many instances that could provide escape cover for bobwhites throughout the year.

MANAGEMENT IMPLICATIONS

Agricultural landscapes provide challenges for managing early-successional (i.e., old field) wildlife species including northern bobwhites. Continued disturbance of many areas can reduce cover and wildlife value. For example, grazing, haying, and dormancy of fescue reduces plant height and can result in isolated patches of winter cover, but grazing fescue during late spring and early summer may provide a mix of plant structure that can support bobwhites. Managers in a fescue-dominated landscape need to focus on increasing habitat connectivity and winter cover needed by coveys for survival. Connectivity can be increased by adding and protecting woody cover within the landscape. Increasing the width of existing fencerows could enhance their value to bobwhites during the covey period. Converting portions of fescue pastures along fencerows to native warm season grasses and shrub buffers may allow for increased connectivity and provide more areas for coveys to survive during the winter as well as providing secure nesting cover.

Management of CRP can also have an impact on bobwhite habitat association. Lack of habitat disturbance can result in reduced value for bobwhites (Burger et al. 1990). Disturbance of CRP can affect its use by bobwhites by potentially altering its structure and reducing its value. Ryan et al. (1998) suggested that applying rotational disturbances to enhance the value of early and mid-successional plant communities on CRP might allow these habitats to meet seasonal needs of bobwhite. One method that might provide a good mix of early and mid-successional habitat is patch burning which has been proposed by Fuhlendorf and Engle (2001) for rangelands. They recommended patch burning as a way to create more heterogeneous native grasslands as opposed to the current management which creates a more homogeneous vegetation structure. This same technique could be used to manage CRP to create more heterogeneous patches to improve its value to bobwhites and other wildlife. Bobwhites are grassland/woodland transitional species that need a diversity of forbs, grasses, and woody cover to survive. More emphasis should be placed on creating and managing woody cover in and around CRP to mimic an early-successional old field community.

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LITERATURE CITED

Aebischer, N. J., P. A. Robertson, and R. E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74:1313–1325.

Applegate, R. D., and C. K. Williams. 1998. Results of 30 years of Kansas April rural mail carrier surveys. Transactions of the Kansas Academy of Science 101:95–100

Barnes, T. G., L. A. Madison, J. D. Sole, and M. J. Lacki. 1995. An assessment of habitat quality for northern bobwhite in tall fescue-dominated fields. Wildlife Society Bulletin 23:231–237.

Bingham, R. L., and L. A. Brennan. 2004. Comparison of Type I error rates for statistical analyses of resource selection. Journal of Wildlife Management 68:206–212.

Bingham, R. L., L. A. Brennan, and B. M. Ballard. 2010. Discrepancies between Euclidean distance and compositional analyses of resource selection data with known parameters. Journal of Wildlife Management 74:582–587.

Brady, S. J., C. H. Flather, K. E. Church, and E. W. Schenck. 1993. Correlates of northern bobwhite distribution and abundance with land-use characteristics in Kansas. Proceedings of the National Quail Symposium 3:115–125.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

Burger, L. W., E. W. Kurzejeski, T. V. Dailey, and M. R. Ryan. 1990. Structural characteristics of vegetation in CRP fields in northern Missouri and their suitability as bobwhite habitat. Transactions of the North American Wildlife and Natural Resources Conference 55:74–83.

Chamberlain, E., R. D. Drobney, and T. V. Dailey. 2002. Winter macro- and microhabitat use of winter roost sites in central Missouri. Proceedings of the National Quail Symposium 5:140–145.

Church, K. E., and J. S. Taylor. 1992. Management and research of northern bobwhite (*Colinus virginianus*) in North America: an overview. Gibier Faune Sauvage 9:787–796.

Conner, J. W., and B. W. Plowman. 2001. Using Euclidean distances to assess nonrandom habitat use. Pages 279–290 *in* J. J. Millspaugh and J. M. Marzluff, eds. Radio tracking and animal populations. Academic Press, San Diego, California, USA.

Conner, J. W., M. D. Smith, and L. W. Burger. 2003. A comparison of distance-based and classification-based analysis of habitat use. Ecology 84:526–531.

Dalhgren, D. 2011. 2011 bobwhite whistle count. Federal Aid in Wildlife Restoration Progress Report W-39-R-17. Kansas Wildlife, Parks and Tourism. Pratt, USA.

Fuhlendorf, S. D., and D. M. Engle. 2001. Restoring heterogeneity on rangelands: ecosystem management based on evolutionary grazing patterns. BioScience 51:625–632.

Hooge, P. N., and B. Eichenlaub. 2001. Animal Movement Extension to ArcView. Version 2.0. Alaska Science Center-Biological Science Office, USDI, Geological Survey, Anchorage, USA. gcmd.nasa.gov/records/USGS_animal_mvmt.html

Klimstra, W. D., and J. L. Roseberry. 1975. Nesting ecology of the bobwhite in southern Illinois. Wildlife Monographs 41.

Klimstra, W. D., and V. C. Ziccardi. 1963. Night-roosting habitat of bobwhites. Journal of Wildlife Management 27:202–214.

Kuvlesky Jr., W. P., T. E. Fulbright, and R. Engel-Wilson. 2002. The impact of invasive exotic grasses on quail in the southwestern United States. Proceedings of the National Quail Symposium 5: 118–128.

Labrum, K. C. 2007. Bobwhite production, brood ecology, and brood movements in response to habitat restoration in northern Arkansas. Thesis. Arkansas Tech University, Russellville, USA.

Leopold, A. 1933. Game management. Charles Scribners and Son's, New York, USA.

Osborne, D. C., D. W. Sparling, and R. L. Hopkins II. 2012. Influence of Conservation Reserve Program mid-contract management and landscape composition on northern bobwhite in tall fescue monocultures. Journal of Wildlife Management 76:566–574.

Peterson, M. J., X. B. Wu, and R. Rho. 2002. Rangewide trends in landuse and northern bobwhite abundance: an exploratory analysis. Proceedings of the National Quail Symposium 5:33–44.

Pitman, J. 2006. 2006 bobwhite whistle count. Federal Aid in Wildlife Restoration Progress Report W-39-R-12. Kansas Department of Wildlife and Parks, Pratt, USA.

Ryan, R. R., L. W. Burger, and E. W. Kurzejeski. 1998. The impact of CRP on avian wildlife: a review. Journal of Production Agriculture 11:61–66.

Roseberry, J. L. 1993. Bobwhite and the "new" biology. Proceedings of the National Quail Symposium 3:16–20.

Roseberry, J. L. and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, USA.

Roseberry, J. L., and S. D. Sudkamp. 1998. Assessing the suitability of landscapes for northern bobwhite. Journal of Wildlife Management 62:895–902.

Rosene, W. 1984. The bobwhite quail- its life and management. The Sun Press, Hartwell, Georgia, USA.

Sandercock, B. K., W. E. Jensen, C. K. Williams, and R. D. Applegate. 2008. Demographic sensitivity of population change in the northern bobwhite: a life-stage simulation analysis. Journal of Wildlife Management 72:970–982.

Smith, T. M., and R. L. Smith. 2009. Elements of ecology. Seventh edition. Benjamin-Cummings, San Francisco, California, USA.

Sole, J. D. 1995. Changes in vegetation and bobwhite quail and eastern cottontail rabbit use in a converted fescue field. Transactions of the Kentucky Academy of Science 56:1–8.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner and Son's, New York, USA.

Taylor II, J. D., and L. W. Burger Jr. 2000. Habitat use by breeding northern bobwhites in managed old-field habitats in Mississippi. Proceedings of the National Quail Symposium 4:7–15.

Taylor, J. S., and F. S. Guthery. 1994. Components of northern bobwhite brood habitat in southern Texas. Southwestern Naturalist 39:73–77.

Taylor, J. S., K. E. Church, and D. H. Rusch. 1999a. Microhabitat selection by nesting and brood-rearing northern bobwhite in Kansas. Journal of Wildlife Management 63:686–694.

Taylor, J. S., K. E. Church, D. H. Rusch, and J. R. Cary. 1999b. Macrohabitat effects on summer survival, movements, and clutch success of northern bobwhite in Kansas. Journal of Wildlife Management 63:675–685.

Veech, J. A. 2006. Increasing and declining populations of northern bobwhites inhabitat different types of landscapes. Journal of Wildlife Management 70:922–930.

Weigel, J. 2004. Nearest Neighbor 3.6. ECOGIS Geomatics, Wennigsen, Germany. arcscripts.esri.com/details.asp?dbid=11765

Williams, C. K., R. S. Lutz, and R. D. Applegate. 2003. Optimal group size and northern bobwhite coveys. Animal Behaviour 66:377–387.

Williams, C. K., R. S. Lutz, R. D. Applegate, and D. H. Rusch. 2000. Habitat use and survival of northern bobwhite (*Colinus virginianus*) in cropland and rangeland ecosystems during the hunting season. Canadian Journal of Zoology 78:1562–1566.

Wiseman, D. S., and J. C. Lewis. 1981. Bobwhite use of habitat in tallgrass rangeland. Wildlife Society Bulletin 9:248–255.

NESTING OF NORTHERN BOBWHITES ON RANGELAND VERSUS CONSERVATION RESERVE PROGRAM HABITATS IN THE ROLLING PLAINS OF TEXAS

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ABSTRACT

Conservation Reserve Program (CRP) contracts account for about 1.7 million ha in Texas, and are often touted as habitat for upland game birds. We compared nest site locations, hatch rates, and arthropod abundance for northern bobwhites (*Colinus virginianus*) on CRP versus rangeland habitats at the Rolling Plains Quail Research Ranch (RPQRR), Fisher County, Texas from 2008 to 2011. Nest sites were monitored via radio-marked females. Simulated nests ($n = 144$/yr) were used to evaluate hatch rates between the 2 habitat types. Arthropod abundance (as an indicator of brood habitat) was measured annually in August using sweep nets and pitfall traps. We documented 103 nest sites, 14% were in CRP while the remaining 86% were in rangeland; bobwhites neither selected nor avoided CRP as nesting habitat. 'Survival' of simulated nests (i.e., percent intact at 28 days exposure) across the 4 years averaged 63.2% for CRP and 74.4% on rangelands. Arthropod availability was greater in rangeland in 3 of the 4 years studied. CRP pastures dominated by kleingrass (*Panicum coloratum*) were used for nesting in proportion to their availability, but rangeland provided better brood habitat.

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Key words: *Bothriochloa saccharoides*, *Colinus virginianus,* Conservation Reserve Program, introduced grasses, kleingrass, nesting, northern bobwhite, *Panicum coloratum,* Rolling Plains, Texas

INTRODUCTION

The Conservation Reserve Program (CRP) has changed the agricultural landscape of the southern Great Plains since inception in 1985, nowhere more than in the High Plains and Rolling Plains ecoregions of Texas. Nationally, ~ 15 million ha were enrolled in CRP with ~ 11% of that (1.7 million ha) in Texas. The CRP was highly touted for its benefits to wildlife (especially upland birds), but expectations have not been uniformly realized across states or species groups (Best et al. 1997, Ryan et al. 1998). The population response by northern bobwhites to the CRP has varied ranging from positive (Riddle et al. 2008) to neutral (Roseberry and David 1994, Ryan et al. 1998, Riffell et al. 2008).

Several studies (Ryan et al. 1998, Riffell et al. 2008) examined the impact(s) of CRP in cropland-dominated landscapes which provide little useable space for bobwhites (e.g., southeastern U.S.), or in the intensively-cropped High Plains of Texas (Abbott et al. 2012). The landscape of the Rolling Plains tends to be rangeland (i.e., useable space for bobwhites) punctuated by agricultural fields (typically < 30 ha in size) (Rollins 2007). Thus, CRP fields are often surrounded by rangelands capable of complementing the lack of forbs and woody cover for bobwhites in CRP.

Several researchers have expressed concern about the value of some Conservation Practices (CPs) included in CRP, i.e., vegetation types used regionally, and their value as habitat for bobwhites (Berthelson et al. 1989, Best et al. 1997, Riffell et al. 2008). Introduced warm-season (CP 1) and native warm-season (CP 2) grasses dominated plantings in northwest Texas (Berthelson and Smith 1995). Native grasses typically included gramas (*Bouteloua* spp.), little bluestem (*Schizachyrium scoparium*), and switchgrass (*Panicum virgatum*).

Introduced species of grass have become a contentious issue for quail managers in South Texas (Sands 2007, Tjelmeland 2007, Moore 2010) and throughout the Midwest where tall fescue (*Schedonorus phoenix)* dominated seeding mixtures (Greenfield et al. 2002). The most commonly planted introduced grasses in the Rolling Plains were weeping lovegrass (*Eragrostis curvula*), old world bluestems (*Bothriochloa* spp.), and kleingrass (*Panicum coloratum*) (Rollins 2007).

The value of CRP for bobwhites varies relative to the age and species composition of the grass stand (Lutz et al. 1994). Initially fields are dominated by annual forbs and thin stands of grasses, and provide acceptable habitat for bobwhites, especially when these fields border brush-dominated rangelands (Lutz et al. 1994, Rollins 2007). The grass stands (often seeded as monocultures) after the first several years (depending on precipitation and soil type) crowd out forbs and decrease bare ground which is

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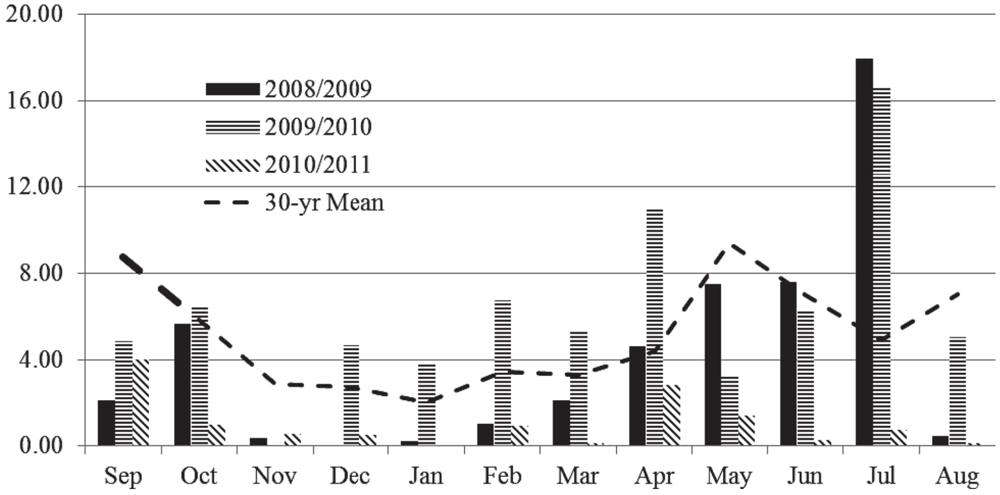

Fig. 1. Monthly precipitation (cm) on the Rolling Plains Quail Research Ranch, Fisher County, Texas, 2008-2011 versus the 30-year mean for Roby, Texas (15 km east of RPQRR).

important for bobwhite foraging and travel. Woody cover is especially limiting in CRP fields in northwest Texas. The absence of woody cover precludes use by bobwhites beyond some distance (e.g., > 50 m) from the edge of the field (Dabbert et al. 2007). Establishment and growth of suitable coverts, typically mesquite (*Prosopis glandulosa*) takes > 15 years in the Rolling Plains (Rollins 2007).

The greatest value of CRP fields for bobwhites may be for nesting cover, which is often limited on adjacent grazed rangelands (Rollins 2007). We initiated a study to document nesting of bobwhites in a landscape of CRP and rangeland typical of the Rolling Plains. Our objectives were to document nest placement and hatching rates of bobwhites in kleingrass-dominated CRP fields compared to adjacent rangelands. We also evaluated abundance of selected arthropods on the 2 vegetation types as an index to brood habitat for bobwhites.

STUDY AREA

We conducted our study on the Rolling Plains Quail Research Ranch (RPQRR), a 1,900-ha ranch 20 km west of Roby, Fisher County, Texas. The average annual precipitation is 61.5 cm with bimodal peaks in May and September. Annual precipitation varied across the years; 2008 and 2010 were above normal while 2009 and 2011 were drier than normal (Fig. 1). Exceptional drought conditions prevailed from October 2010 through September 2011, the driest 13-month period recorded in the past 136 years (Nielson-Gammon 2011).

Native range sites were on land that had only been grazed historically by cattle and not used for crop production since the 1950s. These sites were characterized by silver bluestem (*Bothriochloa saccharoides*), sideoats grama (*Bouteloua curtipendula*), and scattered colonies of old world bluestems (mostly Caucasian bluestem; *B. bladhii*). Common shrubs included mesquite, hackberry (*Celtis laevigata var. reticulata),* lotebush (*Ziziphus obtusifolia)*, catclaws (*Acacia greggii* and *Mimosa aculeaticarpa* var. *biunciferae*), and littleleaf sumac *(Rhus microphylla)*. Prickly pear (*Opuntia* spp.) cacti were abundant on rangeland sites, but largely absent on CRP. No grazing occurred from 2007 to 2011 in the pastures we used for this study. The most common soil types include Miles fine sandy loam, Woodward-Quinlan loams, and Paducah loams (USDA 2011).

Four CRP fields were included comprising 13.2% of the RPQRR's area—rangeland comprised 86.8% (Fig. 2). The sites were enrolled in the CRP in 1987–88 and consisted primarily of kleingrass with lesser amounts of silver bluestem. Regrowth mesquite occurred sporadically across the fields, but was not of sufficient size/density to constitute mid-day cover for bobwhites. The dominant soil types on CRP sites included Wichita clay loam, Weymouth clay loam, and Miles fine sandy loam (USDA 2011).

METHODS

Nesting Surveys

We trapped and radio-marked female bobwhites with neck-loop transmitters weighing ~ 6 g (American Wildlife Enterprises, Monticello, FL, USA) starting in February 2008 and continuing through August 2011. Trapping was conducted across the study area, including the juncture of CRP fields and rangeland; we assumed bobwhites had equal opportunity to select nest sites in either habitat type. We tracked birds > 2 times per week. We moved to within ~ 20 m by quietly circling the bird without flushing it when we suspected nesting. Nests were monitored every day following location until nest fate could be assigned, i.e., hatched, depredated, or abandoned. Nest locations were delineated with a handheld GPS unit and subsequently uploaded to Google Earth Software to measure distance from the edge of the CRP field in which the nest occurred.

We used simulated nests in both CRP and rangeland habitats to provide additional data on hatch rates between

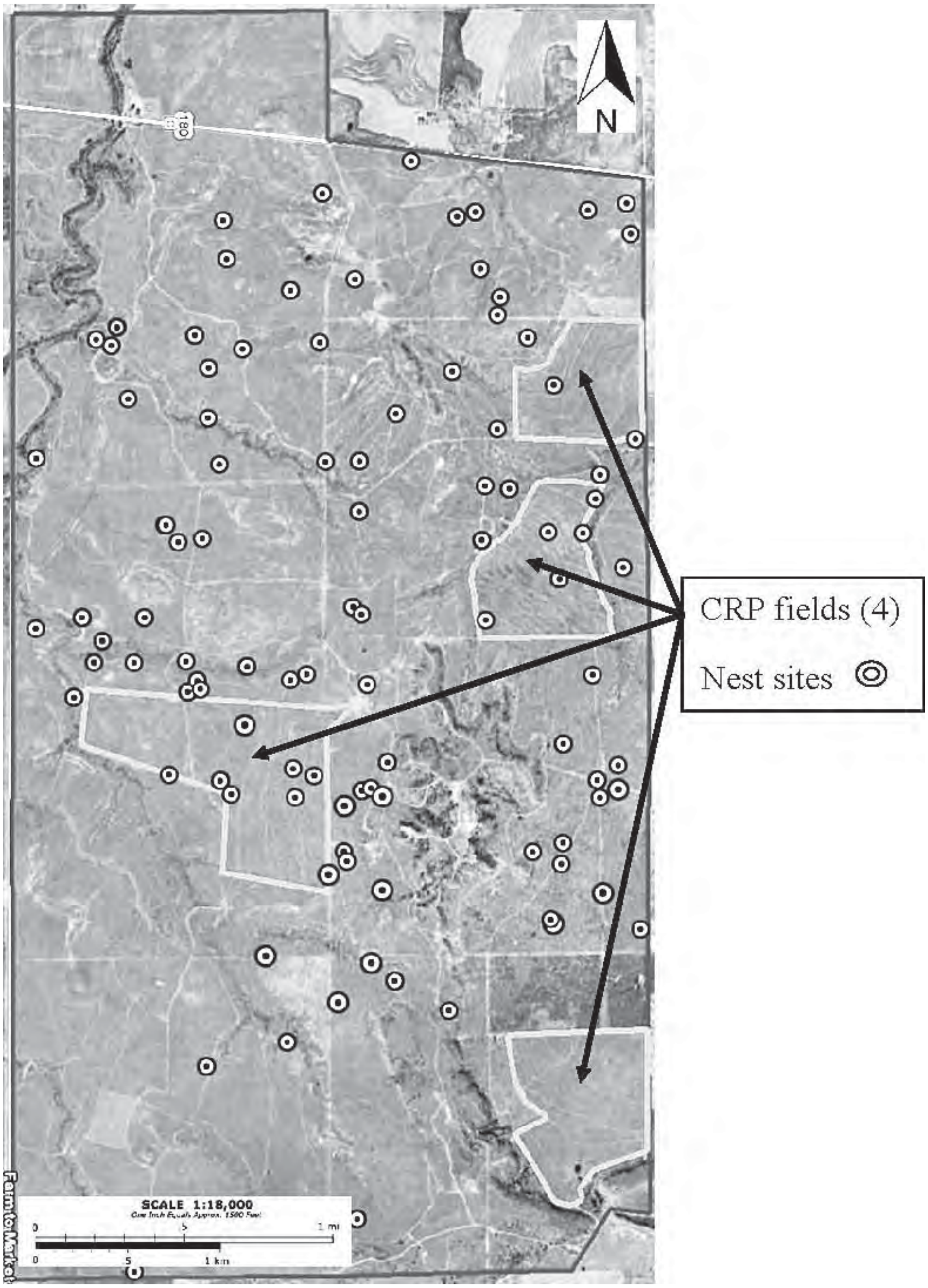

Fig. 2. Locations of Conservation Reserve Program pastures and actual bobwhite nests on the Rolling Plains Quail Research Ranch, Fisher County, Texas, 2008–2011.

the 2 vegetation types. Simulated nests have been found to reasonably depict the fate of actual bobwhite nests in the Rolling Plains (Hernández et al. 2001). We established simulated nests in June following protocols described by Slater et al. (2001) and Rollins et al. (2005), and checked them at 14- and 28-day intervals. Nests consisted of 3 unwashed medium-sized chicken eggs, and were placed at 50-m intervals along randomly-located transects; each transect consisted of 6 nests. Nests were placed alternately in suitably-sized bunchgrasses in rangeland (Lehmann 1984) or prickly pear (Slater et al. 2001). Simulated nests in CRP were placed exclusively in kleingrass. Any eggs still intact at the 14-day check were replaced with fresh eggs to minimize any olfactory cues to predators as a result of putrification.

We used 144 simulated nests each year; 12 transects (72 nests) were placed randomly in CRP (3 transects per field) and 12 were placed randomly across rangeland sites.

Table 1. Nesting locations of northern bobwhites on kleingrass (CRP) and native rangeland on the Rolling Plains Quail Research Ranch, Fisher County, Texas, 2008–2011.

			Nests recorded									
	Area available		2008		2009		2010		2011		Totals	
Vegetation	ha	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
CRP	216	13	6	29	3	7	3	17	1	9	13	14
Rangeland	1,633	87	21	71	41	93	18	83	10	91	90	86

Quality of nesting habitat (e.g., bunchgrass density) was estimated for (1) simulated nests by counting bunchgrasses rooted within a 2.0-m wide belt transect extending along each nest transect for simulated nests (Slater et al. 2001), and (2) for actual nests at randomly-located compass headings with the nest site as the origin along 2, 100-m transects. We calculated apparent nest success (% nests hatched) for actual nests; abandoned nests were included in these calculations and were considered depredated. We estimated hatch rate for simulated nests as the number of simulated nests intact at the 28-day check.

Arthropod Abundance

We conducted arthropod sampling in July each year (2009-2011) to assess arthropod availability. We used 2 sampling methods: sweep nets and pitfall traps. Pitfall traps consisted of plastic cups recessed into the ground so the rim of the cup was flush with the ground surface. The cup was filled ~ 1/3 full with a solution of liquid dish detergent and water. Five transects of 6 cups per transect annually were placed randomly across each of the 4 CRP fields (total of 30 cups per field). Cups were spaced 10 m apart. Pitfall traps were checked/refilled 3 and 6 days later. The soap solution was strained on collection days for arthropods with all specimens stored in paper bags, labeled, and air-dried.

Sweep-net samples consisted of 50 rapid sweeps over a distance of 30–50 m on a randomly selected heading from point of origin. A subset of the pitfall traps was selected randomly and used to ascertain which 4 of 6 pitfall cup locations would be sampled via sweep nets. Sweep-net sampling was conducted on the same day and sampled between 1200 and 1800 hrs to minimize diurnal variability. The contents were stored in paper bags after sweeping, labeled, and frozen until later analysis. We sorted arthropods by Order and counted individual specimens; only counts for the Orders Coleoptera and Orthoptera are included.

Statistical Analyses

We report only apparent nest success for actual nests. Some researchers (e.g., Mayfield 1961, Johnson 1979) suggested that estimates of apparent nest success are biased because the exact date of nest initiation is usually unknown. We assumed any bias in nest success was similar between the 2 vegetation types, and unimportant in the context of our study objectives. We used Chi-square to test whether there was a difference in the proportion of actual nests between CRP and rangeland.

RESULTS

Nesting

Bobwhites neither selected nor avoided CRP as nesting habitat ($\chi^2 = 0.09$, 1 df, $P = 0.77$). We documented 103 actual nests across the 4 years; 13 (12.6%) were in CRP pastures and 90 (87.4%) were in rangeland (Table 1, Fig. 2). Ten of 13 nests in CRP were < 100 m from the nearest edge. All 13 nests in CRP were in kleingrass, whereas most of the rangeland nests were in silver bluestem or silver bluestem-prickly pear assemblages.

Apparent nesting success tended to be lower for nests in CRP, a trend also suggested by simulated nests (Table 2). Apparent nest success pooled across the 4 years of the study averaged 38.5% ($n = 13$) compared to 52.2% for rangeland habitats ($n = 90$). Simulated nest success averaged (± SE) across all 4 years was 62.3 ± 8.0% ($n = 256$) for CRP habitats versus 74.0 ± 6.1% ($n = 256$) on rangeland. Nest success indicated by simulated nests tended to be greater than apparent nest success in both vegetation types. Available nesting clumps varied annually, but averaged (± SE) 2,682.4 ± 726.5/ha in CRP versus 2,079.4 ± 932.5/ha in rangeland. Density of grass clumps suitable for nesting was more variable across years in rangeland habitats versus CRP; this trend was especially evident in the exceptional drought year (2011) when clump density decreased to 397.2 clumps/ha.

Table 2. Fate of simulated bobwhite nests (percent intact at 28 days exposure) and actual nests in kleingrass (CRP) and native rangeland on the Rolling Plains Quail Research Ranch, Fisher County, Texas, 2008–2011; $n = 72$ simulated nests for each year in each vegetation type.

	CRP			Rangeland			
	Simulated	Actual		Simulated	Actual		
Year	(%)	*n*	Hatched	(%)	*n*	Hatched	%[a]
2008	77.8	6	4	80.6	21	12	57
2009	63.9	3	0	58.3	41	22	54
2010	63.6	3	1	86.5	18	8	44
2011	43.9	1	0	70.7	10	4	40
Mean	62.3			74.0			51

[a] Percent not included for actual nests in CRP due to small sample size ($n = 13$).

Table 3. Arthropod abundance for Orthoptera and Coleoptera on CRP (kleingrass) and rangeland sites on the Rolling Plains Quail Research Ranch, Fisher County, Texas, 2008–2011. Data for pitfall traps are mean number of individuals per transect (6 traps) and sweep nets are mean individuals per 100 sweeps. Pitfall trapping was not initiated until 2010.

	Orthoptera				Coleoptera			
	Pitfall		Sweep		Pitfall		Sweep	
Year	CRP	Rangeland	CRP	Rangeland	CRP	Rangeland	CRP	Rangeland
2008			11.5	36.3			9.3	37.1
2009			13.2	45.2			6.2	16.5
2010	7.2	5.7	48.7	18.3	12.7	32.3	10.0	1.7
2011	0.6	0.5	0.6	1.6	7.2	6.1	0.0	0.0
Mean	3.9	3.1	18.5	25.4	10.0	19.2	6.4	13.8

Arthropod Dynamics

Abundance of Orthoptera and Coleoptera varied among years (Table 3). Rangeland habitats tended to support greater arthropod abundance in most years than CRP habitats. Rangelands supported ~ 37% more orthopterans and 116% more coleopterans based on sweep-net sampling and about 92% more coleopterans based on pitfall sampling. There were 2 exceptions. The first was in 2010 (a wet year) when CRP habitats supported much higher numbers of both Orders; the second was in 2011 (exceptional drought) when arthropod availability was minimal on all sites.

DISCUSSION

Nesting

Kleingrass-dominated CRP habitats provided adequate nesting habitat for bobwhites. Bobwhites tended to nest in CRP habitats in proportion to their availability. We concur with other authors that structure of the nesting substrate seems more important than plant species involved (Lehmann 1984, Townsend et al. 2001, Moore 2010).

Rangelands in our study were not grazed, and provided excellent nesting habitat. Hatch rates observed, based on both actual and simulated nests, were well above the average reported for bobwhites across their range (mean = 28%; Rollins and Carroll 2001), and equal or above hatch rates reported for the Rolling Plains (e.g., ~ 50%; Hernández et al. 2001, Cox et al. 2005).

Nesting success tended to be lower in CRP; an observation supported by simulated nests. We believe the lack of, or at least the relative paucity of prickly pear on CRP sites may have contributed to the lower hatch rates observed in CRP relative to rangeland. Actual and simulated bobwhite nests in clumps of prickly pear survive at higher rates than those in bunchgrasses (Slater et al. 2001, Hernández et al. 2009a).

CRP sites may contribute important nesting sites for bobwhites across the Rolling Plains given that CRP sites were not grazed (except in a few exceptions) due to drought-imposed grazing availability. Rangeland sites used in this study on RPQRR were not grazed, but the majority of rangelands in the Rolling Plains were, and overgrazing is a common, and pervasive, issue in quail management in this region (Rollins 2007). Their potential for quail nesting habitat remains unclear as CRP contracts expire, depending on how these sites are managed in the future (Cearley and Kowaleski 2008).

The increasing availability of introduced grasses, and their potential for bobwhites, can be contentious issues for bobwhite managers. Several authors have cited concerns about habitat degradation as a result of introduced grasses, especially in the southwestern U.S. (Kuvlesky et al. 2002). Flanders et al. (2006) reported bobwhites were about twice as abundant on native rangelands in South Texas compared with sites dominated by introduced grasses (e.g., buffelgrass, *Pennisetum ciliare*). Clump-forming species of introduced grasses such as weeping lovegrass, buffelgrass, and guineagrass (*Urochloa maxima*) appear to provide adequate nesting habitat for bobwhites (Sands 2007, Tjelmeland 2007, Moore 2010, Abbott et al. 2012). Kleingrass is a bunchgrass with structural characteristics similar to native bunchgrasses used by bobwhites for nesting (e.g., little bluestem); other species of introduced grasses may not provide similar structure nor provide suitable nesting cover.

Many researchers have maligned introduced grasses as habitat for bobwhites, but it is also possible that presence of introduced grasses may benefit bobwhite populations by providing suitable nesting habitats during drought years or on overgrazed rangelands (Kuvlesky et al. 2002). Our data confirm that (non-grazed) kleingrass habitats maintained desirable clump density even during the most extreme drought in Texas' history. Berthelson et al. (1989) found that CRP contracts seeded with kleingrass and blue grama (*Bouteloua gracilis*) provided high quality nesting habitat for a variety of game birds in the High Plains of Texas. Our data should not be misinterpreted as an endorsement of introduced species—but an acknowledgment that some can provide suitable nesting habitat for bobwhites in the Rolling Plains.

Nest success, while adequate (i.e., > 40%) tended to be lower for nests in CRP fields than non-grazed rangeland. Slater et al. (2001) recommended a minimum of 754 prospective nest clumps/ha as a threshold of quality nesting cover for bobwhites in the Rolling Plains. Rangeland sites on the RPQRR during our study were above this threshold except during the exceptional drought of 2011; CRP sites in our study were well above the suggested threshold, even during exceptional drought. Rangeland in our study area was characterized by moderate to heavy infestations of prickly pear, and prickly pear affords nest protection from mesomammals (Slater et al. 2001, Hernández et al. 2009a).

Brood Habitat

Nesting habitat for bobwhites could be a virtue for CRP sites, but some researchers have questioned the value of introduced grass monocultures for brood-rearing, i.e., arthropod availability (Flanders et al. 2006). Orthoptera and Coleoptera were generally less available on CRP sites, but this pattern varied across years. Neither vegetation type produced many insects during exceptional drought conditions (i.e., 2011).

The CRP sites in our study typically lacked floral species diversity that would promote a more diverse, and perhaps more abundant arthropod community than that occurring on rangelands. Rangelands in typical years (2008–2009) produced greater arthropod biomass than CRP sites. CRP sites tended to produce greater arthropod abundance, especially Orthoptera in above-average precipitation years (e.g., 2010).

Most of the bobwhite nesting activity in CRP occurred near the field's edge (< 100 m). None of the broods monitored used CRP to any appreciable extent. Doxon and Carroll (2007) reported CRP fields in Kansas planted to native grasses provided excellent foraging opportunities for bobwhite chicks; thus, accessibility and other issues may be more important in affecting habitat 'quality' for game bird chicks. Vegetation characteristics such as bare ground cover can impact insect availability for foraging chicks (Burger et al. 1993, Doxon and Carroll 2010). Feeding rates of bobwhite chicks were sensitive to vegetation-influenced mobility on CRP fields in western Kansas (Doxon and Carroll 2010). Management of CRP fields for bobwhite chicks can be reconciled by practices that permit more open space at ground level, such as light disking or burning, to permit easier movement.

Traditional disturbance regimes (e.g., disking) have been evaluated to enhance structure, species, composition, and mobility (i.e., access to bare ground) (Greenfield et al. 2002, Hernández et al. 2009b). Disking of rangeland can improve bobwhite habitat by increasing bare ground (Webb and Guthery 1983, Greenfield et al. 2002), stimulating growth of important food plants (Peoples et al. 1994), and creating plant structural diversity necessary for invertebrates (Manley et al. 1994). Periodic (every 2–3 years), seasonal (winter) disking should be encouraged to enhance successional plant assemblages favored by bobwhites. Other means of increasing plant species diversity (e.g., seeding legumes) have been found to increase arthropod diversity and biomass, and enhance use of CRP fields as brood habitat (Burger et al. 1993).

MANAGEMENT IMPLICATIONS

Conservation Reserve Program contracts consisting mostly of kleingrass serve adequately as nesting cover for bobwhites in the Rolling Plains of Texas. Disturbance regimes (e.g., disking, patch-grazing) may be useful to enhance species diversity and, concomitantly, arthropod diversity for managers who seek to increase their use as habitat for bobwhites once CRP contracts expire.

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LITERATURE CITED

Abbott, C. W., C. B. Dabbert, D. R. Lucia, R. B. Mitchell, and A. K. Andes. 2012. Nest-site characteristics of northern bobwhites translocated into weeping lovegrass CRP. Proceedings of the National Quail Symposium 7:59–62.

Berthelsen, P. S., and L. M. Smith. 1995. Nongame bird nesting on CRP lands in the Texas Southern High Plains. Journal of Soil and Water Conservation 50:672–675.

Berthelsen, P. S., L. M. Smith, and C. L. Coffman. 1989. CRP land and game bird production in the Texas High Plains. Journal of Soil and Water Conservation 44:504–507.

Best, L. B., H. Campa III, K. E. Kemp, R. J. Robel, M. R. Ryan, J. A. Savidge, H. P. Weeks, and S. R. Winterstein. 1997. Bird abundance and nesting in CRP fields and cropland in the Midwest: a regional approach. Wildlife Society Bulletin 25:864–877.

Burger Jr., L. W., E. J. Kurzejeski, T. V. Dailey, and M. R. Ryan. 1993. Relative invertebrate abundance and biomass in Conservation Reserve Program plantings in northern Missouri. Proceedings of the National Quail Symposium 3:102–108.

Cearley, K. A., and C. Kowaleski. 2008. After the Conservation Reserve Program: land management with wildlife in mind. L-5508. Texas Agricultural Extension Service, College Station, USA.

Cox, S. A., F. S. Guthery, J. J. Lusk, A. D. Peoples, S. J. DeMaso, and M. Sams. 2005. Reproduction by northern bobwhites in western Oklahoma. Journal of Wildlife Management 69:133–139.

Dabbert, C. B., D. R. Lucia, and R. B. Mitchell. 2007. Quails on the High Plains. Pages 233–247 *in* L. A. Brennan, ed. Ecology and management of Texas quails. Texas A&M University Press, College Station, USA.

Doxon, E. D., and J. P. Carroll. 2007. Vegetative and invertebrate community characteristics of Conservation Reserve Program fields relative to gamebirds in western Kansas. American Midland Naturalist 158:243–259.

Doxon, E. D., and J. P. Carroll. 2010. Feeding ecology of ring-necked pheasant and northern bobwhite chicks in Conservation Reserve Program fields. Journal of Wildlife Management 74:249–256.

Flanders, A. A., W. P. Kuvlesky Jr., D. C. Ruthven III, R. C. Zaiglin, R. L. Bingham, T. E. Fulbright, F. Hernández, and L. A. Brennan. 2006. Effects of invasive exotic grasses on South Texas rangeland breeding birds. Auk 123:171–182.

Greenfield, K. C., L. W. Burger Jr., M. J. Chamberlain, and E. W. Kurzejeski. 2002. Vegetation management practices on Conservation Reserve Program fields to improve northern bobwhite habitat quality. Wildlife Society Bulletin 30:527–538.

Hernández, F., S. E. Henke, N. J. Silvy, and D. Rollins. 2001. Comparison of success between actual northern bobwhite and wild turkey nests and simulated nests. Wildlife Society Bulletin 29:1212–1218.

Hernández, F., S. E. Henke, N. J. Silvy, and D. Rollins. 2009a. Testing the value of prickly pear cactus as a nest-predator deterrent for northern bobwhite. Proceedings of the National Quail Symposium 6:256–259.

Hernández, F., L. Roberson, R. L. Bingham, S. J. DeMaso, R. Perez, T. E. Fulbright, and L. A. Brennan. 2009b. Vegetation response to timing of discing to manage northern bobwhite habitat in Texas. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 63:61–69.

Johnson, D. H. 1979. Estimating nest success—the Mayfield method and an alternative. Auk 96:651–661.

Kuvlesky Jr., W. P., T. E. Fulbright, and R. Engel-Wilson. 2002. The impact of invasive exotic grasses on quail in the southwestern United States. Proceedings of the National Quail Symposium 5:118–138.

Lehmann, V. W. 1984. The bobwhite in the Rio Grande Plain of Texas. Texas A&M University Press, College Station, USA.

Lutz, S., G. L. Valentine, S. Nelle, D. Rollins, C. Coffman, and G. Miller. 1994. Wildlife management on former CRP lands. Management Note Number 15. Texas Tech University, Lubbock, USA.

Manley, S. W., R. S. Fuller, J. M. Lee, and L. A. Brennan. 1994. Arthropod response to strip discing in old fields managed for northern bobwhites. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 48:227–235.

Mayfield, H. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255–261.

Moore, S. F. 2010. Effects of guineagrass on northern bobwhite habitat use. Thesis. Texas A&M University-Kingsville, USA.

Nielsen-Gammon, J. 2011. Texas drought: a fingerprint. Texas A&M University, College Station, USA. blog.chron.com/climateabyss/2011/08/texas-drought-a-fingerprint/

Peoples, A. D., R. L. Lochmiller, D. M. Leslie Jr., and D. M. Engle. 1994. Producing northern bobwhite food on sandy soils in semiarid mixed prairies. Wildlife Society Bulletin 22:204–211.

Riddle, J. D., C. E. Moorman, and J. H. Pollock. 2008. The importance of habitat shape and landscape context to northern bobwhite populations. Journal of Wildlife Management 72:1376–1382.

Riffell, S., D. Scognamillo, and L. W. Burger Jr. 2008. Effects of the Conservation Reserve Program on northern bobwhite and grassland birds. Environmental Monitoring Assessment 146:309–323.

Rollins, D. 2007. Quails on the Rolling Plains. Pages 117–141 in L. A. Brennan, ed. Texas quails: ecology and management. Texas A&M University Press, College Station, USA.

Rollins, D., and J. P. Carroll. 2001. Impacts of predation on northern bobwhite and scaled quail. Wildlife Society Bulletin 29:39–51.

Rollins, D., J. L. Brooks, R. N. Wilkins, and R. D. Ransom Jr. 2005. Counting quail. Bulletin B-6173. Texas AgriLife Extension Service, College Station, USA.

Roseberry, J. L., and L. M. David. 1994. The Conservation Reserve Program and northern bobwhite population trends in Illinois. Transactions of the Illinois State Academy of Science 87:61–70.

Ryan, M. R., L. W. Burger, and E. W. Kurzejeski. 1998. The impact of CRP on avian wildlife: a review. Journal of Production Agriculture 11:61–66.

Sands, J. P. 2007. Influence of invasive exotic grasses on northern bobwhite habitat use in South Texas. Thesis. Texas A&M University-Kingsville, USA.

Slater, S. C., D. Rollins, R. C. Dowler, and C. B. Scott. 2001. *Opuntia*: a prickly paradigm for quail management in west-central Texas. Wildlife Society Bulletin 29:713–719.

Tjelmeland, A. D. 2007. Habitat restoration and northern bobwhite use of buffelgrass-dominated grasslands. Thesis. Texas A&M University-Kingsville, USA.

Townsend, D. E., R. E. Masters, R. L. Lochmiller, D. M. Leslie Jr., S. J. DeMaso, and A. D. Peoples. 2001. Characteristics of nest sites of northern bobwhites in western Oklahoma. Journal of Range Management 54:260–264.

Webb, W. M., and F. S. Guthery. 1983. Response of wildlife food plants to spring discing of mesquite rangeland in northwest Texas. Journal of Range Management 36:351–353.

U. S. Department of Agriculture (USDA). 2011. Web soil survey. USDA, Natural Resources and Conservation Service, Washington, D.C., USA. websoilsurvey.nrcs.usda.gov/

NEST-SITE CHARACTERISTICS OF NORTHERN BOBWHITES TRANSLOCATED INTO WEEPING LOVEGRASS CRP

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ABSTRACT

Habitat loss and fragmentation have been considered major causes for the decline of northern bobwhite (*Colinus virginianus*). There are $>$ 400,000 ha of weeping lovegrass (*Eragrostis curvula*) Conservation Reserve Program (CRP) fields in the Southern High Plains of Texas some of which could be modified to provide usable habitat for northern bobwhites. Timely colonization of improved CRP habitat by northern bobwhite is unlikely without transplantation, because of distance from existing populations. We radio-marked and transplanted 94 northern bobwhite into weeping lovegrass CRP and monitored nest success. We recorded high nest success in 2002 (70%) and 2003 (71%) for northern bobwhite nesting in weeping lovegrass CRP in the area studied. The composition of weeping lovegrass CRP fields available in our study area appears to be suitable nesting cover for northern bobwhite.

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Key words: artificial brush structures, *Colinus virginianus*, Conservation Reserve Program, nesting ecology, northern bobwhite, Southern High Plains, weeping lovegrass

INTRODUCTION

Populations of many grassland nesting birds have declined during the last 30 years (Askins 1993, Knopf 1994, Peterjohn and Sauer 1999). Habitat loss and fragmentation have been considered the major causes of the decline for most species including the northern bobwhite (Johnson and Schwartz, 1993). The Conservation Reserve Program (CRP) was initiated in 1985 under the Food Security Act to protect highly erodible lands, reduce crop surpluses, improve water quality, and secondarily to provide wildlife habitat (Bartlett 1988). Lands enrolled in CRP have been seeded with both native and exotic grass species. Weeping lovegrass, an exotic, has been seeded on 400,000 ha of land enrolled in CRP on the Southern High Plains of Texas (Oberheu et al. 1999). Many consider the dense monocultures of weeping lovegrass unusable habitat for northern bobwhites. However, research has not been conducted to evaluate this claim (Kuvlesky et al. 2002). We were unable to find any scientific studies evaluating nest success of northern bobwhite in weeping lovegrass CRP fields. The lack of woody cover and low forb production appear to be limiting factors for quail in CRP fields. Northern bobwhites have been found to use weeping lovegrass CRP when woody cover is available. Populations might expand into weeping lovegrass CRP if woody cover or artificial cover sources were added to increase usable space for northern bobwhites. Expansion of northern bobwhites may be slow into improved CRP fields, because many areas are distant from existing populations or isolated by unimproved CRP or agricultural fields. Translocation of wild birds into improved CRP fields is an option in these cases.

Our objectives were to: (1) estimate nesting success of translocated northern bobwhite in weeping lovegrass CRP fields, and (2) identify habitat features associated with successful northern bobwhite nests in weeping lovegrass.

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STUDY AREA

Northern bobwhites were trapped in 2002 on rangelands in 3 northwest Texas counties (Baylor: 30° 37′ N, 99° 12′ W; Garza: 33° 10′ N, 101° 20′ W; and Kent: 33° 10′ N, 100° 45′ W). Northern bobwhites were trapped in 2003 on rangelands in 3 northwest Texas counties (Garza, Kent, and Lubbock: 33° 35 ’N, 101° 52′ W). All birds were released on 400 ha in Lynn County, Texas (33° 10′ N, 101° 50′ W); that site was enrolled in CRP and seeded to weeping lovegrass in 1989. Twenty-four artificial cover structures were evenly spaced across the study area and provided high protein feed (Bluebonnet Game Bird Poultry Starter, Ardmore, OK, USA) and water *ad libitum* (Abbott 2003). Northern bobwhites were not present on the area when we initiated the study. The predominant herbaceous plants were weeping lovegrass, silver bluestem (*Bothriochloa laguroides*), and three awn (*Aristida* spp.).

The climate of the area is subhumid with hot summers and moderate winter temperatures punctuated by severe cold spells (Mowery and McKee 1959). Soils are primarily loams and sandy loams with slopes $< 1\%$. The average elevation of Lynn County is 951 m above mean sea level. Average annual precipitation is 51 cm with 85% occurring from 1 April through 31 October (Mowery and McKee 1959). Many potential nest predators including coyote (*Canis latrans*), striped skunk (*Mephitis mephitis*), cotton rat (*Sigmodon hispidus*), bull snake (*Pituophis catenifer*), hognose snake (*Heterodon nasicus*), rattlesnake (*Crotalus* spp.), and barn owl (*Tyto alba*) were present in the study area.

METHODS

Field Procedures

Northern bobwhites were captured in native rangeland off the study site from 20 February through 4 April 2002, and from 1 to 24 March 2003 using walk-in funnel traps (Smith et al. 1981) baited with milo. Traps were checked twice daily, ~ 3 hrs after sunrise and at sunset. Quail were immediately removed from traps and placed into ventilated cotton bags until they could be processed. Birds were leg-banded, classified to age (adult, immature) and gender (male, female) (Rosene 1969), and weighed to the nearest 0.01 g. Birds were placed together in a ventilated cage after processing and transported ≥ 56 km to the release site. All birds were radio-marked at the release site with necklace-style transmitters weighing 6.5 g and equipped with mortality sensors (American Wildlife Enterprises, Monticello, FL, USA). All birds captured during one trapping period were released together as one covey inside an artificial cover structure. Radiotelemetry was used to monitor all birds at least every 3 days from time of release until 15 August each year. All hen activity was closely monitored from the time we discovered the first nest until the end of the study period.

Nests were flagged to facilitate location at a later time. All flags were at least 5 m from the nest bowl in an attempt to minimize nest predation by animals investigating the flags. We did not intentionally flush hens from nests and rarely did so inadvertently. We approached the nest to ascertain the number of eggs in each clutch when the hen was known to be away from the nest. A nest was considered successful if any of the eggs hatched. We described characteristics of nest sites and 4 locations corresponding to the 4 cardinal directions 10 m from each nest site after the eggs hatched, nests were depredated, or the hen abandoned the nest. Nest-site metrics included visual obstruction and percent ground cover of weeping lovegrass, native grass, forbs, and bare ground in a 0.25-m^2 quadrat centered over the nest, and distance (m) to the nearest artificial cover structure. Visual obstruction by the horizontal component of foliage was quantified using a Robel pole (Robel et al. 1970). The pole was 2.5 m high, 2.54 cm wide, and marked in alternating florescent orange and white colors at 10-cm intervals. The height of vegetation was estimated by recording the 10-cm interval that was directly above the height of the tallest vegetation directly in line of the pole. Visual obstruction was evaluated from a distance of 4 m and a height of 1 m. Non-nest sites (no nest present) were described to evaluate habitats used by northern bobwhites versus that available. All non-nest sites were ≥ 10 m from known nest-sites and vegetation measurements were averaged for comparisons between nest and non-nest sites.

Data Analysis

We used stepwise logistic regression to differentiate northern bobwhite nest-sites from non-nest sites as well as successful versus depredated nests based on measured habitat characteristics. We used percent weeping lovegrass, native grasses, forbs, bare ground, and visual obstruction as the potential predictor variables to classify nest sites. These 5 variables and distance from the nearest artificial cover source were used to classify successful nests. The data sets were constructed so the analysis would solve for nest-site location and a successful nest in separate analyses. We set criteria for inclusion of a variable at 0.15 to prevent exclusion of potentially important predictor variables (Hosmer and Lemeshow 2000). We interpreted logistic regression coefficients by using odds ratios. We used 2-factor (year and location; year and success category) analysis of variance to illustrate differences in predictor variables (SPSS 2002). We used binomial proportions tests to compare nest success between years (Ott 1988).

RESULTS

We radio-marked and transplanted 15 hens (13 subadults, 2 adults) in 2002 and 32 hens (25 subadults, 7 adults) in 2003. Five northern bobwhites nested in an area in 2002 containing weeping lovegrass and produced 7 nests. Two hens each produced 2 nests in 2002 and no hens produced more than 2 nests. Two northern bobwhites nested in a wheat field containing no weeping lovegrass in 2002. Fifteen northern bobwhites nested in an area in 2003 containing weeping lovegrass and produced 20 nests. Seven northern bobwhites nested in areas not

Table 1. Vegetation characteristics of northern bobwhite nest ($n = 32$) and non-nest sites ($n = 32$), Lynn County, Texas averaged over 2002 and 2003.

	Nest site		Non-nest site		
Variable	Mean	SE	Mean	SE	*P*
Weeping lovegrass	57.88	4.95	18.13	4.95	< 0.001
Native grasses	17.34	4.13	18.16	4.13	0.217
Forbs	1.10	0.75	2.30	0.75	0.559
Bare ground	20.96	2.95	58.67	2.95	< 0.001
Robel measurement	15.47	0.80	14.06	0.80	0.252

Table 2. Characteristics of successful northern bobwhite nests compared to depredated nests, Lynn County, Texas averaged over 2002 and 2003.

	Successful		Depredated		
Variable	Mean	SE	Mean	SE	*P*
Weeping lovegrass	36.68	5.35	41.33	8.38	0.615
Native grasses	16.74	3.43	20.04	5.38	0.717
Forbs	2.26	0.62	0.33	0.97	0.109
Bare ground	42.36	4.10	33.63	6.43	0.311
Robel measurement	14.23	0.68	16.08	1.07	0.240
Distance to nearest ACS[a]	266.7	72.4	255.3	113.9	0.933

[a] ACS = artificial cover source (distance in m).

containing weeping lovegrass and produced 8 nests. Four hens produced 2 nests and no hens produced 3 nests. One male incubated a nest in 2002 while 4 males incubated nests in 2003. Re-nesting occurred after loss of a previous nest during both years with the exception of 1 hen in 2002 which successfully hatched 13 eggs, but still renested. Nest success was not different ($P = 0.47$) between years (71% in 2002 and 70% in 2003).

Stepwise logistic regression revealed a positive relationship ($\chi^2 = 45.87$, $P < 0.001$) for a model with percent bare ground ($B = -0.156$, SE = 0.040, Wald = 15.61, $P < 0.001$, Exp $(B) = 0.856$) as a predictor of nest sites. Potential nest-sites were 14% less likely to be classified as nest-sites with each 1% increase in the amount of bare ground present. No other variables were associated with classification of nest and non-nest sites. There was greater percent bare ground at non-nest sites compared to nest sites (Table 1). The percent weeping lovegrass composition at nest-sites was greater than at non-nest sites (Table 1), but this variable was not selected as a predictor of potential nest-site classification. No other variables differed between nest and non-nest sites. No variables were selected as predictors of successful nests ($P \geq 0.19$). The absence of relationship between nest-site success and vegetative characteristics of the nest-site is illustrated by the lack of differences between successful and depredated nests in all vegetative characteristics examined (Table 2). Vegetative characteristics were not different between years for any variable ($P > 0.05$). There were no year by location or year by success category interactions ($P > 0.05$).

DISCUSSION

Most quail stayed in the study area and reproduced in weeping lovegrass CRP. We observed extremely high nest success of 70 and 71%, respectively during 2002 and 2003. Our nest success was greater than reported by most other researchers in Texas (Mueller 1999 [38%], Hernández 1999 [46%], Carter et al. 2002 [38%], Treadway 2002 [42%]). It is unclear why northern bobwhites in our study had such high nest success, but the *ad libitum* availability of food and water may have affected the results. Weeping lovegrass CRP at the composition available in our study area appears to be suitable nesting cover for northern bobwhites.

Northern bobwhites generally nest in relatively thick vegetation (Rosene 1969). However, the growth form of weeping lovegrass has been suggested to be too thick for northern bobwhite use. Weeping lovegrass in our study areas was thick but did not form a monoculture throughout the sites and was not avoided by nesting northern bobwhites. Every nest initiated on sites containing weeping lovegrass contained this exotic grass within the 0.25-m^2 quadrat measured at the nest. Most birds select nest sites based on vegetative structure and not for or against certain grass species (Davis and Duncan 1999). We found northern bobwhite using weeping lovegrass as nesting cover in the absence of native grasses**.** It is unclear why no factors differentiated successful nests from depredated nests.

MANAGEMENT IMPLICATIONS

Thousands of hectares of weeping lovegrass CRP are present in the Southern High Plains of Texas. Factors such as changes in land ownership, CRP regulations, and the present belief that weeping lovegrass and northern bobwhite are incompatible are leading many landowners to attempt to convert weeping lovegrass fields to native warm season grasses. This process is expensive and it can be difficult to establish native warm season grasses in the semi-arid Southern High Plains of Texas without a year of greater than normal rainfall. Our data suggest converting weeping lovegrass CRP to native warm season grasses may not be necessary to effectively manage for northern bobwhite. Vegetative diversity is important, but it is likely this diversity can be achieved gradually using several different management techniques. It may be beneficial to burn strips in weeping lovegrass CRP in December or January to remove accumulated litter. We recommend burning no more than half of any single area to maintain some herbaceous cover on the site. It may also be beneficial to disk a portion (up to 10%) of the burned area to encourage early seral species and increase herbaceous plant diversity.

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LITERATURE CITED

Abbott, C. W. 2003. Transplanting northern bobwhite (*Colinus virginianus*) in the Southern High Plains of Texas. Thesis. Texas Tech University, Lubbock, USA.

Askins, R. A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America. Current Ornithology 11:1–34.

Bartlett, E. T. 1988. Social and economic impacts of the Conservation Reserve Program. Pages 52–54 *in* J. E. Mitchell, ed. Impacts of the Conservation Reserve Program in the Great Plains. USDA, Forest Service General Technical Report RM-158. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.

Carter, P. S., D. Rollins, and C. B. Scott. 2002. Initial effects of prescribed burning on survival and nesting success of northern bobwhites in West-Central Texas. Proceedings of the National Quail Symposium 5:129–134.

Davis, S. K., and D. C. Duncan. 1999. Grassland songbird occurrence in native and crested wheatgrass pastures of southern Saskatchewan. Studies in Avian Biology 19:211–218.

Hernández, F. 1999. The value of prickly pear cactus as nesting cover for northern bobwhite. Dissertation. Texas A&M University, College Station, USA.

Hosmer, D. W., and S. Lemeshow. 2000. Applied logistic regression, Second edition. John Wiley and Sons Inc., New York, USA.

Johnson, D. H., and M. D. Schwartz. 1993. The Conservation Reserve Program and grassland birds. Conservation Biology 7:934–937.

Knopf, F. L. 1994. Avian assemblages on altered grasslands. Studies in Avian Biology 15:247–257.

Kuvlesky Jr., W. P., T. E. Fullbright, and R. Engel-Wilson. 2002. The impact of invasive exotic grasses on quail in the southwestern United States. Proceedings of the National Quail Symposium 5:118–128.

Mowery, I. C., and G. S. McKee. 1959. Soil survey of Lynn County, Texas. U. S. Department of Agriculture, Soil Conservation Service, Washington, D.C., USA.

Mueller, J. M. 1999. Effect of red-imported fire ants on reproduction, health, and survival of northern bobwhites. Dissertation. Texas Tech University, Lubbock, USA.

Oberheu, D., R. Mitchell, B. Dabbert, and S. Davis. 1999. Observations of avian nesting activity in burned and non-burned weeping lovegrass CRP. Texas Journal of Agricultural and Natural Resources 12:14–17.

Ott, L. 1988. An introduction to statistical methods and data analysis. Third edition. PWS Kent Publishing Company, Boston, Massachusetts, USA.

Peterjohn, B. R., and J. R. Sauer. 1999. Population status of North American grassland birds from the North American Breeding Bird Survey, 1966–1996. Studies in Avian Biology 19:27–44.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationship between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295–297.

Rosene, W. 1969. The bobwhite quail: its life and management. Rutgers University Press, New Brunswick, New Jersey, USA.

SPSS. 2002. SPSS® Base 11.5. User's guide. SPSS Inc., Chicago, Illinois, USA.

Smith, H. D., F. A. Stormer, and R. D. Godfrey Jr. 1981. A collapsible quail trap. USDA, Forest Service Research Note RM-400. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.

Treadway, J. H. 2002. Protecting northern bobwhite nests from mammalian predators in areas inhabited by the red-imported fire ant. Thesis. Texas Tech University, Lubbock, USA.

CLIMATE CHANGE AND NORTHERN BOBWHITES: THE STATE OF OUR KNOWLEDGE, POSSIBLE OUTCOMES, AND THE RISK OF IGNORANCE

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ABSTRACT

No disturbance in the Holocene has received more scientific resources or public scrutiny than global climate change. This phenomenon and associated uncertainty in its' potential effects reduces our ability to effectively manage species such as northern bobwhite (*Colinus virginianus*). This uncertainty is complex because of the hierarchical nature of spatial and temporal scales of ecological and societal processes that can influence bobwhite persistence. A loss of financial resources can occur if the threat of climate change is false because of inefficient resource allocation. However, if effects are real and system dynamics are altered, management concerns and decisions must adapt in response to new information. Furthermore, decisions relative to climate change occur at time scales for which scientists are not accustomed. Climate change effects will likely be subtle in regions inhabited by bobwhites and occur over decades. The climate change paradigm (and all that it encompasses) should be viewed as a decision-making issue and not a scientific exercise. It behooves bobwhite scientists and managers to understand potential effects of climate change regardless of the causal agent. Ecological changes are likely to occur even if variation in climate is minimal; thus, the risk is too high to ignore. I propose addressing bobwhite management relative to climate change using a hierarchical decision framework that incorporates a mechanistic approach of relevant processes (e.g., land-use changes, raptor migratory patterns, and bobwhite life history) at multiple spatial and temporal scales.

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SURVIVAL AND REPRODUCTION OF PARENT-REARED NORTHERN BOBWHITES

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ABSTRACT

Captive-reared and released game birds typically have low reproductive success in the wild which limits their use for restoration of game bird populations. A fundamental problem with captive-rearing techniques is the absence of a mechanism for imprinting. We developed a parent-rearing technique that facilitates pre- and post-hatch imprinting using parent-reared wild strain northern bobwhite (*Colinus virginianus*) chicks in outdoor pens. Parent-reared chicks were marked with patagial wing tags and recaptured during October and the following March. We radiomarked juveniles captured in March to monitor survival and reproductive success in two separate studies, one in Georgia, and one in South Carolina, USA. Band-recapture survival estimates of parent-reared chicks from release to the following breeding season in Georgia (2005–2007) averaged 0.12 (range = 0.06 to 0.25) and was dependent on release period. Radio-marked, parent-reared bobwhites had lower survival than wild bobwhites and produced 0.3 nests per hen for the breeding season versus 1.0 nests per hen for radio-marked wild resident bobwhites. Nesting success and subsequent chick survival did not differ among groups, but sample sizes were small. Radio-marked, parent-reared hens ($n = 26$) in the South Carolina study (2008–2010) produced 0.67 nests per hen for the breeding season versus 0.62 nests per hen for radio-marked wild resident hens. Nesting success and brood-rearing success of parent-reared hens did not differ from that of wild resident hens and breeding season survival was also similar. Survival and reproduction of parent-reared wild strain bobwhites were greater than previously reported for pen-reared bobwhites and may useful for restoring or enhancing bobwhites populations at the local scale.

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Key words: chicks, *Colinus virginianus,* imprinting, nest, northern bobwhite, parent-reared, pen-reared, reproduction, survival

INTRODUCTION

Recovery of northern bobwhite populations begins with sound habitat management (NBTC 2011). However, bobwhites may exist at densities in many regions too low to permit population recovery even with increased habitat. The lack of bobwhites in many regions of their range is considered a major impediment to their recovery (NBTC 2011). A number of management strategies have been tested to re-establish bobwhites in areas of suitable habitat including release of pen-reared bobwhites and translocation of wild bobwhites (Roseberry et al. 1987, Terhune et al. 2010, Sisson et al. 2012). The value of released bobwhites for restoration purposes depends on their survival and reproductive potential being sufficiently high to result in an increase in bobwhite abundance. Studies have found comparable demographics among translocated wild bobwhites and resident individuals (Terhune et al. 2010) and translocation of wild bobwhites has been shown to expedite developing huntable bobwhite populations (Sisson et al. 2012). Conversely pen-reared and released bobwhites often demonstrate survival rates too low to establish a viable population (Buechner 1950, Roseberry et al. 1987, Perez et al. 2002, Thackston et al. 2012). Pen-

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reared bobwhites that survive until the following breeding season have been found to nest (DeVos and Speake 1995, Eggert et al. 2009), but apparent lack of brooding skills results in low recruitment of young (Cass 2008, Eggert et al. 2009). Thus, release of pen-reared bobwhites is now used primarily for enhancing fall populations for greater harvest (DeVos and Speake 1995, Eggert et al. 2009).

Poor demographic rates of pen-reared bobwhites may be due to maladaptive behaviors resulting from generations in captivity (Backs 1982, Roseberry et al. 1987). Backs (1982) found greater survival of pen-reared bobwhites from wild parents than those from game farm parents suggesting a genetic causation. However, others have reported no difference in survival of pen-reared bobwhites from game farm parents and wild lineage (Roseberry et al. 1987, Perez et al. 2002). Researchers have noted important behavioral differences, thought to be linked to predator avoidance, between wild and pen-reared bobwhites (Backs 1982, Roseberry et al. 1987, Perez et al. 2002), suggesting genetic background is important to rearing a bird capable of surviving in the wild.

The effect of rearing method on bobwhite demographics has received little research but other species indicate that early-learning is critical (Hess 1973). Dowell (1992) found that, without parent-rearing, gray partridge (*Perdix perdix*) did not show appropriate predator avoidance behaviors. Buner and Schaub (2008) reported significantly greater survival and reproduction of gray partridge chicks fostered with gray partridge parents versus those reared by bantam (*Gallus gallus*) hens or artificially-reared. Gaudioso et al. (2011) found early predator training increased survival of captive-reared red-legged partridge (*Alectoris rufa*). Filial imprinting is an important form of learning during short pre- (Lickliter 1989, 2005) and post-hatch periods in which the chicks learn to identify their parents (Jaynes 1956, 1957). Imprinting in birds has a suite of behavioral consequences including sexual selection, social-learning, predator recognition, predator avoidance, recognition of alarm calls, food selection, and parenting skills (Hess 1973, Dowell 1992, Lickliter and Harshaw 2010). Pen-reared bobwhites are reared 'communally' in brooder pens without a parent which does not allow pre-hatch conditioning to occur, results in social imprinting rather than filial imprinting, and may have implications for survival of released pen-reared bobwhites.

Our objectives were to: (1) develop a parent-rearing method for bobwhites that includes pre- and post-hatch imprinting, and (2) compare the demographics of wild strain parent-reared bobwhites to wild resident bobwhites and pen-reared bobwhites (e.g., 'fall-released'). The purpose of this research was to learn if parent-rearing and imprinting would improve the survival and reproductive success of captive-reared bobwhites.

STUDY AREAS

We conducted field research on Pinion Point Plantation (PPP) in Brooks County in the Red Hills region of southern Georgia (2005–2007) and on Mount Pleasant Plantation (MPP) near Andrews, South Carolina (2008–2010). PPP consisted of 1,821 ha of 'old field' pine (*Pinus* spp.) forests with low basal areas (3–9 BA m^2/ha) (72%), rotational fallow fields (10%), longleaf pine (*Pinus palustris*) plantings (5%), and bald cypress (*Taxodium distichum*) dome wetlands (13%). PPP was an established wild bobwhite property, but MPP was a new property developed beginning in 2005. Soils on MPP are primarily hydric and vegetation consists of dense stands of warm season grasses. Fallow fields, 1 to 2 ha in size, occur on 20% of property and are managed by annual disking. Intensive management for bobwhites at both sites includes prescribed burning, hardwood reduction, timber thinning, seasonal disking, drum chopping, nest predator reduction, and supplemental feeding. Both MPP and PPP have wild bobwhite populations with densities $>$ 2.5 bobwhites/ha based on covey-call counts and hunting records.

METHODS

Outdoor Rearing Pens for Parent-reared Chicks

We constructed 16 trapezoidal-shaped rearing pens adjacent to one another (Stoddard 1931). The long sides of each pen were 5 m and the ends were 1 m on the short end and 3.6 m on the long end. Each pen had a 1-m^2 shelter attached to the outside of each pen to facilitate changing water and providing feed. Pens were 2 m tall. The tops of the pens consisted of netting to allow for chick acclimation to local weather. Pens were enclosed by a snake fence and a solar-powered electric fence to exclude mammalian and reptilian predators. Vegetation in pens included common weeds (e.g., *Ambrosia* spp., *Cassia* spp.) to simulate natural brood habitat. A commercial operation was developed nearby beginning in 2009 following the same procedures and same source of eggs. This produced chicks for the studies on MPP; pens at Tall Timbers Research Station produced chicks for the PPP studies.

Rearing of Bobwhites

We obtained wild-strain bobwhite eggs from deserted nests on Tall Timbers Research Station which has maintained a wild bobwhite population for more than a century. Wild-strain eggs were hatched in an incubator and chicks were reared in brooders. These birds were used as layers to obtain eggs for the study. All chicks released were one generation removed from wild bobwhites with both parents from the wild. The wild-strain bobwhite chicks were raised either in a communal brooder (brooder-reared), communally-reared in flight pens (fall-released), or with parental imprinting and adoption (parent-reared).

Brooder-reared.—Brooder-reared chicks were removed from the incubator at hatching, placed into universal box type brooder pens (G. Q. F. Manufacturing Co., Savannah, GA, USA), and reared to 35 days of age. Brooder-reared chicks received commercial gamebird starter feed (Purina, St. Louis, MO, USA) with free-standing waterers. Proso millet was mixed into the commercial feed at 2 weeks of age and grain sorghum was mixed into commercial feed at 4 weeks of age. Brooder-reared chicks were weighed at 12-days-of-age and numbered bands were attached to their right wing patagium (National Band and Tag Co., Newport, KY, USA). Brooder heaters were reduced at 21 to 35-days-of-age to prepare chicks for ambient temperatures upon release.

Parent-reared.—We played a recording of the calls hens produce on the nest when their eggs are hatching ~ 36 hrs prior to hatching. This call series was previously recorded by placing a recording microphone in the clutch of wild bobwhite nests. Pre-hatch audio stimulation from parents has been found to have behavioral consequences in several bird species (Lickliter 2005). Chicks were taken from the incubator within 6 hrs of hatching and introduced to a wild-strain, bobwhite foster parent. We first placed foster parents in adoption boxes for 10–15 min after which 20 chicks were added behind a plexiglass divider. The divider was removed if the foster parent remained calm so chicks and adult came into contact and began the imprinting and adoption process. We removed the parent if a brood was rejected and added another potential parent. Parents of successfully-adopted chicks brooded and vocalized with chicks. We held adopted chicks and foster birds in a brooding box overnight in an attempt to strengthen their bond (Stoddard 1931). We released the brood with parent into the rearing pens the following morning where they remained for 35 to 42 days until release. No supplemental heating was provided. Chicks were fed, watered, and banded as described for pen-reared birds. All care, housing, and capture of bobwhites were in compliance with requirements of the University of Georgia's Institutional Animal Care and Use Committee (AUP # A3437-01).

Fall-released Bobwhites.—This group of bobwhites was reared by a cooperating game bird breeder (Quail Call Farms, Beachton, FL, USA). Bobwhites were reared communally in the same age groups with minimal exposure to people and no exposure to adult bobwhites. Chicks were maintained in a heated brooder room attached to flight pens for 5 weeks and then released into flight pens until 10-weeks-of-age. Fall-released bobwhites were released on a separate section of the PPP property in fall 2005 and 2006 to avoid influencing the wild bobwhites and parent-reared bobwhites on our study area. Birds were banded the day before release with size 7 aluminum leg bands (National Band and Tag Company, Newport, KY, USA).

Study 1. Survival of Brooder-reared and Parent-reared Chicks

We released broods during 3 monthly periods during 2005 and 2006. Quail in 2005 were released in July, August, and September while in 2006 quail were released in July, August, and October. Release locations were selected based on known use of the area by wild bobwhite broods, and sites were recorded with global positioning systems (Trimble XT, Sunnyvale, CA, USA) for importing into ArcGIS 9.2 (ESRI 2009). Release locations were ≥200 m apart to avoid mixing of parent-reared and brooder-reared chicks. The actual release site for each group was randomly selected and paired for each group (brooder- and parent-reared). Grain sorghum was broadcast around the release location before the release and a recording of a bobwhite hen call played over a speaker to attract males or possibly females to the area to facilitate mixing with wild bobwhites for brood amalgamation (Faircloth et al. 2005). Quail were left with the release boxes which were removed the following day to minimize chick disturbance and provide shelter if needed.

Post-release Monitoring.—Recapture sessions were conducted in October and March following releases of parent-reared and brooder-reared bobwhites. October trapping sessions were ~ 2 weeks in length and the March trapping periods were ~ 4 weeks. Bobwhites were captured using walk-in funnel traps baited with commercial grain sorghum (Stoddard 1931). Captured quail were classified to age and sex, weighed, and banded (if weighing ≥ 120 g) with an aluminum number 7 leg band. All birds were released at trap locations.

Parent-reared Survival Estimate.—We used Program MARK (White and Burnham 1999) to estimate survival of parent-reared bobwhites. We used the Burnham model incorporating live and dead recoveries (Palmer and Wellendorf 2007, Terhune et al. 2007) to calculate survival (φ), recapture (ρ), and recovery (r) estimates (White and Burnham 1999). We used 5 intervals (LD-LD-LD-LD-LD) where the first 3 intervals were release periods and the following were October and March trapping sessions, respectively. Each interval designated as L included live trapping encounters, and the D interval included dead recoveries or encounters outside the designated trapping sessions. We defined interval lengths from July to August, August to September, September to October, and October to March for 2005 and 2006. Interval lengths in days for 2005 releases were 39, 39, 15, and 133, respectively, and interval lengths in days for 2006 releases were 39, 39, 15, and 128, respectively. We also modeled year as a covariant to assess variation in annual survival. We imposed several constraints prior to the analysis: recapture probabilities (ρ) for periods 1 and 2 were constrained to 0 because recapture (no trapping occurred) was not possible during these periods; recovery periods (r) 1, 2, and 3 were constrained to 0 because these were designated release periods and no harvest (recovery) occurred providing 0 probability of recovery; we constrained site fidelity (F) to 0.99, because radiotelemetry revealed that movement from the study site was minimal. We used information-theoretic approaches to evaluate our biologically-derived candidate models (Burnham and Anderson 1998, Anderson et al. 2000). We used QAIC*c* to compare the set of candidate models and considered the best model to have the lowest QAIC*c* value (Burnham and Anderson 1998). We increased the precision of our estimates and accounted for model uncertainty by averaging parameter estimates over all candidate models that included the parameter of interest (Burnham and Anderson 1998, White and Burnham 1999).

Table 1. Survival (φ), recapture (*p*), recovery (*r*), and fidelity (*f*) models for parent-reared bobwhite chicks tested for year effect (year) at Pinion Point Plantation in south Georgia during 2005–2007.

Models	QAIC*c*	ΔQAIC*c*	Parameters	Deviance	w_i
$\varphi.\rho.r.f.$	278.494	0	3	272.460	0.40883
$\varphi_{year}\rho.r.f.$	279.101	0.6074	4	271.044	0.30175
$\varphi_{year}\rho_{year}r_{year}f.$	280.150	1.6557	6	268.029	0.17865
$\varphi_{year}\rho_{year}r.f.$	281.106	2.6116	5	271.019	0.11077

Study 2. Reproductive Effort and Success on PPP

Parent-reared, brooder-reared, fall-released, and wild bobwhites weighing ≥ 140 g during March capture efforts received a 6-g (150–151 MHz), pendant-style, radio transmitter (American Wildlife Enterprises, Monticello, FL, USA) to monitor breeding season demographics. All birds were released at trap locations. Daily monitoring began in mid-April to document breeding season demographics and continued through September. Weekly monitoring began after this time period until the next breeding season. We monitored radio-marked quail ≥ 5 days a week. We flagged supposed nest sites when we found a bobwhite at the same location over a 2-day-period. We recorded clutch size when the incubating bird was on recess from incubation. We captured broods of radio-marked bobwhites at 8 days-of-age (Smith et al. 2003).

Data Analysis.—We report nests and broods per hen, nesting success, and brood survival for radio-marked hens. We based nests per hen and broods per hen on the number of radio-marked hens alive on 15 April. Nests per hen was the total number of nests divided by available radio-marked hens. Nest success was the proportion of nests that hatched ≥ 1 egg. Broods per hen was the number of successful hens hatching ≥ 1 egg divided by the number of radio-marked hens alive on 15 April. Apparent chick survival was based on calculations of chick survival rates for each brood and obtaining an average chick survival for all broods. We assumed there would be no differences among broods in rates of brood amalgamation (Faircloth et al. 2005).

Study 3. Reproductive Effort and Success on MPP

Parent-reared chicks were released on MPP during July through August 2008 and 2009 following protocols established for Studies 1 and 2. Chicks were recaptured the March following the year of release and a sample of wild and parent-reared bobwhites were banded and radio-marked as in Studies 1 and 2. We monitored summer survival and nesting activity of radio-marked bobwhites. We did not capture broods and band chicks in this study, but conducted flush counts at 3 weeks to compare brood-rearing success between wild and parent-reared bobwhites.

We calculated summer survival (1 Apr to 30 Sep) for resident wild and parent-reared, radio-marked bobwhites using Kaplan-Meier staggered entry (Pollock et al. 1989). We recognized sample sizes were low for Kaplan-Meier estimates and viewed these estimates with caution. However, low sample size is more likely to bias survival rates lower than higher (Pollock et al. 1989, Palmer and Wellendorf 2007) and may be considered conservative for the purpose of estimating parent-reared bobwhite summer survival.

RESULTS

Study 1. Parent-reared Chick Survival on PPP

We released 595 chicks for each treatment over the 2-year study. We released 58, 45, and 50 parent-reared and brooder-reared bobwhites each in July, September, and August, respectively. Releases in 2006 for parent-reared and brooder-reared bobwhites each were 165, 96, and 181 for July, September, and October, respectively. We recaptured 68 parent-reared chicks in October and 35 in March; 3 were recovered during hunting. One of the brooder-reared chicks was recaptured in October and 5 were recaptured in March; 1 was recovered during hunting.

Low recapture of brooder-reared chicks ($n = 6$) precluded estimating their survival rates. Parent-reared bobwhites had sufficient recaptures to estimate survival, recapture, and recovery probabilities. The model that minimized QAIC*c* ($\varphi.p.r.f.$) included the parameters survival, recapture, recovery, and site fidelity (fixed) being constant (Table 1). Model weight for the QAIC*c* lowest model ($w_i = 0.41$) provided evidence this was the top model. The second best fitting model ($\varphi_{year}p.r.f.$) included year dependence for survival, but all other parameters were constant. Model weight for this model was close to the top model ($w_i = 0.30$) and was 1.3 times less likely than the model that minimized QAIC*c*.

Survival estimates for parent-reared bobwhites released in July, August, and September 2005 until the October trapping session were 24.7, 44.4, and 79.8%, respectively (Table 2) and 42.6, 60.9, and 87.1%, respectively in 2006. Survival estimates for parent-reared bobwhites released in July, August, and September 2005 until the following March trapping session were 3.5, 6.2, and 11.1% , respectively (Table 3) and 12.8, 18.3, and 26.2% , respectively in 2006. Over-winter survival (Oct to Mar) estimates of parent-reared bobwhites was 14.0% and 30.1% for 2005 and 2006 releases, respectively.

Study 2. Reproductive Effort and Success on PPP

Wild ($n = 35$), parent-reared ($n = 7$), and fall-released ($n = 14$) hens during 2006 incubated 37, 2, and 2 nests, respectively. Bobwhites successfully hatched 26, 1, and 1

Table 2. Parent-reared bobwhite modeled averaged survival estimates and confidence intervals from release to fall trapping sessions, Pinion Point Plantation, Brooks County, Florida, 2005–2006.

			95% CI	
Periods	Year	Estimate	LCI	UCI
Jul-Oct	2005	0.247	0.0333	0.5652
	2006	0.426	0.3080	0.5388
Aug-Oct	2005	0.444	0.1386	0.718
	2006	0.609	0.5047	0.6983
Sep-Oct	2005	0.798	0.5776	0.9121
	2006	0.871	0.8270	0.9051

of these nests, respectively. Nests per hen was 1.06 ($n=37$) for wild, 0.29 ($n=2$) for parent-reared, and 0.14 ($n=2$) for fall-released bobwhites. Apparent nest success was 0.83, 0.50, and 0.50 for wild, parent-reared, and fall-released bobwhites in 2006, respectively. Average clutch sizes were similar 12.5 (11.5-13.6, 95% CI), 13.0 (9.1–16.9, 95% CI), and 12.5 (9.6-15.4, 95% CI) for wild, parent-reared, and fall-released bobwhites. One female fall-released bobwhite had a clutch size of 27 eggs of which 21 hatched but had no chicks at 8-days-of-age. Apparent chick survival of wild, parent-reared, and fall-released bobwhite broods was 24.0% ($n=16$), 71.0% ($n=1$), and, 0.0% ($n=1$), respectively.

Wild ($n=29$), parent-reared ($n=12$), and fall-released ($n=21$) hens in 2007 incubated 31, 4, and 19 clutches and successfully hatched 19, 3, and 8, respectively. Nests per hen was 1.07 ($n=31$) for wild, 0.33 ($n=4$) for parent-reared, and 0.90 ($n=19$) for fall-released bobwhites. Average clutch sizes were 14.4 (12.8-15.9, 95% CI), 14.3 (10.6-17.9, 95% CI), and 17.1 (15.3-19.0, 95% CI) for wild, parent-reared, and fall-released bobwhites in 2007, respectively. Parent-reared males incubated 4 nests in 2007 that were not included in the nests per hen statistic. Males hatched all 4 clutches and 2 broods were captured at 8-days-of-age. Apparent chick survival for wild, parent-reared, and fall-released bobwhites for the 2007 breeding season was 31.0% ($n=13$), 28.0% ($n=6$), and 13.0% ($n=8$), respectively.

Study 3. Reproductive Effort and Success on MPP

We released 843 and 2,345 parent-reared chicks on MPP during July-September 2008 and 2009. We radiomarked 27 parent-reared and 22 wild bobwhites in March and April. Summer Kaplan-Meier survival was 0.39 ± 0.18 for wild bobwhites and 0.27 ± 0.12 for parent-reared bobwhites. We monitored reproductive success of parent-reared hens ($n=11$) and wild resident hens ($n=19$) on MPP. Parent-reared hens produced 7 nests and hatched 6 broods resulting in nests per hen and broods per hen of 0.64 and 0.55, respectively. Clutch size averaged 14.3 ± 1.76 eggs. Wild bobwhites produced 10 nests and hatched 6 clutches resulting in nests per hen at 0.53 and hatches per hen at 0.32. Clutch size averaged 12.2 ± 0.84 eggs. The proportion of hens with broods at 3 weeks was 20% for both wild and parent-reared bobwhites.

Table 3. Parent-reared bobwhite modeled averaged survival estimates and confidence intervals on Pinion Point Plantation from release to capture in March 2005 and 2006, Brooks County, Florida.

			95% CI	
Periods	Year	Estimate	LCI	UCI
Jul-Mar	2005	0.035	0.0003	0.253
	2006	0.128	0.0586	0.2255
Aug-Mar	2005	0.062	0.0011	0.3214
	2006	0.183	0.0961	0.2923
Sep-Mar	2005	0.111	0.0048	0.4083
	2006	0.262	0.1574	0.3788
Oct-Mar	2005	0.140	0.0083	0.4476
	2006	0.300	0.1904	0.4185

We radiomarked 25 wild bobwhites and 31 parent-reared bobwhites in 2010. Summer Kaplan-Meier survival was 0.387 ± 0.119 and 0.295 ± 0.101 for parent-reared bobwhites. We monitored reproductive success of parent-reared hens ($n=13$) and wild resident hens ($n=25$) on MPP. Parent-reared hens produced 9 nests and hatched 4 clutches resulting in nests per hen and brood per hen of 0.69 and 0.31, respectively. Clutch size averaged 10.45 ± 1.06 eggs. Wild bobwhites produced 18 nests and hatched 9 clutches resulting in nests per hen of 0.36 and broods per hen of 0.31. Clutch size averaged 11.8 ± 1.01 eggs. Fifty percent of parent-reared hens had broods at 3 weeks (2 of 4 hens) compared to 33% of wild bobwhites (3 of 9 hens).

Sixteen nests were produced by 24 parent-reared hens and 28 nests were produced by 44 wild hens over both years. Nests per hen was 66.7% for parent-reared and 63.6% for wild bobwhites. Ten broods were produced by the parent-reared bobwhites and 15 broods were produced by wild hens. Broods per hen was 41.7% for parent-reared and 34.1% for wild bobwhites.

DISCUSSION

Study 1. Survival of Released Chicks

Over-winter survival estimates of parent-reared bobwhites were higher than previous survival estimates of released pen-reared bobwhites. Pierce (1951) reported pen-reared bobwhite over-winter survival of 7% whereas DeVos and Speake (1995) reported 20% survival of pen-reared bobwhites to April. Perez et al. (2002) reported no survival of released bobwhites. Brooder-reared chicks in our study had low survival rates unlike parent-reared chicks. This was likely a combination of improper rearing and lack of imprinting. Ring-necked pheasants (*Phasianus colchicus*) reared with species-specific foster parents had greater clutch and brood survival than brooder-reared counterparts (Brittas et al. 1992). We noticed that when chicks imprinted to a species-specific parent, they immediately developed fear of humans and were more likely to express normal predator avoidance behaviors (Dowell 1992). Parent-reared chicks rarely gave lost calls; whereas, brooder-reared chicks frequently gave lost calls which also likely influenced survival. Parent-reared chicks were more often captured with wild bobwhites; whereas, brooder-reared bobwhites were often found in like groups. Brooder-reared chicks were also less fearful of humans and were less likely to hide in vegetation than parent-reared bobwhite chicks.

Our survival estimates suggest a demographically-significant number of parent-reared chicks could survive until the following breeding season and positively influence future populations if recruitment was adequate. The combination of imprinting to species-specific foster parents and rearing in a semi-natural environment may have increased chick survival through appropriate behavioral responses (Roseberry et al. 1987, Dowell 1992). Wild bobwhites may have also had a role in increased survival through adoption of chicks by wild bobwhite broods (Faircloth et al. 2005).

Survival estimates for parent-reared bobwhites released in 2006 were higher than in 2005 possibly because of different weather and habitat conditions. Rainfall amounts were greater during summer months from tropical storms and hurricanes in 2005, which likely reduced chick survival. Thinning of timber stands and intensive dragging of steel tracks over burned areas to increase soil disturbance resulted in thin cover and possibly attributed to increased winter mortality. Prescribed burning was conducted using recommended management guidelines in 2006 (Masters et al. 2003) and other habitat manipulations were minimal on study areas.

Study 2. Reproductive Effort and Success on PPP

Sample sizes were low for parent-reared chicks and likely an artifact of sampling. For example, based on our survival estimates and releases scattered across the study area, ~150 chicks should have survived until the March trapping session over the 2 years. We recaptured ~23% of these in March. Our sample size of hens were small given half of recaptures were males. However, the data reflected important biological distinctions among groups, specifically in differences between parent-reared versus fall-released bobwhites.

Fall-released bobwhites nested as readily as wild bobwhites, although nesting success was numerically lower. Other studies have shown a propensity to nest and hatch clutches (Dollar 1969, DeVos and Speake 1995). However, nesting activity does not provide a complete view of recruitment because of poor parenting skills of fall-released bobwhites. Reduced chick survival is common after fall-released bobwhites leave the nest, possibly due to lack of brooding ability and poor anti-predator behaviors (Dowell 1992). Fall-released hens during brood captures displayed abnormal behavior such as flying into trees and gave lost chick calls. Other abnormal behaviors included lack of fear of humans. For example, fall-released bobwhites would circle < 1 m from observers or attack observers conducting the brood capture. Typical behavior of wild bobwhites during brood captures is to flush from observers and remain at a distance in vegetation, calling to regroup the chicks. Collectively, these abnormal parenting behaviors indicate fall-released bobwhites have low potential to rear young.

Parent-reared bobwhites had similar success rearing broods as wild bobwhites. Habitat use, home range size, and movements (not reported in this paper) of parent-reared bobwhites were similar to wild broods. Male parent-reared bobwhites also demonstrated typical incubation and brooding behaviors. The apparent normal successful brooding ability demonstrated in this study, while preliminary, is an important finding and demonstrates a probability that released parent-reared bobwhites may be useful for restocking purposes.

Nesting attempts by parent-reared chicks were lower than either wild or fall-released bobwhites at PPP. This was possibly an artifact of small sample sizes, but we did observe 2 parent-reared bobwhites that nested, added to the clutch daily, but did not initiate incubation of the clutch. Lower breeding season survival of the parent-reared bobwhites versus wild bobwhites also reduced opportunity to lay clutches. Nesting attempts were lower, but nesting success of parent-reared bobwhites was similar to that of wild bobwhites and numerically greater than fall-released bobwhites. Parent-reared bobwhites hatched their clutches and brooded normally. This was not the case for wild-strain fall-released bobwhites. We observed one fall-released bobwhite leaving the nest with 1 chick while the remainder of the clutch hatched.

Study 3. Reproductive Effort and Success on MPP

We monitored 26 parent-reared bobwhites over the course of 2 breeding seasons. This sample size was improved by a combination of factors, including more intensive management and a larger sample of chicks released on MPP each year of the study. There was no difference in nesting parameters of parent-reared and wild bobwhites. Nesting rate of parent-reared hens was identical to radio-marked wild bobwhite hens. Nesting success was not different between groups, similar to Study 2 at PPP, and flush counts showed similar brood-rearing success between groups. We did not observe parent-reared hens abandoning nests. Habitat use of parent-reared broods on MPP was similar to wild broods as with the parent-reared broods on PPP. Hens hatched clutches and took their broods to areas similar to wild bobwhites. Percent locations by habitat for broods of parent-reared bobwhites was 78% fields, 13% burned woods, and 9% unburned wood versus 60, 33, and 9% for the same habitats, respectively, by wild bobwhites. Similar behaviors by parent-reared bobwhites typical of wild bobwhites included covey and single flushes, flight behavior, covey calling in autumn, and covey sizes. Quantification of the magnitude of behavioral differences between wild and parent-reared bobwhites, and their offspring, is needed. We observed some parent-reared bobwhites with broods to display the broken-wing behaviors more aggressively than their wild counterparts. This may be a function of watching their parents defend them in our rearing facilities when observers entered pens. Refinements in rearing protocols should be tested to develop best management practices.

Summer survival rates of parent-reared bobwhites were slightly lower than wild bobwhites but typical of summer survival from other telemetry studies in good habitat (Sisson et al. 2009). Additional anti-predator training and avoiding human contact may be important to increasing survival of parent-reared bobwhites (Gaudioso et al. 2011).

MANAGEMENT IMPLICATIONS

Parent-reared, wild-strain, bobwhite demographic rates appeared sufficiently high to be useful for restocking management areas with depleted quail populations, similar to translocation of wild bobwhites, although additional testing is needed. Our study areas had existing wild bobwhites that may have facilitated survival of parent-reared chicks. Further testing is needed to examine if this technique could be used to actually establish a population rather than increase numbers. This technique may have usefulness for restoring bobwhite populations at the scale of an individual management area where habitat is sufficiently managed and few or no wild bobwhites exist (e.g., the piedmont or northeastern U.S.). However, recovery of bobwhites over large landscapes will not be solved with releases of quail but rather long-term commitment to habitat management (NBTC 2011).

We suspect land use history of a site may be as important as current habitat conditions to demographics of released bobwhites. Areas with an on-going practice of releasing pen-reared, fall-released bobwhites appear to be less successful than those that have not and do not release pen-reared bobwhites. Areas with a history of, or active releasing, bobwhites may predispose the local predator community to foraging on naïve bobwhites. Success of parent-reared chicks and translocation of wild bobwhites appears to be improved following major habitat improvement projects, possibly because both habitat and predator communities are more favorable for their survival.

Captive-rearing programs for game birds should consider implementing pre- and post-hatch imprinting, and species-specific parent-rearing to avoid maladaptive behaviors of released birds. Pre- and post-hatch imprinting appears to be important to fitness of released bobwhites, but additional research is needed to better understand limiting factors to chick and adult survival.

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LITERATURE CITED

Anderson, D. R., K. P. Burnham, and W. L. Thompson. 2000. Null hypothesis testing: problems, prevalence, and an alternative. Journal of Wildlife Management 64:912–923.

Backs, S. E. 1982. An evaluation of releasing first generation (F1) bobwhite quail produced from wild stock. Pittman-Robertson Bulletin 14. Indiana Department of Natural Resources, Indianapolis, USA.

Brittas, R., V. Marcstrom, R. E. Kenward, and M. Karlbom. 1992. Survival and breeding success of reared and wild ring-necked pheasants in Sweden. Journal of Wildlife Management 56:368–376.

Buechner, H. K. 1950. An evaluation of restocking with pen-reared bobwhite. Journal of Wildlife Management 14:363–377.

Buner, F., and M. Schaub. 2008. How do different releasing techniques affect the survival of reintroduced grey partridge *Perdix perdix*? Wildlife Biology 14:26–35.

Burnham, K. P., and D. R. Anderson. 1998. Model selection and multi-model inference: a practical information-theoretic approach. Second edition. Springer-Verlag, New York, USA.

Cass, R. 2008. Rearing and release techniques for captive northern bobwhite quail. Thesis. Warnell School of Forestry, University of Georgia, Athens, USA.

DeVos Jr., T., and D. W. Speake. 1995. Effects of releasing pen-raised northern bobwhites on survival rates of wild populations of northern bobwhites. Wildlife Society Bulletin 23:267–273.

Dollar, W. M. 1969. Movements, survival, and behavior patterns of pen-raised bobwhite quail (*Colinus virginianus*) on an established management area. Thesis. Auburn University, Auburn, Alabama, USA.

Dowell, S. D. 1992. Problems and pitfalls of gamebird reintroduction and restocking: an overview. Pages 773–780 *in* M. Birkan, G. R. Potts, N. J. Aebischer, and S. D. Dowell, eds. Perdix VI: First International Symposium of Partridges, Quails, and Francolins, Fordingbridge, Hampshire, United Kingdom.

Eggert, D. A., B. S. Mueller, L. Robinette, and S. D. Wellendorf. 2009. Comparison of survival, productivity, movements, and habitat use of pre-season released quail on wild northern bobwhites on Groton Plantation, South Carolina. Pages 396–408 in S. B. Cederbaum, B. C. Faircloth, T. M. Terhune, J. J. Thompson, and J. P. Carroll, eds. Gamebird 2006: Quail VI and Perdix XII. 31 May-4 June 2006. Warnell School of Forestry and Natural Resources, Athens, Georgia, USA.

Environmental Systems Research Institute (ESRI). 2009. Arc GIS Desktop: Release 9.2, Redlands, California, USA.

Faircloth, B. C., W. E. Palmer, and J. P. Carroll. 2005. Post-hatching brood amalgamation in northern bobwhites. Journal of Field Ornithology 76:175–182.

Gaudioso, V. R., C. Sanchez-Garcia, J. A. Perez, P. L. Rodriguez, J. A. Armeteros, and M. E. Alonso. 2011. Does early antipredator training increase suitability of captive red-legged partridges (*Alectoris rufa*) for releasing? Poultry Science 90:1900–1908.

Hess, E. H. 1973. Imprinting. Van Nostrand Reinhold, New York, USA.

Jaynes, J. 1956. Imprinting: the interaction of learned and innate behavior: development and generalization. Journal of Comparative Physiological and Psychology 49:201–206.

Jaynes, J. 1957. Imprinting: the interaction of learned and innate behavior: the critical period. Journal of Comparative Physiological and Psychology 50:6–10.

Lickliter, R. 1989. Intersensory functioning in bobwhite quail chicks: early sensory dominance. Developmental Psychobiology 22: 651–667

Lickliter, R. 2005. Prenatal sensory ecology and experience: implications for perceptual and behavioral development in precocial birds. Advances in the Study of Behavior 35: 235–274.

Lickliter, R., and C. Harshaw. 2010. Canalization and malleability reconsidered: the developmental basis of phenotypic stability and variability. Pages 491–525 *in* K. Hood, C. Halpern, G. Greenberg, and R. Lerner, eds. Handbook of developmental science, behavior, and genetics. Blackwell, Malden, Massachusetts, USA.

Masters, R., K. Robertson, W. Palmer, J. Cox, K. McGorty, L. Green, and C. Ambrose. 2003. Red Hills Forest Stewardship Guide. Tall Timbers Miscellaneous Publication 12. Tallahassee, Florida, USA

National Bobwhite Technical Committee (NBTC). 2011. The National Bobwhite Conservation Initiative: a range-wide plan for re-covering bobwhites. W. E. Palmer, T. M. Terhune, and D. F. McKenzie, eds. National Bobwhite Technical Committee Technical Publication. Version 2.0. Knoxville, Tennessee, USA.

Palmer, W. E., and S. D. Wellendorf. 2007. Effect of radiotransmitters on northern bobwhite annual survival. Journal of Wildlife Management 71:1281–1287.

Perez, R. M., D. E. Wilson, and K. D. Gruen. 2002. Survival and flight characteristics of captive-reared and wild northern bobwhite in southern Texas. Proceedings of the National Quail Symposium 5:81–85.

Pierce, R. A. 1951. Survival of pen-reared quail. Final Report. Pittman-Robertson Project. Kentucky Division of Fish and Game, Lexington, USA.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53:7–14.

Roseberry, J. L., D. L. Ellsworth, and W. D. Klimstra. 1987. Comparative post-release behavior and survival of wild, semi-wild, and game farm bobwhites. Wildlife Society Bulletin 15:449–455.

Sisson, D. C., W. E. Palmer, T. M. Terhune, and R. E. Thackston. 2012. Development and implementation of a successful northern bobwhite translocation program in Georgia. Proceedings of the National Quail Symposium 7:289–293.

Sisson, D. C., T. M. Terhune, H. L. Stribling, J. F. Sholar, and S. D. Mitchell. 2009. Survival and causes of mortality for northern bobwhites in the southeastern USA. Proceedings of the National Quail Symposium 6:467–479.

Smith, M. D., A. D. Hammond, L. W. Burger Jr., W. E. Palmer, A. V. Carver, and S. D. Wellendorf. 2003. A technique for capturing northern bobwhite chicks. Wildlife Society Bulletin 31:1054–1060.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner's Sons Publishers, New York, USA.

Terhune, T. M., D. C. Sisson, J. B. Grand, and H. L. Stribling. 2007. Factors influencing survival of radiotagged and banded northern bobwhites in Georgia. Journal of Wildlife Management 71:1288–1297.

Terhune, T. M., D. C. Sisson, W. E. Palmer, B. C. Faircloth, H. L. Stribling, and J. P. Carroll. 2010. Translocation to a fragmented landscape: survival, movement, and site fidelity of northern bobwhites. Ecological Applications 20:1040–1052.

Thackston, R. E., D. C. Sisson, T. L. Crouch, D. L. Baxley, and B. A. Robinson. 2012. Hunter harvest of pen-reared northern bobwhites released from the Surrogator®. Proceedings of the National Quail Symposium 7:72–76.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 (Supplement):120–138.

HUNTER HARVEST OF PEN-REARED NORTHERN BOBWHITES RELEASED FROM THE SURROGATOR®

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ABSTRACT

There has been increased interest in releasing pen-reared northern bobwhites (*Colinus virginianus*) to meet quail hunting and shooting objectives as populations have declined. The Surrogator® is a commercially available product for rearing and releasing gamebirds into the wild and is promoted as a method to enhance bobwhite survival, improve hunting, and increase recruitment from natural reproduction. We used return-to-hunter bag data from 3 properties in Alabama, Georgia, and Kentucky to evaluate the Surrogator® as a pre-hunting season release technique for pen-reared bobwhites. Across all sites, 3,859 5-week old banded bobwhite chicks were released at varying times during June through October, 2005–2010. Ninety-three quail hunts were conducted during November through January 2005–2011 comprising 431 hunt party hours which resulted in 19 banded bobwhites being harvested. The return-to-hunter bag for all sites combined was 0.005 (range = 0.000 to 0.008). This was considered unsatisfactory at each site and across all sites combined for a quality hunting/shooting experience. The mean cost per chick released was $3.41 (range = $2.74 to $3.88) including the costs of quail chicks, Surrogator® units, propane, and feed across all sites. The mean cost per bird returned-to-hunter bag (Alabama and Georgia) was $655.80 (range = $489.91 to $821.68). These costs did not include economic depreciation of Surrogator® units.

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Key words: Alabama, bobwhite chicks, *Colinus virginianus,* Georgia, hunter harvest, Kentucky, Surrogator®

INTRODUCTION

Northern bobwhite populations across the eastern United States have experienced severe long-term declines (Sauer et al. 2011) primarily as a result of widespread changes in land use, which have greatly reduced habitat suitability (Klimstra 1982, Brennan 1991, Burger 2002, NBTC 2011). This decline has resulted in decreased wild quail hunting opportunities, declining quail hunter numbers and harvest, and led to an apparent increase by landowners and managers in releasing pen-reared bobwhites to meet quail hunting/shooting objectives. For example, in Georgia during the 1960–1961 quail hunting season, 142,000 (± 20,000 SE) bobwhite hunters comprised 50% of the state's licensed resident hunters and harvested an estimated 3,518,000 (± 888,000 SE) bobwhites (Georgia Game and Fish Commission 1961). The number of bobwhite hunters decreased to 22,423 (± 1,054 SE) by 2008–2009 and comprised only 10% of licensed resident hunters. These hunters harvested an estimated 808,036 (± 39,977 SE) bobwhites, of which 97% were reported as pen-reared birds (Duda et al. 2009).

Pen-reared bobwhites have long been released to improve hunting and augment self-sustaining wild quail populations (Stoddard 1931, Buechner 1950). However, studies have shown that pen-reared quail do not adapt to wild conditions, experience low survival, and are ineffective for sustaining or increasing wild populations (Frye 1942, Barbour 1950, Klimstra and Scott 1973, Fies et al. 2000, Perez et al. 2002). New release techniques continue to be developed and marketed with claims of increasing survival of pen-reared bobwhites released into the wild. These releases may help sustain the sport of quail hunting, but are cause for concern for conservation agencies and organizations focused on wild quail habitat management and population restoration. Pen-reared

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Fig. 1. Surrogators®, commercially available propane-powered gamebird brooders, were used to release 5-week old pen-reared northern bobwhite chicks during June through October 2005–2010 on study sites in Alabama, Georgia, and Kentucky. (Photograph courtesy Georgia Department of Natural Resources Wildlife Resources Division).

releases may serve to divert landowner and organizational resources from habitat restoration and management (Stoddard 1931), and may pose risks to wild quail populations through increased disease, predation, social dispersion, and genetic dilution (Brennan 1991, Eggert et al. 2009).

The Surrogator® is marketed by Wildlife Management Technologies (WMT 2011) as a technique whereby "birds become imprinted on the surrounding area" and ultimately "establishes a huntable game bird population" (www.wildlifemanagementtechnologies.com) (Fig. 1). It is widely promoted through magazine articles, cable television, and the internet as an effective pen-reared gamebird release system; this has generated numerous inquiries to state wildlife agencies relative to its effectiveness for pre-hunting season gamebird release and population restoration. Thus, in response to the growing popularity of the Surrogator®, landowners in Alabama, Georgia, and Kentucky worked with researchers to objectively evaluate this system. We used Surrogators® in each state to release bobwhites on properties comprised of high quality, well-managed habitat but where wild quail populations were insufficient to meet landowner hunting objectives. The sites differed in geographical location, cover type composition, and management practice application and intensity, but shared the commonality of being comprised of high quality early succession habitats considered to be capable of supporting bobwhites. We used return-to-hunter bag data and other metrics from each site to independently evaluate the Surrogator® as a pen-reared bobwhite pre-hunting season release technique.

STUDY AREAS

Alabama Study Site

The study site was 1,214 ha of privately owned property in the Alabama Upper Coastal Plain Region, Russell and Barbour counties (32.157447–85.334028). The area had been intensively managed for $>$ 30 years to produce high quality habitat for bobwhites with predominate cover types being open canopy pine (*Pinus* spp.) forest with contiguous fire maintained savanna ground cover interspersed with fallow fields maintained by seasonal disking and planting. The forest overstory was comprised of a mixture of loblolly (*P. taeda*), longleaf (*P. palustris*), shortleaf (*P. echinata*), and slash (*P. elliottii*) pines. The understory consisted primarily of native early successional plant species predominated by native warm

Table 1. Northern bobwhite chicks marked and released (range) from Surrogators® in Alabama, Georgia, and Kentucky during June through October 2005–2010.

Study site	Number marked chicks	Number release sub-sites	Mean number chicks/released	Marking method	Release years
Alabama	1,366	6	137 (20-141)	Wing tagged	2008–2009
Georgia	1,641	8	109 (89-129)	Wing tagged	2005
Kentucky	852	4	86 (24-121)	Leg banded	2007, 2009–2010
Totals	3,859	18	110 (20–141)		5

season bunch grasses, e.g., broomsedge (*Andropogon virginicus*) and little bluestem (*Schizachyrium scoparium*), legumes (Fabaceae), and blackberry (*Rubus* spp.). Additionally this site was characterized by the practices of meso-mammalian nest predator control and year-long broadcast spreading of supplemental feed. These practices were not part of our study design nor were they tested as treatments.

Georgia Study Site

This site was 202 ha in the Georgia Piedmont Physiographic Region, Monroe County (33.126386–83.843783). Bobwhite management had been the primary objective of the property for well over a decade. It was a fire-maintained pine savanna with native grass-forb-shrub ground cover and scattered fallow fields. Historical and ongoing management included meso-mammalian predator control and supplemental feeding.

Kentucky Study Site

This site was comprised of 303 ha of privately owned land (38.097758–84.857193) in the Bluegrass Physiographic Region of Woodford County, Kentucky. Bobwhite management has been the primary objective of the property for nearly a decade, and the habitat had been extensively renovated. The site was characterized by fallow fields established and maintained through conversion of Kentucky 31 tall fescue (*Festuca arundinacea)* to native warm season bunch grasses including Indiangrass (*Sorghastrum nutans*), little bluestem, and big bluestem (*Andropogon gerardii*). Intact fence rows and blackberry thickets were present throughout, as well as fallow fields of common ragweed (*Ambrosia artemisiifolia*). The primary management techniques used to maintain the habitat were rotational prescribed burning, small disked blocks (< 1 ha), and herbicide use to eradicate non-native species.

METHODS

We worked independently at varying times and sites during June-October 2005 and 2007–2010 and used commercially available propane-powered brooders (Surrogators®) (WMT 2011) to release bobwhite chicks on study sites in Alabama, Georgia, and Kentucky. Quail chicks (1–7 days of age) were purchased from reputable producers, placed in Surrogators® with ample feed and water, and released at age 5 weeks. The Surrogators® were in landscapes deemed to be high quality early successional habitats. Costs of brooders, propane, chicks, and feed were recorded.

The chicks in Alabama and Georgia were marked at the time of releases with self-piercing monel wing tags (Style 4-1005, Size 1, National Band and Tag, Newport, KY, USA) following Caver et al. (1999). Chicks released on the Kentucky site were leg banded with plastic colored leg bands (2007) and metal leg bands (2009, 2010). Thirty-five releases resulted in 3,859 chicks being liberated across all sites and years. The releases were conducted on 18 sub-sites with a mean of 110 (range = 20-141) marked chicks per release (Table 1).

Quail hunts were conducted during November–January in years following summer bobwhite chick releases using pointing dogs and at least 2 hunters per party. Hunt parties attempted to methodically cover the release sites. Records were maintained of total hunts, hours hunted, and marked birds in the hunter harvest. Satisfaction level surveys were completed by hunters at the Kentucky site for all hunts during the 2009–2010 season.

RESULTS

Ninety-three quail hunts were conducted across all sites and years comprising 431 hunt party hours resulting in harvest of 19 marked bobwhites; this equated to a 0.005 proportional return to hunter bag (Table 2). Hunter surveys on the Kentucky site showed that 95% of the hunters were unsatisfied to highly unsatisfied with covey numbers, and 68.2% indicated their overall hunt quality to be unsatisfactory.

The costs associated with Surrogator® releases were similar across all sites and averaged $1,666.00 (range = $1,350.00 to $1,849.00) per Surrogator®, $0. 41 (range = $0.35 to $0.45) per quail chick, $309.00 (range = $150.00 to $600.00) for propane, and $169.00 (range = $104.00 to $252.00) for chick feed. The mean cost per bird returned-to-hunter bag (Alabama and Georgia) was $655.80 (range = $489.91 to $821.68). These costs did not include economic depreciation of Surrogator® units.

DISCUSSION

The Surrogator® technique in this study failed across a wide geography of sites with varying management intensities. Our results are consistent with other studies (Fies et al. 2000, Kinsey 2011) that found pre-season

Table 2. Return-to-hunter bag and cost per bird harvested for pen-reared northern bobwhites released from Surrogators® in Alabama, Georgia, and Kentucky during November through January 2005–2011.

State	Marked bobwhites released	Number hunts	Number hrs hunted	Number marked bobwhites harvested	Return to hunter bag	Cost[a] per marked bobwhite harvested
Alabama	1,366	59	321	5	0.004	$821.68
Georgia	1,641	15	70	14	0.008	$489.91
Kentucky	852	19	40	0	0.000	NA
Totals	3,859	93	431	19	0.005	NA

[a] Cost calculations based on chicks, brooders, feed, and propane; brooder cost is not depreciated.

release of pen-reared bobwhites to be ineffective for significantly increasing bobwhite abundance during the hunting season. Specifically, Kinsey (2011) used Surrogators® to release bobwhites in south-central Texas and reported 8% as his best survival to hunting season. He concluded the Surrogator® was ineffective as a method for supplementing wild bobwhite populations. Similarly, Lusk et al. (2009) used Surrogators® to release ring-necked pheasants (*Phasianus colchicus*) in Nebraska and through radiotelemetry documented a 12% survival rate from time of release to the hunting season and an annualized survival of $< 1\%$. They reported a return to hunter bag of 3.5% and concluded the release system would not increase pheasant populations. We did not radiomark any of the birds released and it remains unknown whether the paucity of quail in the hunting seasons in our study areas was due to poor survival and/or emigration. However, published studies documenting survival of Surrogator® released pen-reared quail and pheasants lead us to speculate the low return-to-hunter bag in our study was due primarily to on site mortality and not emigration.

MANAGEMENT IMPLICATIONS

We found Surrogators® to be ineffective at each site independently and across all sites and years combined as a pen-reared bobwhite pre-season release technique to augment fall-winter bobwhite hunter harvest. The proportion of released birds harvested was low and the cost per bird was high. We strongly suspect Surrogators® would have been ineffective on these sites as a technique for increasing spring bobwhite abundance to enhance population restoration based on the paucity of marked birds returned-to- hunter bag.

Habitat management to increase wild quail populations remains the only viable solution for providing high quality bobwhite hunting. However, releasing pen-reared bobwhites may be the only alternative in poor quality landscapes incapable of sustaining wild quail populations. The potential return-to-hunter bag and associated costs in these situations should be considered in the decision-making process relative to the release timing and technique.

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LITERATURE CITED

Barbour, R. W. 1950. A high mortality of pen-raised bob-white quail. Journal of Wildlife Management 14:474–475.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

Buechner, H. K. 1950. An evaluation of restocking with pen-reared bobwhite. Journal of Wildlife Management 9: 363–377.

Burger Jr., L. W. 2002. Quail management: issues, concerns, and solutions for public and private lands–a southeastern perspective. Proceedings of the National Quail Symposium 5:20–34.

Caver, V. A., L. W. Burger Jr., and L. A. Brennan. 1999. Passive integrated transponders and patagial tag markers for northern bobwhite chicks. Journal of Wildlife Management 63:162–166.

Duda, M. D., T. Beppler, S. J. Bissell, A. Criscione, J. B. Herrick, M. Jones, A. Lanier, J. Nobile, A. Ritchie, C. L. Schilli, M. Wilkes, and T. Winegord. 2009. Harvest of small game in Georgia 2008–2009. Responsive Management National Office, Harrisonburg, Virginia, USA.

Eggert, D. A., B. S. Mueller, L. Robinette, and S. D. Wellendorf. 2009. Comparison of survival, productivity, movements, and habitat use of pre-season released quail on wild northern bobwhites on Groton Plantation, South Carolina. Quail VI and Perdix XII: 396–408.

Fies, M. L., J. E. Fischer, and D. E. Steffen. 2000. Survival of game farm, F1-wild progeny, and wild-relocated northern bobwhites using two release methods. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 54:350–364.

Frye Jr., O. E., 1942. The comparative survival of wild and pen-reared bobwhite in the field. Transactions of the North American Wildlife Conference 7:168–178.

Georgia Game and Fish Commission. 1961. Annual report. Georgia Game and Fish Commission, Atlanta, USA.

Kinsey, J. C. 2011. Effectiveness of Surrogators as a propagation tool for northern bobwhites in south-central Texas. Thesis. Texas State University, San Marcos, USA.

Klimstra, W. D. 1982. Bobwhite quail and changing land use. Proceedings of the National Quail Symposium 2:1–5.

Klimstra, W. D., and T. G. Scott. 1973. Adaptation of pen-reared bobwhites to foods in a natural environment. Journal of Wildlife Management 37:492–494.

Lusk, J. J., J. S. Taylor, M. Feeney, M. Bresley, and B. M. Meduna. 2009. An evaluation of the Surrogator®captive propagation system for ring-necked pheasants. Final Report. Nebraska Game and Parks, Lincoln, USA.

National Bobwhite Technical Committee (NBTC). 2011. W. E. Palmer, T. M. Terhune, and D. F. McKenzie, eds. The National Bobwhite Conservation Initiative: a range-wide plan for recovering bobwhites. National Bobwhite Technical Committee

Technical Publication Version 2.0. Knoxville, Tennessee, USA.

Perez, R. M., D. E. Wilson, and K. D. Gruen. 2002. Survival and flight characteristics of captive-reared and wild northern bobwhite in southern Texas. Proceedings of the National Quail Symposium 5:81–86.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski Jr., and W. A. Link. 2011. The North American Breeding Bird Survey, results and analysis 1966–2009. Version 3.23.2011. USGS, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. Third edition. Charles Scribner's Sons, New York, USA.

Wildlife Management Technologies (WMT). 2011. Wichita, Kansas, USA. www.wildlifemanagementtechnologies.com

PROPAGATION EFFECTIVENESS OF THE SURROGATOR® FOR NORTHERN BOBWHITES IN SOUTHERN TEXAS

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ABSTRACT

Attempts to restore populations of northern bobwhites (*Colinus virginianus*) using pen-raised quail have been documented since the early 1900s. Low restoration success, based on low post-release survival rates and long distance dispersal from release sites, have proven the ineffectiveness of pen-raised quail in restoration of wild populations. The Surrogator®, a recent quail propagation tool using pen-raised quail, has been publicized as a method for increasing success rates in restoration of northern bobwhite populations by producing higher post-release survival and minimal dispersal. We tested the hypothesis that the Surrogator® is an effective means of supplementing populations of northern bobwhites in southern Texas. We raised 1,000 northern bobwhites in 2 Surrogators and conducted 2 trials in 2010 on a 990-ha ranch in Wilson County, Texas. Twenty northern bobwhites from each Surrogator were fitted with radio transmitters 12 hrs before release. We attempted to locate each bird daily for 3 weeks upon release from Surrogators followed by a reduced effort of 3 times per week until 100% mortality. Daily survival rates were low in Trial 1 (Surrogator A = 0.87 and Surrogator B = 0.96) and Trial 2 (Surrogator A = 0.83 and Surrogator B = 0.87). Mean distances traveled by post-released birds for Trial 1 were 401 and 1,416 m for Surrogators A and B, respectively. The Surrogator is not an effective means of restoring wild populations of northern bobwhites in southern Texas.

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Key words: *Colinus virginianus*, dispersal, northern bobwhite, post-release survival, restoration of population, southern Texas, Surrogator

INTRODUCTION

Northern bobwhites are one of North America's most economically important game birds, especially in the southern and Midwestern United States (Brennan 1999, Burger et al. 1999). The decline of bobwhite populations first became a matter of concern to wildlife managers in the early 1900s (Leopold 1931). Subsequently, concern grew among wildlife biologists when bobwhite populations became substantially reduced or extirpated in northern areas and a trend of declining numbers in the central part of the distribution was documented (Brennan 1993). Broad-scale data derived from Christmas Bird Counts, Breeding Bird Surveys, and state game agencies provided strong evidence of a widespread decline throughout the United States (Brennan 1991, 1993). Annual estimated declines from 1966 to 1988 in the United States averaged 1.8% per year with estimated declines of 0.7% in the central range and 3% per year in the eastern distribution (Droege and Sauer 1990).

These declines were attributed primarily to habitat loss from changing agricultural and forestry land-use patterns and expanding urbanization (Leopold 1933, Rosene 1969, Lehmann 1984, Wilkins and Swank 1992, Brennan 1993). Northern bobwhite populations in Texas have declined at an estimated rate of 5.6% per year since

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1980 (Texas Parks and Wildlife Department 2005) with many factors likely involved in declining populations including habitat loss and fragmentation (Veech 2006).

Wildlife biologists have attempted to restore bobwhite populations using pen-raised quail since the early 1900s with artificial propagation regarded as a quick fix (McAtee 1930, Barron 1935, Handley 1938, Nestler and Bailey 1941, Hart and Mitchell 1947, Kozicky 1993, Perez et al. 2002); however, this method proved unsuccessful for replenishing bobwhite populations. Two recognized problems associated with restoration using pen-raised birds were low survival rates post-release (averaging 8-15 days) and long-distance dispersal from release sites (Baumgartner 1944, Buechner 1950, Roseberry et al. 1987, Oakley et al. 2002).

Long-term population decline estimates of 2.4% per year for northern bobwhites throughout North America, coupled with unsuccessful attempts to restore populations, led to development of a game-bird propagation tool called the Surrogator® (Church et al. 1993). The Surrogator provides food, water, heat, and shelter for day-old chicks through the first 5 weeks of life during which the only contact chicks have with humans is during weekly maintenance. Quail are released after 5 weeks into the wild. The artificial brooding facility was developed to enhance existing methods for releasing pen-raised game birds to supplement existing wild populations.

Wildlife Management Technologies (WMT) reported 300,000 bobwhite quail released from Surrogators in 2006 had a survival rate of 65% (WMT 2009). The company also suggests site fidelity is instilled in quail raised in the Surrogator by imprinting to an area (WMT 2009). The objectives of our study were to test whether pen-reared northern bobwhites raised in Surrogators have increased (1) survival rates and (2) minimal dispersal rates. We tested the hypothesis that the Surrogator is an effective means of supplementing populations of northern bobwhites in southern Texas.

STUDY AREA

Our study was conducted on a 990-ha, high-fenced, ranch (29° 11′ 23.53" N, 97° 49′ 22.31" W) 12.8 km southwest of Nixon, Wilson County, Texas, in the Rio Grande Plains ecological area near the northern extent of the South Texas Plains ecoregion (Gould 1975). The ranch has characteristics of both South Texas Plains and Post Oak Savannah ecoregions. Approximately 70% of the ranch has native mesquite (*Prosopis*) thickets consisting largely of honey mesquite (*P. glandulosa*), granjeno (*Celtis pallida*), black brush (*Acacia rigidula*), and various species of cacti (*Opuntia* spp.). Oaks (*Quercus* spp.) are the predominant tree cover.

Predominant grass species include buffelgrass (*Pennisetum ciliare*), bristle grass (*Setaria* spp.), windmill grass (*Chloris truncata*), sideoats grama (*Bouteloua curtipendula*), and little bluestem (*Schizachyrium scoparium*). An abundance of forbs including Texas croton (*Croton texensis*) and western ragweed (*Ambrosia psilostachya*) provided ground cover at the time chicks were released from Surrogators.

METHODS

Field Procedures

Our study was conducted in late spring and summer 2010 using 2 Surrogators. We carefully followed guidelines in the Surrogator System Guide (WMT 2009). Two trials were conducted with Surrogators placed at different locations on the ranch (~1,500 m apart) in areas we categorized as suitable northern bobwhite habitat. We defined suitable habitat as areas providing shade and ample vegetative cover for food and escape from predators (WMT 2009). All vegetation and leaf litter at each site were removed from the immediate surrounding area for ease of maintenance. A 1.83-m length x 3.05-m width x 1.52-m height fence of cattle panels was constructed around each Surrogator to keep resident elk (*Cervus elaphus*) from damaging or disturbing Surrogators. Surrogators were placed following standard guidelines (WMT 2009). The same locations were used for both trials.

Surrogator Use

Trial 1 involved placing 250 1-day-old northern bobwhite chicks purchased from Outdoor Access Quail Farm (Devine, TX, USA) in each Surrogator on 11 June. Chicks were maintained in Surrogators for 5 weeks. We conducted weekly maintenance (i.e., adding water, removing fatalities, application of ant bait, and adjustment of heat settings) during this period as recommended (WMT 2009). Each chick received a color leg-band for future identification after 5 weeks in Surrogators, and 20 randomly selected chicks from each Surrogator were each fitted with a 3.5-g necklace radiotransmitter (Advanced Telemetry Systems, Isanti, MN, USA) after which chicks were returned to Surrogators. We released chicks from each Surrogator the following morning (17 Jul) by opening all doors ~30 min after sunrise. We immediately evacuated the area allowing for a soft release (WMT 2009). We returned to each release site 12 hrs later to confirm all chicks had left the units. We used the same protocol for Trial 2. Chicks were placed in Surrogators on 27 July and released on 2 October.

Radiotracking and GPS

We used a telemetry receiver (Model D50; Advanced Telemetry Systems, Isanti, MN, USA) to locate chicks released from both Surrogators and a Garmin eTrex Vista HCx hand-held Global Positioning System (GPS) unit (Garmin Inc., Olathe, KS, USA) to obtain locations of each individual. We radiotracked chicks on alternate days for 7 days because mortality substantially reduced the number of radiotracked quail by day 7, each surviving chick was located daily for 2 weeks. Individuals were located 3 times weekly following the 3-week period until mortality reached 100%.

Analyses

We used a Maximum Likelihood Estimator (Bart and Robson 1982) to calculate daily survival rates for chicks from each Surrogator for each release (Krebs 1999). We extrapolated daily survival estimates to estimate survival to the first day of the 2010 bobwhite hunting season (105 and 33 days) and an annual survival rate (365 days).

We downloaded the 2010 National Agriculture Imagery Program Mosaic Map from the Texas Natural Resources Conservation Services (www.tnris.org/get-data) and imported it into ArcGIS, Version 9.3 (ESRI 2008). We transferred chick observation locations and Surrogator release sites from the GPS unit to ArcGIS using Garmin software obtained from the Minnesota Department of Natural Resources (http://www.dnr.state.mn.us/rlp/index.html). We created a map using layers of observation points from each release site, locations for both Surrogators, and dispersal locations of chicks released from Surrogators. We joined the observation location layer to the release site layer of both releases through a distance spatial join function. This created a distance attribute with the measured distance (m) of each chick observation to its respective release site. We reclassified observations to include chicks observed a minimum of 5 times to allow for acclimation to transmitters and to reduce any bias in dispersal distance influenced by early mortality.

We used the attribute statistic function in ArcGIS and data from the distance attribute to calculate minimum distance, maximum distance, and mean (± SD) distance for the remaining bobwhites. We generated a scatter plot in Microsoft Excel (Microsoft Inc., Bellevue, WA, USA) depicting the relationship between number of days post-release and distance each chick dispersed from its respective release site. All activities were conducted in accordance with Texas State University-San Marcos IACUC approval # 0825_0804_26 and Texas permit #SPR-0890-234.

RESULTS

Survival

Mean weekly pre-release bobwhite mortality was < 2 mortalities per week for both surrogators combined for Trial 1. The Maximum Likelihood Estimates of Daily Survival Rates for chicks released from Surrogators A and B were 0.87 and 0.96, respectively. The 105-day finite survival rate (number of days from release to bobwhite hunting season) was > 0.01 (95% CI = 0 - $>$ 0.01) and 0.0167 (95% CI = 0.01-0.08) for Surrogators A and B, respectively. The 365-day finite survival rate for Surrogator A was 0 and > 0.01 for Surrogator B. The number of live chicks declined sharply over time from release to 100% mortality (Figs. 1, 2).

Mean weekly pre-release bobwhite mortality was 4 chicks per week for both Surrogators combined during Trial 2. The Maximum Likelihood Estimates of Daily Survival Rates for chicks released from Surrogators A and B were 0.86 and 0.87, respectively. The 33-day finite survival rate was > 0.01 (95% CI = $>$ 0.01-0.01) and 0.01 (95% CI = $>$ 0.01-0.05) for Surrogators A and B, respectively. The 365-day finite survival rate for both Surrogators was 0.

Dispersal

Released chicks readily moved from Surrogators. The mean dispersal distance from Surrogator A was 401.3 ± 263.6 m (max = 630.6 m, min = 118.4 m) and 1,416.5 ± 581.1 m (max = 2,036.3 m, min = 537.0 m) for Surrogator B during Trial 1. Dispersal data for Trial 2 had an insufficient sample size ($n < 2$).

DISCUSSION

Wildlife Management Technologies reported about 300,000 quail released from Surrogators in 2006 had a mean survival of 65% to the hunting season and quail released from Surrogators successfully reproduced during the next breeding season (WMT 2009). However, using the upper 95% confidence interval survival rate (0.08) calculated for our most successful release, 100-released northern bobwhite would have only 8 individuals survive until the first day of the next bobwhite hunting season. Thus, to acquire a favorable hunting density of 1.25 bobwhites/ha on our 990-ha study site, 153 releases of 100 bobwhites per release would be required simultaneously to have 1,222 live bobwhites available for harvest on opening day. Thus, using these survival rates, 2,000,000 bobwhites would have to be released simultaneously for 2 survivors to the next breeding season with only a 50% chance that a surviving pair would be a breeding pair. Maple and Silvy (1988), depending on the season of release, also had variable survival rates ranging from 1.9 to 58.3% for pen-raised adult northern bobwhites released in northern Texas. Krebs (2009) illustrated how single birds have a greater probability of predation than birds in a group. This was evident in our study by the lack of group cohesiveness and lower survival among chicks for the second release versus chicks from the first release.

Wildlife Management Technologies (2009) indicated properly raised bobwhites in Surrogator units were instilled with site fidelity and imprint on the property where released. The results of our study did not support these findings. The majority of our observations were on the study area, but we observed bobwhites with the greatest survival time occurred at greater distances from release sites, including observations on neighboring ranches and at distances much greater than the mean home range size for northern bobwhites (Brennan 1999).

The broader range of dispersal distances and dispersal distribution of northern bobwhites from Surrogator B may be explained by the difference in number of observations (Surrogator A = 43, Surrogator B = 203) and increased survival of chicks from Surrogator B compared to Surrogator A (4 and 10 weeks, respectively). Dispersal distance from respective Surrogators increased as number of days post-release increased (Fig. 2).

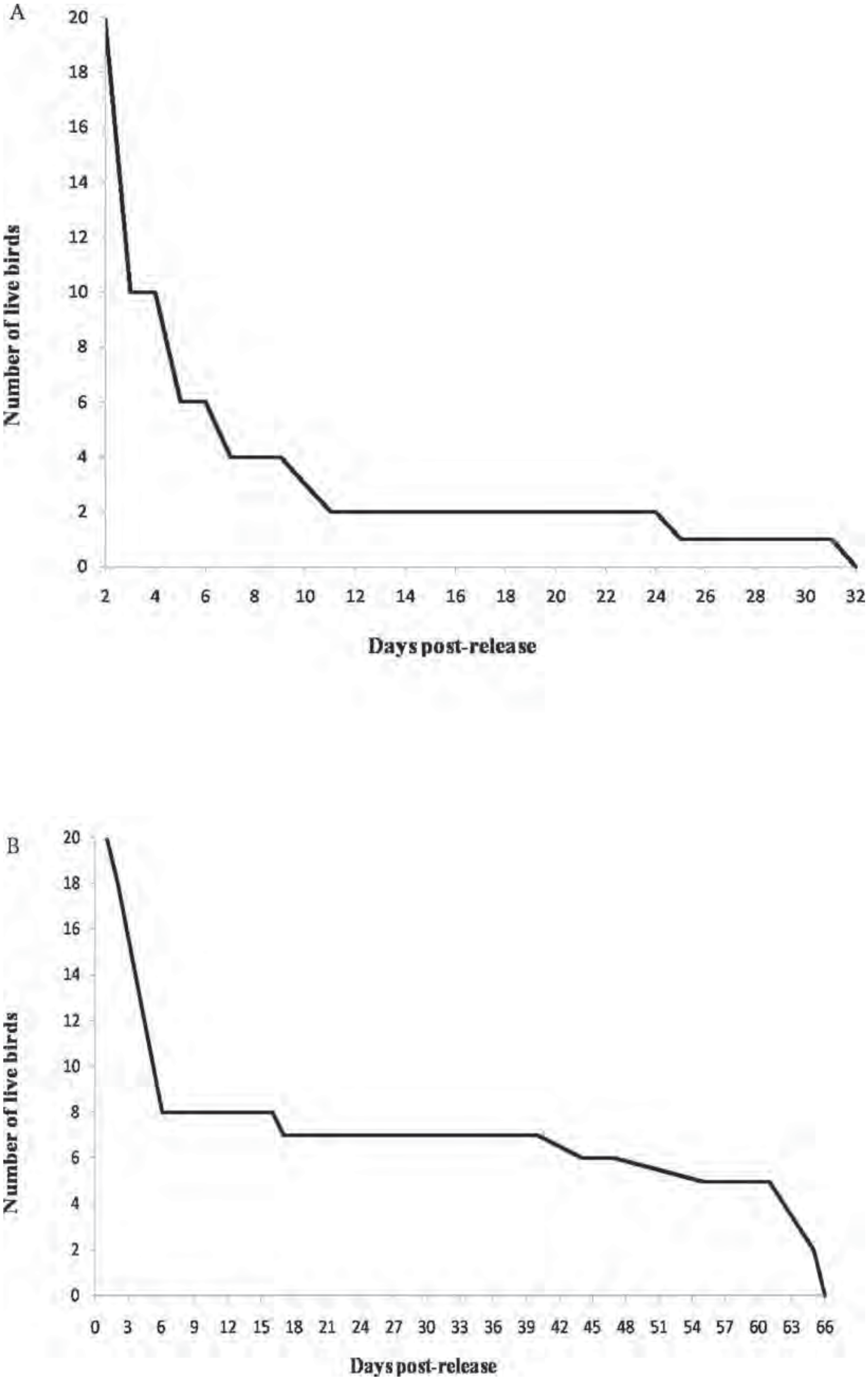

Fig. 1. Post-release survival of northern bobwhites released from Surrogator (A) and Surrogator (B) during Trial 1 in 2010 at the Sheffield Ranch, Wilson County, Texas.

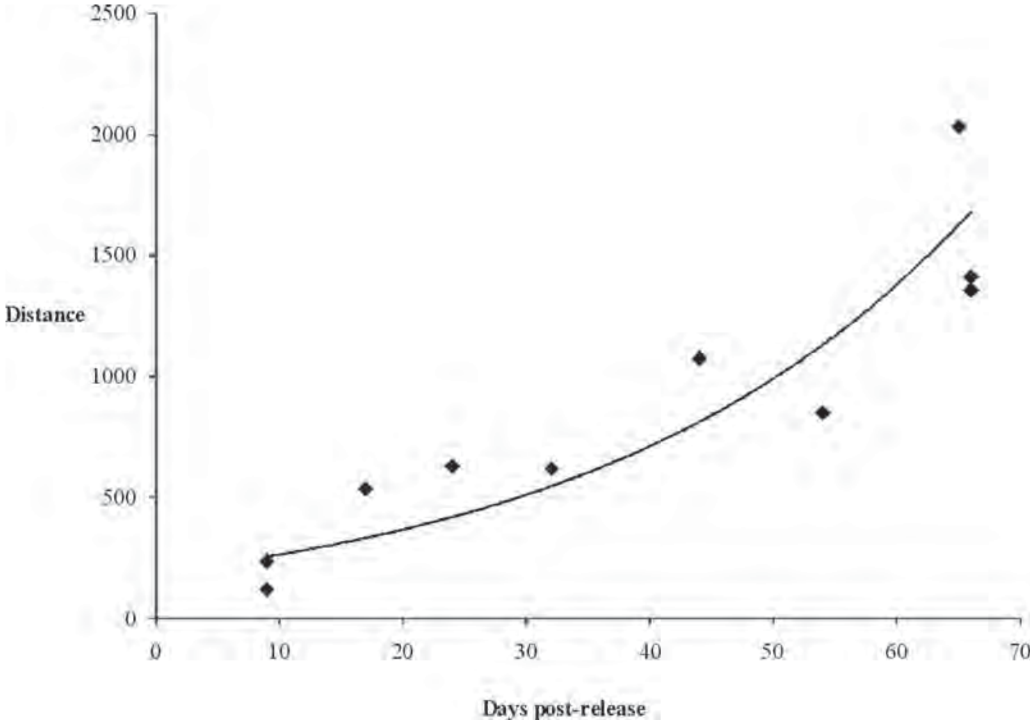

Fig. 2. Relationship between days of survival post-release and dispersal distance (m) from release site of northern bobwhites released from Surrogators during Trial 1 in 2010 at the Sheffield Ranch, Wilson County, Texas.

MANAGEMENT IMPLICATIONS

We rejected the hypothesis that the Surrogator is an effective method for supplementing populations of wild northern bobwhites in southern Texas. The Surrogator has become a tool used by landowners with varying success, and we sought to provide information for landowners and Texas Parks and Wildlife biologists for informed decisions for purchase and potential use of this propagation tool. We recommend a best practice for maintaining consistent bobwhite populations by investing in habitat management that increases native bunchgrasses and forbs, managing grazing by livestock, use of prescribed burning, and control of harvest of the annual production of northern bobwhites.

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LITERATURE CITED

Barron Jr., F. 1935. Pen-raising the bobwhite. Modern Game Breeding 5(12):19–22, 25.

Bart, J., and D. S. Robson. 1982. Estimating survivorship when the subjects are visited periodically. Ecology 63:1078–1090.

Baumgartner, F. M. 1944. Dispersal and survival of game-farm bobwhite quail in north central Oklahoma. Journal of Wildlife Management 8:112–118.

Buechner, H. K. 1950. An evaluation of restocking with pen-reared bobwhite. Journal of Wildlife Management 14:363–377.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

Brennan, L. A. 1993. Strategic plan for quail management and research in the United States. Proceedings of the National Quail Symposium 3:160–169.

Brennan, L. A. 1999. Northern bobwhite (*Colinus virginianus*). The birds of North America. Number 397.

Burger, L. W., D. A. Miller, and R. I. Southwick. 1999. Economic impact of northern bobwhite hunting in the southeastern United States. Wildlife Society Bulletin 27:1010–1018.

Church, K. E., J. R. Sauer, and S. Droege. 1993. Population trends of quails in North America. Proceedings of the National Quail Symposium 3:44–54.

Droege, S., and J. R. Sauer. 1990. Northern bobwhite, gray partridge, and ring-necked pheasant population trends (1966–1988) from the North American Breeding Bird Survey. Pages 2–20 *in* K. E. Church, R. E. Warner, and S. J. Brady, eds. Perdix V: Gray Partridge and Ring-necked Pheasant Workshop. Kansas Department of Wildlife and Parks, Emporia, USA.

ESRI. 2008. ArcGIS, Version 9.3. Environmental Systems Research Institute Inc., Redlands, California, USA.

Gould, F. W. 1975. Texas plants, a checklist and ecological summary. Miscellaneous Publication 585 (Revised). Agriculture Experiment Station, Texas A&M University, College Station, USA.

Handley, D. O. 1938. The survival of liberated bobwhite quail. Transactions of the American Game Conference 21:377–380.

Hart, D., and T. R. Mitchell. 1947. Quail and pheasant propagation. Wildlife Management Institute, Washington, D.C., USA

Kozicky, E. L. 1993. The history of quail management with comments on pen-rearing. Proceedings of the National Quail Symposium 3:1–7.

Krebs, C. J. 1999. Ecological methodology. Second edition. Benjamin Cummings, Menlo Park, California, USA.

Krebs, C. J. 2009. Ecology. Sixth edition. Benjamin Cummings, Menlo Park, California, USA.

Lehmann, V. W. 1984. Bobwhites in the Rio Grande Plain of Texas. Texas A&M University Press, College Station, USA.

Leopold, A. 1931. Report on a game survey of the North Central states. Democrat Printing Company, Madison, Wisconsin, USA.

Leopold, A. 1933. Game management. Charles Scribner's Sons, New York, USA.

Maple, D. P., and N. J. Silvy. 1988. Recovery and economics of pen-reared bobwhites in north-central Texas. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 42:329–332.

McAtee, W. L. 1930. Propagation of upland game birds. U. S. Department of Agriculture. Farmer's Bulletin 1613:8–10.

Nestler, R. B., and W. W. Bailey. 1941. Bobwhite quail propagation. Conservation Bulletin 10. USDI, Fish and Wildlife Service, Washington, D.C., USA.

Oakley, M. J., D. L. Bounds, T. A. Mollett, and E. C. Soutiere. 2002. Survival and home range estimates of pen-raised northern bobwhites in buffer strip and non-buffer strip habitats. Proceedings of the National Quail Symposium 5:74–80.

Perez, R. M., D. E. Wilson, and K. D. Gruen. 2002. Survival and flight characteristics of captive-reared and wild northern bobwhite in southern Texas. Proceedings of the National Quail Symposium 5:81–85.

Roseberry, J. L., D. L. Elsworth, and W. D. Kilmstra. 1987. Comparative post release behavior and survival of wild, semi-wild and game-farm bobwhites. Wildlife Society Bulletin 15:449–455.

Rosene, W. 1969. The bobwhite quail: its life and management. Rutgers University Press, New Brunswick, New Jersey, USA.

Texas Parks and Wildlife Department. 2005. Where have all the quail gone. Texas Parks and Wildlife Department, Austin, USA.

Veech, J. A. 2006. Increasing and declining populations of northern bobwhites inhabit different types of landscapes. Journal of Wildlife Management 70:922–930.

Wildlife Management Technologies. 2009. Wildlife Management Technologies Surrogator® System Guide. Wichita, Kansas, USA. www.wildlifemanagementtechnologies.com/sparticle.html

Wilkins, R. N., and W. G. Swank. 1992. Bobwhite habitat use under short-duration and deferred-rotation grazing. Journal of Range Management 45:549–553.

FECUNDITY OF WILD NORTHERN BOBWHITE HENS UNDER HATCHERY CONDITIONS

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ABSTRACT

We describe egg production by 88 pairs of randomly selected, mature, wild-caught northern bobwhite (*Colinus virginianus*) hens housed under optimal conditions of food, water, climate, and a 17-hr photoperiod in a hatchery. We collected eggs daily using an 18-day period to differentiate between clutches. Hens continuously laid eggs until ceasing production. We evaluated number of eggs laid by each hen individually and hens collectively including total number, number/clutch, number/day, hatching success, and egg mass. Eighty-six hens produced 5,888 eggs. Number of eggs produced by individual hens ranged from 0 to 172 over ~ 200 days. Mean number of eggs laid/hen/day was 0.86. Clutch size ranged from 0 ($n = 2$) to 12 ($n = 1$). Mean number of eggs/clutch was 8.57. There was a strong correlation between clutch size and number of clutches. Some hens demonstrated continuous production of several large clutches. Hatching success of 5,793 eggs included for analysis was 61.6% (3,571 hatched, 2,222 failed to hatch). Hatched eggs had a greater mean mass compared to those that did not hatch.

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Key words: *Colinus virginianus*, differential production, hatchery, northern bobwhite, reproduction, Texas

INTRODUCTION

Population studies of northern bobwhites were key factors in developing early concepts of wildlife ecology (Stoddard 1931, Leopold 1933, Errington and Hamerstrom 1935, Errington 1945), and numerous field studies have examined impacts of management on the demography of northern bobwhites, including components of fecundity (DeVos and Mueller 1993, Burger et al. 1995, Cox et al. 2005). Annual productivity depends on reproductive performance by hens buffered by environmental pressures. Northern bobwhite hens lay eggs at a rate of < 1 egg/day beginning 1 day after nest completion with completion of a clutch of 12–15 eggs in about 18 days (Rosene 1969, Dimmick 1992). Klimstra and Roseberry (1975) reported variation in clutch size ranging from 6 to 28 eggs. However, northern bobwhites reduce clutch size after each nest failure or clutch produced (Dimmick 1992). Maximum number of broods/female is not known definitively, but can be up to 3/breeding season (Guthery and Kuvlesky 1998). Percentage of hens capable of producing > 1 brood/year is unknown, but of those hatching a first nest, up to 30% may attempt a second (Burger et al. 1995). Questions about multiple-clutch production and clutch size remain unanswered because of a paucity of information on biotic potential of bobwhite hens. The objective of our study was to examine reproductive potential of northern bobwhite hens from southern Texas under controlled environmental conditions by assessing: (1) total eggs and number of clutches laid by individual hens and hens collectively, (2) hatching success (proportion of eggs hatched), and (3) multi-clutching (probability a female will continue laying clutches).

METHODS

We captured wild northern bobwhites in walk-in traps (Reeves et al. 1968) on 2 ranches (27° 15′ 07.92″ N, 97°

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51′ 52.30″ W in Kenedy County, Texas and 26° 50′ 51.87″ N, 98° 13′14.82″ W in Brooks County, Texas) in April 1992 and January 1993. We released captured juveniles. We banded all adults with leg bands and placed them in 3.6 × 1.2 × 0.25 m holding pens for transport to the Texas State University Game Bird Alliance facility at the Freeman Ranch in San Marcos. Bobwhites were acclimated to captivity by slowly changing the diet from milo to Gamebird Layena (Ralston Purina, St. Louis, MO, USA) and replacing water in open poultry water basins to water supplied by modified, automatic drinking cups. We provided food *ad libitum* and refreshed it daily.

We transferred 88 adult males from holding pens in mid-February to a 5 × 5-m breeder room with a dual lighting system, a low intensity (60 W) blue light, and 13 high intensity (100 W) white incandescent lights. The breeder room had 3 banks of breeding cages (Model 0330, Georgia Quail Farms, Savannah, GA, USA) with 30 (25.6 × 61.5 × 25.6 cm) compartments per bank. Each compartment contained a modified automatic drink cup (Model 4086, Georgia Quail Farm, Savannah, GA, USA) at the rear and food tray at the front. Water and food were provided *ad libitum*. We maintained brood stock on a production diet consisting of Gamebird Layena and ground oyster shell (DeWhitt et al. 1949). All cages were in the same room with birds having visual and acoustical contact but not physical contact. All breeder cages received equal amounts of light from high-intensity white lights. An electronic timer (Model 1103, Tork Inc., Mount Vernon, NY, USA) controlled the photoperiod. Workers entering the breeder room to dispense feed or maintain equipment worked under low-intensity blue light. An evaporative cooler maintained a stable climate (temperature and humidity) (Vandepopuliere et al. 1969).

A single, healthy, adult male was placed in each compartment in mid-February and initially exposed to a 15-hr photoperiod to stimulate gonadal development and spermatogenesis (Kendeigh 1941, Robinson 1963). We paired males with adult hens from the same holding pen in early March but did not attempt to match individuals based on previous pairing because we could not recognize pairings in the holding pen. This arrangement was expected to produce the greatest fertility and hatching success rates (Schom 1973). We increased the photoperiod by 30 min every 5 days until a 17-hr photoperiod was established (Dozier and Bramwell 2002).

A constant 17-hr lighting treatment eliminated one of many variables influencing reproductive performance of breeder hens, namely, extent and timing of a light stimulus prior to the onset of egg production (Gous and Cherry 2004). The photoperiod with associated civil twilight (30 min before sunrise and 30 min after sunset at the latitude at which quail were collected exceeds 15 hrs/day. Civil twilight was included in the photoperiod used because birds are active before sunrise and after sunset (Palmgren 1949, Leopold and Eynon 1961). We assumed no difference in laying performance between birds on 17-hr instead of 15-hr photoperiod (Robinson 1963, Lewis 1996). We also tested an extreme photoperiod (17 hrs) as a component to elicit biotic potential by hens.

Egg collection began 30 March 1993 after acclimation of pairs to the 17-hr photoperiod for 21 days. We used 18 days to differentiate a clutch (Rosene 1969). We collected eggs daily from each compartment under blue-light illumination while wearing surgical latex gloves to prevent contamination. We marked each egg with sequential and compartment numbers with a soft lead pencil. We weighed each egg to 0.1 g on a digital balance (Model C305-5, Ohaus Inc., Florham Park, NJ, USA), wrapped all eggs produced/day/compartment in Saran™ plastic wrap to prevent moisture loss, and stored them in a refrigerator at a constant temperature of 12.8 °C (Miller and Wilson 1975). Eggs remained refrigerated between 7 and 14 days until incubation. Hart and Mitchell (1947) suggested storage of eggs should not exceed 10 days; we found no appreciable reduction in hatching success for eggs stored > 10 days in a pilot study when eggs were turned daily (Schom and Abbott 1974, Miller and Wilson 1976).

We removed eggs from the refrigerator and allowed them to reach ambient temperature (22 °C) before placement in an incubator. We assumed these eggs had equal fertility and potential hatching success. Eggs were incubated in an inverted position (i.e., small end up) to increase hatching success (Cain and Abbott 1971) for 21 days at a temperature of 37.5 °C and a relative humidity of 86–88%. We candled eggs for fertility at day 21 with a small penlight, transferred fertile eggs to a hatcher, and arranged them tightly to synchronize hatching (Pani et al. 1969). Eggs remained in the hatcher ~ 48 hrs at a temperature of 36 °C and relative humidity of 88–89%.

We terminated egg production at 202 days when hens began showing signs of physiological stress, declining egg production, fertility, and hatching success. All activities were conducted in accordance with Texas State University-San Marcos IACUC approval # CYOy 91–92 and Texas permit #SPR-0890-234. We used student's *t*-test to evaluate whether mass of fertile eggs differed from infertile eggs. We tested the relationship between mean eggs/clutch and number of clutches by an analysis of variance.

RESULTS

Eighty-six hens produced 5,888 eggs over a 202-day period (30 Mar to 19 Oct 1993), and 2 hens (2%) produced no eggs. These 86 hens collectively produced 687 clutches of eggs (mean ± SD = 8.57 ± 4.86; Table 1). Seventy-six hens (86%) laid at least 4 clutches, and 51 hens (58%) produced 9 clutches. The maximum number of clutches produced by a hen was 12 and 1 hen produced 172 eggs (11 clutches, mean ± SD = 16.3 ± 3.14). Intra-seasonal clutch size by clutch number was normally distributed and consistent across clutch number. Mean eggs/clutch increased from the first to third clutch, decreased slightly by the fourth clutch, and remained relatively stable through clutch 10, after which there was a substantial reduction in production (Table 1). This pattern of clutch number affecting clutch size was strongly

Table 1. Number of sequential clutches (C1-12) and mean (± SD), maximum (max), and minimum (min) number of eggs produced/clutch collectively by wild, northern bobwhite hens under 17-hr photoperiod in a hatchery.

Category	*n*	Mean ± SD	Max	Min
All	687	8.57 ± 4.86	28	5
C1	76	7.03 ± 3.74	18	5
C2	76	9.50 ± 5.06	28	5
C3	76	9.61 ± 4.99	23	5
C4	76	8.18 ± 4.84	24	5
C5	73	9.00 ± 5.21	19	5
C6	67	8.52 ± 5.23	22	5
C7	63	7.84 ± 5.08	21	5
C8	57	8.47 ± 4.93	18	5
C9	51	9.35 ± 4.44	18	5
C10	43	8.26 ± 4.40	16	5
C11	24	7.21 ± 3.92	18	5
C12	1	5.00 ± 0	5	5

correlated (second-order polynomial regression, $r^2 = 0.98$, $P > 0.001$; Fig. 1).

The mean (± SD) number of eggs laid/day was 0.86 ± 0.53. Hatching success of the 5,793 eggs included for analysis was 61.6% (3,571 hatched, 2,222 failed to hatch). Hatched eggs had a greater mean (± SD) mass (8.98 ± 1.94 g) compared to non-hatch eggs (mean ± SD = 8.83 ± 1.52 g; $t_{5,836} = -3.39$, $P = 0.001$).

DISCUSSION

The intra-seasonal clutch size remained consistent through clutch 9 in our hatchery study. This finding was surprising based on the extensive literature that a seasonal decline in clutch size is common in bird populations (Klomp 1970, Drent and Daan 1980, Martin 1987, Daan et al. 1989). Examples of this phenomenon include Arctic nesting geese (Hamann and Cooke 1989), temperate raptors (Dijkstra et al. 1982), and some passerines (Murphy 1986). Dimmick (1992) also reported reduction of clutch size after each nest failure or clutch event by bobwhites. Drent and Daan (1980) suggested that timing and variation in clutch size were based on accumulated body condition (i.e., accumulated nutrient reserves) required for egg production. Birds in poor condition might lead to the observed pattern of seasonal decline in clutch size (Daan et al. 1989).

Rowe et al. (1994) presented a model to explain multiple clutch production based on residual fitness. A hen will expend a certain amount of accumulated nutrients in laying her first clutch leaving a residual fitness based on unexpended nutrient reserves. There should be a time lag before she can start to accumulate condition for the second clutch. Her condition is assumed to decrease to a fixed level during this time interval. The loss of condition is assumed to be related to the amount of endogenous nutrients required for producing and rearing the clutch. Nutrients reserves needed to produce a second clutch will be less than the original reserves before production of the first clutch. One result of lower residual fitness may be fewer eggs in the second clutch. However, the results of our study did not indicate a continual decline in clutch size. The hen, for example, that produced 172 eggs showed a remarkable consistency in clutch size (18, 18, 16, 16, 19, 16, 17, 14, 15, and 8). There was no lag time in our study for replenishing nutrients, since eggs were continuously removed as laid. Perhaps the high quality diet fed to hens allowed maintenance of a sufficient nutrient reserve.

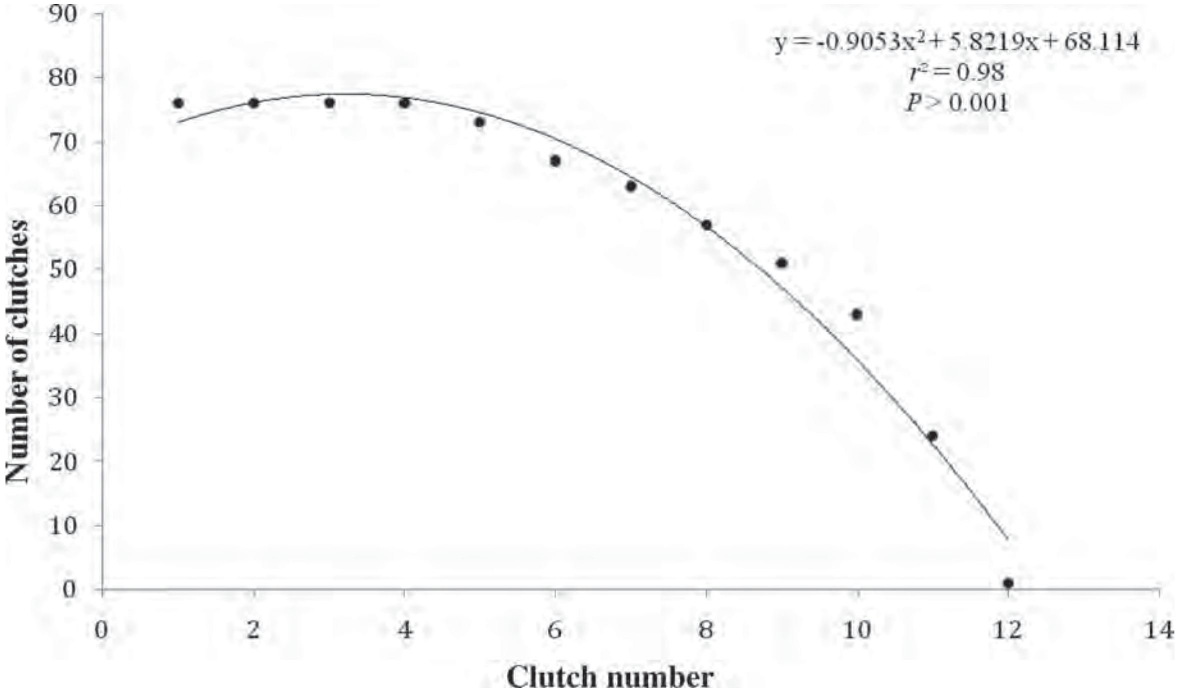

Fig. 1. Second-order polynomial regression showing the relationship between clutch size and clutch number.

Robinson (1963) reported mature captive bobwhite hens produced eggs with a mean mass of 9.65 g ($n = 143$); however, hens in our study produced eggs with a slightly less mean mass (8.98 g, $n = 3,571$) but heavier than the mean mass (7.78 g, $n = 96$) of young hens.

We showed that wild, captive northern bobwhites could produce multiple clutches of eggs. We suggest this species in a hatchery environment has high biotic potential as evidenced by 86 of 88 hens collectively producing 687 clutches of eggs with 61.6% hatching success over 202 days. Fifty-one of 86 (67%) hens produced 9 clutches, 51% of hens laid 10 clutches, 31% 11 clutches, and only 1 (1%) hen produced 12 clutches. Northern bobwhite hens in our study demonstrated differential reproduction and the potential in captivity to produce large numbers of eggs over at least 6 months under optimum conditions.

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LITERATURE CITED

Burger Jr., L. W., M. R. Ryan, T. V. Dailey, and E. W. Kurzejeski. 1995. Reproductive strategies, success and mating systems of northern bobwhite in Missouri. Journal of Wildlife Management 59:417–426.

Cain, J. R., and U. K. Abbott. 1971. Incubation of avian eggs in an inverted position. Poultry Science 50:1223–1226.

Cox, S. A., F. S. Guthery, J. J. Lusk, A. D. Peoples, S. J. DeMaso, and M. Sams. 2005. Reproduction by northern bobwhites in western Oklahoma. Journal of Wildlife Management 69:133–139.

Daan, S., C. Dijkstra, R. H. Drent, and T. Meijer. 1989. Food supply and the annual timing of avian reproduction. Proceedings of the International Ornithological Congress 19:392–407.

DeVos Jr., T., and B. S. Mueller. 1993. Reproductive ecology of northern bobwhite in north Florida. Proceedings of the National Quail Symposium 3:83–90.

DeWhitt, J. B., R. B. Nestler, and J. V. Derby Jr. 1949. Calcium and phosphorus requirements of breeding bobwhite quail. Journal of Nutrition 39:567–577.

Dijkstra, C., L. Vuursteen, S. Daan, and D. Masman. 1982. Clutch size and lay date in the kestrel (*Falco tinnunculus*): the effects of supplementary food. Ibis 124:210–213.

Dimmick, R. 1992. Northern bobwhite (*Colinus virginianus*): Section 4.1.3. Wildlife Resources Manual. U.S. Army Corps of Engineers, Vicksburg, Mississippi, USA.

Dozier III, W. A., and K. Bramwell. 2002. Bobwhite quail production and management guide. Article 154, Poultry Science Department, University of Georgia, Athens, USA.

Drent R. H., and S. Daan. 1980. The prudent parent: energetic adjustment in avian biology. Ardea 68:225–252.

Errington, P. L. 1945. Some contributions of a fifteen-year local study of the northern bobwhite to a knowledge of population phenomena. Ecological Monographs 15:1–34.

Errington, P. L., and F. N. Hamerstrom Jr. 1935. Bobwhite winter survival on experimentally shot and unshot areas. Iowa State College Journal of Science 9:625–639.

Gous, R. M., and P. Cherry. 2004. Effects of body weight at, and lighting regimen and growth curve to, 20 weeks on laying performance in broiler breeders. British Poultry Science 45:445–452.

Guthery, F. S., and W. P. Kuvlesky Jr. 1998. The effect of multiple-brooding on age ratios of quail. Journal of Wildlife Management 62:540–549.

Hamann, J., and F. Cooke. 1989. Intra-seasonal decline of clutch size in Lesser Snow Geese. Oecologia 79:83–90.

Hart, D., and T. R. Mitchell. 1947. Quail and pheasant propagation. Wildlife Management Institute, Washington, D.C., USA.

Kendeigh, S. C. 1941. Length of day and energy requirements for gonad development and egg-laying in birds. Ecology 22:237–248.

Klimstra, W. D., and J. L. Roseberry. 1975. Nesting ecology of the bobwhite in southern Illinois. Wildlife Monographs 41.

Klomp, H. 1970. The determinants of clutch size in birds: a review. Ardea 58:1–125.

Leopold, A. 1933. Game management. University of Wisconsin Press, Madison, USA.

Leopold, A., and A. E. Eynon. 1961. Avian daybreak and evening song in relation to time and light intensity. Condor 63:269–293.

Lewis, P. D. 1996. The domestic hen's response to photo-periodic influences. Proceedings of XX World's Poultry Science Congress, New Delhi 11:737–745.

Martin, T. E. 1987. Food as a limit on breeding birds: a life history perspective. Annual Review of Ecology and Systematics 8:453–487.

Miller, E. R., and H. R. Wilson. 1975. The temperature required to initiate blastoderm development of bobwhite quail eggs. Poultry Science 54:901–902.

Miller, E. R., and H. R. Wilson. 1976. Hatchability of bobwhite quail eggs as influenced by pre-incubation storage and turning. Poultry Science 55:2476–2478.

Murphy, M. T. 1986. Temporal components of reproductive variability in eastern kingbirds (*Tyrannus tyrranus*). Ecology 67:1483–1492.

Palmgren, P. 1949. On the diurnal rhythm of activity and rest in birds. Ibis 91:561–576.

Pani, P. K., T. H. Coleman, H. D. Georgis, and A. W. Kulenkamp. 1969. Between family synchronization of hatching time in bobwhite quail. Poultry Science 48:665–667.

Reeves, H. M., A. D. Geis, and F. C. Kniffin. 1968. Mourning dove capture and banding. Special Scientific Report 117. USDI, Fish and Wildlife Service, Washington, D.C., USA.

Robinson, T. S. 1963. Egg production by bobwhites under a fifteen-hour photoperiod. Journal of Wildlife Management 27:215–220.

Rosene Jr., W. 1969. The bobwhite quail: its life and management. Rutgers University Press, New Brunswick, New Jersey, USA.

Rowe, L., D. Ludwig, and D. Schlute. 1994. Time, condition, and the seasonal decline of avian clutch size. American Naturalist 143:698–722.

Schom, C. B. 1973. Effect of cage size, location, and mating procedure on fertility of egg production of bobwhite quail. Poultry Science 52:2083.

Schom, C. B., and U. K. Abbott. 1974. Studies with bobwhite quail: reproductive characteristics. Poultry Science 53:1860–1865.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. Charles Scribner's Sons, New York, USA.

Vandepopuliere, J. M., R. D. Kealy, D. E. Greene, and J. L. Williamson. 1969. The influence of environment and housing on pheasant, quail, chukar reproduction. Poultry Science 48:1885.

EFFECTS OF TWO COMMERCIAL GAME BIRD FEEDS ON CAPTIVE NORTHERN BOBWHITE CHICK GROWTH RATES

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ABSTRACT

Supplemental feeding of northern bobwhites (*Colinus virginianus*) is a widespread management practice. Bobwhite chicks in the wild consume only arthropods for their first 30–60 days of life. Arthropods may become less abundant and managers have supplied bobwhites with supplemental feed during times of drought to mitigate the lack of arthropods. We compared growth rates of captive bobwhite chicks consuming a new, commercial 24% crude protein supplement to growth rates of bobwhites consuming a commercial 30% crude protein complete ration. There was no male/female bias related to chick growth. Chicks consuming the 24% protein diet grew slower and reached adult mass (150 g) 1 month later than birds on the 30% protein diet. Birds grew 4–6 times faster than documented rates from wild chicks in Florida, but this is attributed to captivity bias. A 24% protein supplement has insufficient protein to optimize growth of bobwhites and is a poor substitute for arthropods in time of drought. A 30% protein diet has sufficient nutrient levels to justify further research as a supplement to mitigate a lack of arthropods in times of drought.

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Key words: chicks, *Colinus virginianus*, growth, northern bobwhite, protein pellets, supplemental feed

INTRODUCTION

The practice of supplemental feeding of wild bobwhite populations is a common practice, despite equivocal results from research (Haines et al. 2004). Wild bobwhites in South Texas are supplementally-fed along roadsides in an attempt to mitigate harsh climatic conditions. Considerable research effort has been devoted to commercial production of bobwhites during the past 70 years (Nestler et al. 1942, 1944; Nestler 1949; Andrews et al. 1973), but researchers have yet to quantify the role of supplemental food on wild bobwhite chick growth.

Arthropods are the most important food source for wild bobwhite chicks from 1 to 60 days of age (Hurst 1972, Palmer et al. 2001). Arthropods contain high amounts of crude protein ($>$ 46.5%) and provide the nutrients necessary for chick growth (Wood et al. 1986, Bell 1990). A bobwhite chick's diet consists of 80% insects in the first 2 weeks of life—primarily, Coleoptera, Hymenoptera, Diptera, and Hemiptera (Lehmann 1984, Brennan 1999). The diet gradually changes to seeds and other plant material over the next 6 to 8 weeks of life (Handley 1931, Nestler et al. 1945, Hurst 1972, Utz et al. 2001).

Bobwhite chicks have high crude protein requirements. Chicks require $>$ 28% crude protein in their diet to optimize growth (Nestler et al. 1942, Andrews et al. 1973, Robbins 1983). Butler (2007) documented reduced growth rates of bobwhite chicks that did not consume a high proportion of insects in their diet. A bobwhite chick has few options for obtaining high quality food on South Texas rangelands. Legumes and arthropods are the most common sources of protein for bobwhite chicks in South Texas but availability of these resources is weather dependent (Varley et al. 1973, Brennan 2007) . Drought is common in South Texas (Brennan 2007). If arthropods are

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not abundant during drought, food available for chicks is poor quality and advocates of supplemental feeding claim that providing food will mitigate for the lack of arthropods (Varley et al. 1973, Smith 1982, Hawkins and Holyoak 1998).

Many wildlife managers contend that supplemental feed enables adult bobwhites to withstand harsh climatic events (i.e., drought or severe winters), and provide bobwhites with supplemental feed (commonly milo-corn mixtures) (Hernández and Guthery 2012). Bobwhites are also fed to increase survival and subsequent breeding; however, empirical evidence suggests supplemental feeding is a demographically neutral management practice, at best (Guthery 2000, 2002; Guthery et al. 2004). The importance of supplemental food for wild bobwhite chicks is unknown. Some commercial feed companies claim a commercially-formulated ration (16 or 24% crude protein) will produce healthy, fast-growing chicks (Lyssy and Eckel Feeds 2012). A commercial feed ration may increase available dietary protein and allow for optimized chick growth, assuming chicks in the wild will eat supplemental feed in times of low arthropod abundance.

Insect abundance is inherently low during drought (Varley et al. 1973). Supplemental feed may be a convenient foodstuff available to wild bobwhites during drought conditions on South Texas ranches (Haines et al. 2004). The impact of a new, commercial protein supplement (Quail Breeder Feeds; Lyssy and Eckel Feeds, Poth, TX, USA) on bobwhite chick growth has not been documented. We wanted to learn how the growth rate of captive bobwhite chicks would change when food is limited to only supplemental feeds. Our objective was to compare captive bobwhite chick growth on a weekly basis among chicks fed a new, commercially available supplement (24% crude protein) with chicks fed a commercially available (30% crude protein) complete ration in an effort to provide managers more information on the potential utility of supplementally providing protein feed to wild populations. We hypothesized that chicks consuming the 30% crude protein diet would grow faster and reach adult mass (150 g) faster than chicks consuming the 24% crude protein diet.

METHODS

This study was conducted at the Duane Leach Aviary on the campus of Texas A&M University–Kingsville, TX, USA from 1 May to 8 October 2009. We purchased 60, 1 day-old bobwhites from a commercial game farm (Wes' Game Birds, Orange Grove, TX, USA). We used a completely randomized design to assign chicks to 1 of 2, 8.9-m^2 pens (30 chicks per pen). We recorded the gender of each individual and banded each chick with an aluminum leg band (American Band and Tag, Co., Newport, KY, USA), numbered so that each individual could be identified. Each pen was outfitted with a 100W brooder lamp, water dispenser, and feeder tray. A 1-cm layer of cedar shavings was spread on the floor to reduce odor and maintain sanitation. Brooder lamps remained on 24 hrs/day for 30 days until bobwhites could self-thermoregulate (Borchelt and Ringer 1973). All birds were fed turkey starter feed *ad libitum* (30% crude protein; Purina Mills LLC, New Brighton, MN, USA; Appendix) for the first week to acclimate chicks to consuming a commercial feed. Water was provided *ad libitum*. We recorded the mass (g) of each bird after 1 week and commenced the experiment.

We used 2 different commercial feeds in this experiment. The 30% crude protein (Appendix, 30% CP) had all of the nutrients required for bobwhite chick growth, simulating the diet of a chick feeding on insects (Nestler 1949). The new, commercial supplement diet (Appendix) was a 24% crude protein (24% CP), commercial bobwhite pellet marketed to increase chick growth, among other claims. The 24% CP was ground into ~ 1-mm^3 pieces for ease of consumption for the first 30 days of the experiment. The 30% CP came pre-ground into ~1-mm^3 pieces. Thirty bobwhite chicks were fed the 24% CP ration and 30 bobwhites were fed the 30% CP ration until termination of the experiment; both groups were fed *ad libitum*. We used a spring scale (Pesola Co., Baar, Switzerland) to record bobwhite mass to the nearest gram each week for 15 weeks. Quail were euthanized at the end of the experiment according to procedures outlined by Texas A&M University–Kingsville's Institutional Animal Care and Use Committee (IACUC # 2008-09-30A). If birds died, we tried to ascertain the cause of death.

We analyzed the data using the repeated measures analysis of variance (ANOVA) procedure (PROC MIXED) in SAS 9.1.3 (SAS Institute, Cary, NC, USA). We used Akaike's Information Criterion with small sample size correction (AIC*c*, Burnham and Anderson 2002) to identify the best variance-covariance matrix for our data. We considered all models within $< 4\ \Delta$AIC as possible matrices. We had no reason to assume that male or female bobwhite chicks grow at the same rates. We used gender as a fixed effect in the model to account for any potential differences. Our random effect was subject (individual bird) and our fixed effects were feed type and gender. We tested for interactions between feed type and week after adjusting for gender. We calculated means and confidence intervals for feed type by week interaction to interpret the effect of feed on bobwhite growth for each week. We compared the masses of our bobwhites to the adult mass of bobwhites from 4 different states based on review of the literature. Adult bobwhite mass of Illinois bobwhites is 178 ± 0.52 g SE ($n = 847$ bobwhites; Roseberry and Klimstra 1971), adult mass of Kansas bobwhites is 186 ± 1.03 g SE ($n = 368$ bobwhites; Robel 1969), Oklahoma adult bobwhite mass was 151 g (no SE provided, $n = 136$ bobwhites; Lusk et al. 2005), and South Texas adult bobwhite mass is 158 ± 0.47 g SE ($n = 72{,}797$ bobwhites; Brazil 2006).

RESULTS

The effect of bobwhite gender on growth was not significant (Table 1). There was a significant feed type by week interaction (Table 1), and the main effects could not

Table 1. Repeated measures ANOVA of a captive northern bobwhite (*Colinus virginianus*) feed trial comparing commercially available quail supplement (24% crude protein) to a commercial nutritionally complete ration (30% crude protein) during May–October, 2009 in Kleberg County, Texas, USA.

	Repeated measures ANOVA values			
Effect	Numerator df	Denominator df	*F*	*P*
Gender	1	57	0.25	0.6194
Week	14	781	713.2	<0.0001
Diet	1	57	58.03	<0.0001
Diet by week	14	781	116.2	<0.0001

be interpreted individually. Bobwhite chicks on the 30% CP diet reached Oklahoma adult mass at week 8, South Texas adult mass at week 9, Illinois adult body mass at week 11, and Kansas adult mass at week 12 (Fig. 1). Bobwhite chicks on the 24% CP diet reached Oklahoma adult mass at week 12, South Texas adult mass at week 12, Illinois adult body mass at week 15, and did not reach Kansas adult mass (Fig. 1). Chicks on the 24% reached mean adult bobwhite mass 4–7 weeks later than chicks on the 30% CP diet. Mean bobwhite masses were similar during the first 4 weeks, differed during weeks 5–14, and converged during week 15 (Fig. 1). Growth rate peaked in weeks 4 and 5 for birds on the 30% CP diet and in week 5 for birds on the 24% CP diet (Fig. 2). Four birds on the 24% CP diet died and 3 birds on the 30% diet died. The cause of mortality for all dead birds was hen-pecking and cannibalism from the other birds in the pen.

DISCUSSION

Protein deficiencies, caused by a diet containing < 28% crude protein, can slow bobwhite chick growth (Nestler et al. 1942, Andrews et al. 1973). Nestler's study was conducted in captivity with methods similar to ours, but with a larger sample size ($n = 816$) and more treatments (5 protein levels). Bobwhites fed a 24% CP diet in our study grew at a slower rate than those fed a diet containing 30% CP protein. However, both mean weekly growth rates from our study were greater than growth rates of wild bobwhites (Lusk et al. 2005). Mean weekly growth rates were similar between diets when averaged across all weeks, but bobwhites fed the 24% CP diet reached adult mass 1–1.5 months later than bobwhites fed the 30% CP diet. The lack of adequate protein in the diet of chicks on the 24% CP diet was similar to the pattern observed by Nestler et al. (1942). They found a threshold of crude protein (> 28%) that optimized chick growth in captivity. Birds in their study had a lower growth rate and died when fed solely a low (20% CP) protein diet; body mass was lower for birds on the 20% CP diet than those on the highest protein (36%) diet (Nestler et al. 1942).

Mean weekly chick mass in our study exhibited a semi-logistic growth curve, similar to those documented by Robbins (1983) and Lusk et al. (2005). Logistic growth

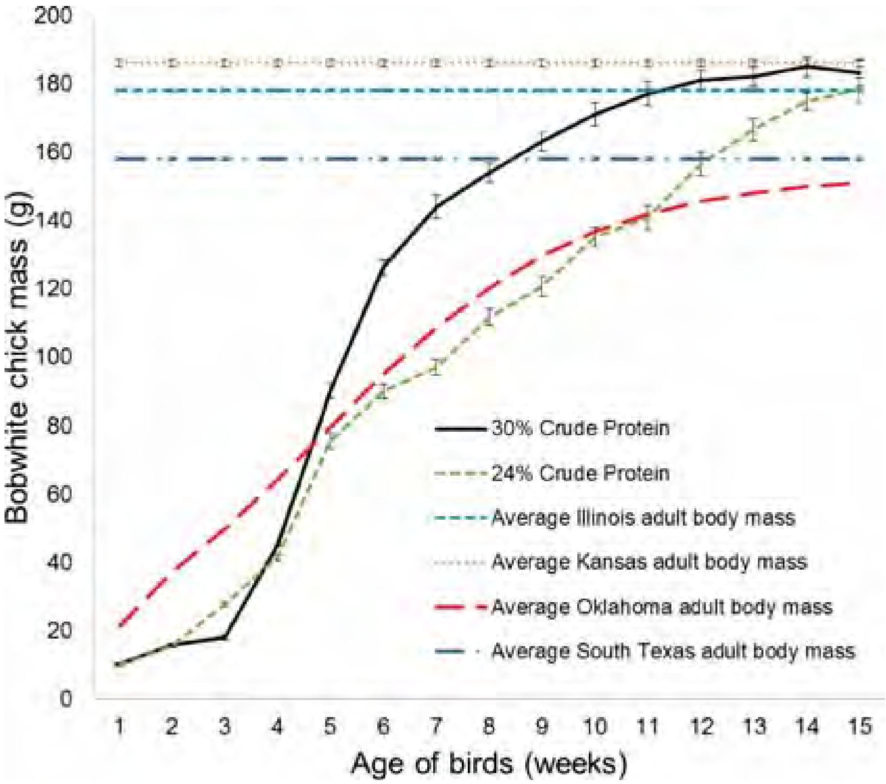

Fig. 1. Cumulative weekly mass accumulation (mean ± SE) of northern bobwhite chicks on diets with two different protein levels compared to adult bobwhite mass estimates (mean ± SE) from Kansas (Robel 1969), Oklahoma (Lusk et al. 2005), Illinois (Roseberry and Klimstra 1971), and South Texas (Brazil 2006).

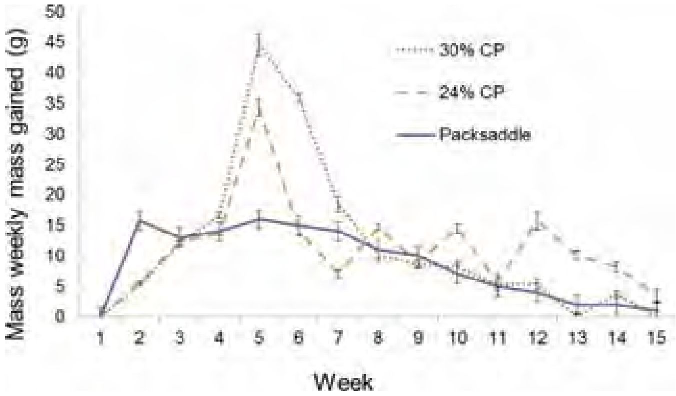

Fig. 2. Mean weekly mass gained by captive northern bobwhite chicks for diets with 2 different protein levels (30% crude protein and 24% crude protein) compared to mean weekly mass gained by wild bobwhites on the Packsaddle Wildlife Management Area, Oklahoma, USA (Lusk et al. 2005).

curves are also common in most bird species (Ricklefs 1968, 1969, 1979, 1984; Bryant and Hails 1983). Logistic growth curves have been documented in other captive bobwhite chick growth studies (Nestler et al. 1942, 1945; Andrews et al. 1973; Blem and Zara 1980; Lochmiller et al. 1993). This growth curve is similar in (both wild and captive) red grouse (*Lagopus lagopus scotica*; Park et al. 2001), dusky (blue) grouse (*Dendragapus obscurus*; Stiven 1961), gray partridge (*Perdix perdix*; Potts 1986), and greater sage-grouse (*Centrocercus urophasianus;* Johnson and Boyce 1990).

Chicks on both diets had a higher growth rate than wild bobwhite chicks documented by Lusk et al. (2005) on the Packsaddle Wildlife Management Area in Oklahoma; however, the difference only lasted 1–3 weeks depending on feed type. Additionally, chicks in our study grew, on average, 4–6 times faster than imprinted bobwhites in Florida on the Tall Timbers Research Station (Palmer et al. 2001). The *ad libitum* feeding and the controlled environment of our captive study likely explain their faster growth. Bobwhites in commercial game farms, such as those used in this study, are selectively bred to grow faster than wild birds to improve profit and decrease time from hatch to market. Our use of commercially-farmed bobwhite chicks may have biased the growth rates compared to wild growth rates. Chicks in the wild must hunt for arthropods, avoid predators, and thermoregulate through cold nights—rather than consume feed from a trough in a temperature-controlled environment—resulting in higher metabolic costs and slower growth rates in wild birds. We believe the 30% CP would increase the likelihood that more bobwhites will attain adult body mass quickly, and then move to a plant-based diet enabling higher rates of survival in times of low arthropod abundance relative to the 24% CP ration. Making a direct connection between captive and wild bobwhite chicks is one that cannot be made without caution. Wild bobwhites need a high amount of protein in their first 2 months of life, but assuming that chicks get all of their protein from supplemental feed is not likely true in wild populations.

MANAGEMENT IMPLICATIONS

Managers who wish to provide supplemental feed in times of food stress should provide the 30% CP ration because wild conditions require higher energetic costs due to thermoregulation, predator avoidance, and foraging caloric needs, based on our results. However, wild birds will presumably be foraging for natural foodstuffs and likely do not need a complete ration. A true field test of the 24% and the 30% CP ration using truly wild bobwhite chicks is needed to make inferences about effects of supplemental feed on their growth and the role of supplemental feed in their overall diet.

ACKNOWLEDGMENTS

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LITERATURE CITED

Andrews, T. L., R. H. Harms, and H. R. Wilson. 1973. Protein requirement of the bobwhite chick. Poultry Science 52:2199.

Bell, G. P. 1990. Birds and mammals on an insect diet: a primer on diet composition analysis in relation to ecological energetics. Studies in Avian Biology 13:416–422.

Blem, C. R., and J. Zara. 1980. The energetics of young bobwhite (*Colinus virginianus*). Comparative Biochemistry and Physiology Part A: Physiology 67:611–615.

Borchelt, P., and R. K. Ringer. 1973. Temperature regulation development in bobwhite quail (*Colinus virginianus*). Poultry Science 52:793.

Brazil, K. B. 2006. Northern bobwhite productivity and habitat relationships in South Texas. Thesis. Texas A&M University–Kingsville, USA.

Brennan, L. A. 1999. Northern bobwhite (*Colinus virginianus*). The birds of North America. Number 397.

Brennan, L. A. 2007. South Texas climate 2100: potential ecological and wildlife impacts. Pages 79–90 in J. Norwine and K. John, eds. The changing climate of South Texas: problems and prospects, impacts and implications. CREST-RESSACA. Texas A&M University– Kingsville, USA.

Bryant, D. M., and C. J. Hails. 1983. Energetics and growth patterns of three tropical bird species. Auk 100:425–439.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer-Verlag, New York, USA.

Butler, D. A. 2007. The role of invertebrates in the diet, growth and survival of northern bobwhite, *Colinus virginianus*, chicks in the southeastern United States. Dissertation. Liverpool John Moores University, Liverpool, United Kingdom.

Guthery, F. S. 2000. On bobwhites. Texas A&M University Press, College Station, USA.

Guthery, F. S. 2002. The technology of bobwhite management: the theory behind the practice. First edition. Iowa State University Press, Ames, USA.

Guthery, F. S., T. L. Hiller, W. H. Puckett Jr., R. A. Baker, S. G. Smith, and A. R. Rybak. 2004. Effects of feeders on dispersion and mortality of bobwhites. Wildlife Society Bulletin 32:1248–1254.

Haines, A. M., F. Hernández, S. E. Henke, and R. L. Bingham. 2004. Effects of road baiting on home range and survival of northern bobwhites in southern Texas. Wildlife Society Bulletin 32:401–411.

Handley, C. O. 1931. Food of the young. Pages 113–165 *in* H. L. Stoddard, ed. The bobwhite quail: its habits, preservation and increase. Charles Scribner's Sons, New York, USA.

Hawkins, B. A., and M. Holyoak. 1998. Transcontinental crashes of insect populations? American Naturalist 152:480–484.

Hernández, F., and F. S. Guthery. 2012. Beef, brush, and bobwhites: quail management in cattle country. Texas A & M University Press, College Station, USA.

Hurst, G. A. 1972. Insects and bobwhite quail brood habitat management. Proceedings of the National Bobwhite Quail Symposium 1:65–82.

Johnson, G. D., and M. S. Boyce. 1990. Feeding trials with insects in the diet of sage grouse chicks. Journal of Wildlife Management 54:89–91.

Lehmann, V. W. 1984. Bobwhites in the Rio Grande Plain of Texas. Texas A&M University Press, College Station, USA.

Lochmiller, R. L., M. R. Vestey, and J. C. Boren. 1993. Relationship between protein nutritional status and immunocompetence in northern bobwhite chicks. Auk 110:503–510.

Lusk, J. J., F. S. Guthery, S. A. Cox, S. J. DeMaso, and A. D. Peoples. 2005. Survival and growth of northern bobwhite chicks in western Oklahoma. American Midland Naturalist 153:389–395.

Lyssy and Eckel Feeds. 2012. Quail Breeder 24 brochure. Poth, Texas, USA. www.lefeeds.com/Brochures/QuailFeed2.pdf

Nestler, R. B. 1949. Nutrition of bobwhite quail. Journal of Wildlife Management 13:342–358.

Nestler, R. B., W. W. Bailey, and H. E. McClure. 1942. Protein requirements of bobwhite quail chicks for survival, growth, and efficiency of feed utilization. Journal of Wildlife Management 6:185–193.

Nestler, R. B., L. Llewellyn, and M. Benner. 1944. Wartime diet for growing bobwhite quail. Journal of Wildlife Management 8:211–218.

Nestler, R. B., L. M. Llewellyn, and M. J. Rensberger. 1945. Comparison of animal and plant proteins for young pen-reared bobwhite quail. Journal of Wildlife Management 9:274–279.

Palmer, W. E., M. W. Lane II, and P. T. Bromley. 2001. Human-imprinted northern bobwhite chicks and indexing arthropod foods in habitat patches. Journal of Wildlife Management 65:861–870.

Park, K. J., P. A. Robertson, S. T. Campbell, R. Foster, Z. M. Russell, D. Newborn, and P. J. Hudson. 2001. The role of invertebrates in the diet, growth and survival of red grouse (*Lagopus lagopus scoticus*) chicks. Journal of Zoology 254:137–145.

Potts, G. R. 1986. The partridge: pesticides, predation and conservation. Sheridan House, London, United Kingdom.

Ricklefs, R. E. 1968. Patterns of growth in birds. Ibis 110:419–451.

Ricklefs, R. E. 1969. Preliminary models for growth rates in altricial birds. Ecology 50:1031–1039.

Robbins, C. T. 1983. Wildlife feeding and nutrition. Academic Press. San Diego, California, USA..

Ricklefs, R. E. 1979. Patterns of growth in birds. V. A comparative study of development in the starling, common tern, and Japanese quail. Auk 96:10–30.

Ricklefs, R. E. 1984. The optimization of growth rate in altricial birds. Ecology 65:1602–1616.

Robel, R. J. 1969. Food habits, weight dynamics, and fat content of bobwhite in relation to food plantings in Kansas. Journal of Wildlife Management 33:237–249.

Roseberry, J. L., and W. D. Klimstra. 1971. Annual weight cycles in male and female bobwhite quail. Auk 88:116–123.

Smith, K. G. 1982. Drought-induced changes in avian community structure along a montane sere. Ecology 63:952–961.

Stiven, A. E. 1961. Food energy available for and required by the blue grouse chick. Ecology 42:547–553.

Utz, K., J. P. Carroll, and S. J. Moreby. 2001. Comparison of northern bobwhite chick crop and fecal analyses. Proceedings of the National Quail Symposium 5:225–228.

Varley, G. C., G. R. Gradwell, and M. P. Hassell. 1973. Insect population ecology: an analytical approach. University of California Press, Berkeley, USA.

Wood, K. N., F. S. Guthery, and N. E. Koerth. 1986. Spring-summer nutrition and condition of northern bobwhites in South Texas. Journal of Wildlife Management 50:84–88.

APPENDIX. Feed tag information for a feed trial comparing a new, commercially available quail supplement (Lyssy and Eckel Foods' Quail Breeder 24 [24% crude protein in captive trial]) to a commercial nutritionally complete ration (Purina Mills Show Turkey Chow; denoted 30% crude protein in captive trials) during May–October 2009 in Kleberg County, Texas, USA.

	Feed type	
	Quail Breeder 24	Show Turkey Chow
Crude protein, % (min)	24.0	30.0
Lysine, % (min)	1.0	1.4
Methionine, % (min)	0.7	0.6
Crude fat, % (min)	3.0	3.0
Calcium, % (Ca) (min)	1.0	1.2
Calcium, % (Ca) (max)	1.2	1.7
Phosphorus, % (P) (min)	1.0	0.8
Salt, % (Na Cl) (min)	0.3	0.1
Salt, % (Na Cl) (max)	0.5	0.5

PREFERENCE AND NUTRITION OF QUAIL BREEDER 16™, COMMON AGRICULTURAL FEEDS, AND A MIX OF NATIVE SEEDS AS NORTHERN BOBWHITE FOOD

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ABSTRACT

Agricultural feeds are commonly dispersed along roads or in openings as an attractant or dietary supplement for northern bobwhites (*Colinus virginianus*). Quail Breeder 16™ is a pelletized ration specifically developed by Lyssy & Eckel Feeds for breeding bobwhites to maximize nutritive content of diets. Captive bobwhites were used to examine relative preference of the pellets, sorghum, corn, soybean, and a mix of seeds of 8 native plant species. Protein, fat, acid detergent fiber, gross energy, and mineral content of the feeds were measured and we examined changes in body mass of bobwhites fed exclusive diets of each of the five feeds. A Latin rectangle experimental design with single and multiple-offer treatments was used to compare feed preference. Sorghum was most highly preferred in both the single and multiple offering experiments. Soybeans and the pelletized ration were least preferred. The native seed mix and corn were intermediate in preference. Nutritionally, soybeans had the highest protein (40%), highest fat (19%), and highest gross energy (21 kJ/g). Bobwhites fed exclusive diets of the native seed mix exhibited the greatest increase in body mass (40%), and birds fed the sorghum diet had the greatest decrease in body mass (–8%). Providing supplements (pelletized rations and agricultural feeds) should not take precedence over managing bobwhite habitat to produce a variety of native grasses and forbs when improving bobwhite nutrition is a management objective.

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Key words: *Colinus virginianus*, Latin rectangle, northern bobwhite, nutrition, Quail Breeder 16™, relative preference, supplement

INTRODUCTION

Many landowners and wildlife managers use commercially available foodstuffs as a nutritional supplement or to attract northern bobwhites (Doerr 1988, Guthery et al. 2004). This practice is widespread in Texas (Guthery et al. 2004). The concept behind supplemental feeding via feeding stations or scattered seeds and pellets is to provide a food source additional to the natural foods available to bobwhites. The objective of supplemental feeding is often to increase survival or reproduction, thus increasing bobwhite density via improved body condition (Doerr 1988). Dispersing feed along roadsides or in openings to attract bobwhites also is used with the goal of concentrating and making locating bobwhites easier, thus providing hunters with more opportunities for harvest (Guthery et al. 2004).

Supplemental feeding may be advantageous as a management tool when food is limiting. Survival rates of bobwhites in western Oklahoma were greater (6-fold and 2-fold, respectively, for 1992–1993 and 1993–1994) in areas with supplemental feeders than in areas without supplemental feeders during 2 winters (Townsend et al. 1999). Population densities were also greater for bobwhites (fed sites averaged 3.8 ha less/bird than unfed sites) in Florida offered supplemental feed when natural food supplies were limiting (Frye 1954). Bobwhite hen survival (8% greater), chick production (0.2 more hatches/

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hen), and fall densities (1.7 more birds/ha) were greater on sites with supplemental food than sites without feed from 2001 through 2006 in southwest Georgia and northwest Florida (W. E. Palmer, Tall Timbers Research Station, unpublished data). Supplemental feeding may be effective during periods of limited food availability, such as during drought or colder months, in increasing survival of bobwhites (Frye 1954, Townsend et al. 1999, Doerr and Silvy 2002). However, results of other studies (Kane 1988, DeMaso et al. 2002) in Texas have shown no increase in abundance of bobwhites with access to supplemental feed, and supplemental feeding had little or no effect on survival or abundance.

Quail Breeder 16™ is a pelletized feed developed by Lyssy & Eckel Feeds (Poth, TX, USA) to provide breeding bobwhites (i.e., laying hens) with supplemental nutrition to maximize reproduction. Our objectives were to examine: (1) relative use of Quail Breeder 16™ compared to other common supplemental feeds and a mix of native forb and grass seeds, (2) nutritional quality of Quail Breeder 16™ compared to other common supplemental feeds and a mix of native forb and grass seeds, and (3) temporal changes in body mass of hatchery-produced bobwhites fed exclusive diets of Quail Breeder 16™, other common supplemental feeds, and a mix of native forb and grass seeds.

STUDY AREA

The research was conducted in the Duane M. Leach Research Aviary at the Tio and Janell Kleberg Wildlife Research Park, Texas A&M University-Kingsville, Texas, USA.

METHODS

Pre-experimental Period

We selected five feed types (treatments) for this experiment: whole corn, sorghum, soybeans, Quail Breeder 16™, and a mixture of native forb and grass seeds. The native mix was comprised of seeds of pigweed (*Amaranthus palmeri*), common sunflower (*Helianthus annuus*), wooly croton (*Croton capitatus*), partridge pea (*Chamaecrista fasciculata*), red prickly poppy (*Argemone sanguinea*), switchgrass, (*Panicum virgatum*), plains bristlegrass (*Setaria leucopila*), and Texas signaltop (*Urochloa texana*). We selected these species because they are commonly eaten by bobwhites in southern Texas (Lehmann and Ward 1941, Campbell-Kissock et al. 1985, Wood 1985, Larson et al. 2010) and were commercially available. These seeds were mixed at a rate of 3:1 forb to grass seeds (Fig. 1).

We purchased 125 adult bobwhites from a privately-owned hatchery in San Antonio, Texas, USA. Hatchery-produced birds, fed only commercial diets, were used so there was no prior exposure to any of the feeds used in the experiment (Barras et al. 1996). Each bird was weighed, banded with tarsal leg bands, and housed communally in groups of 10–12 by gender. We provided the birds with a commercial, pelletized upland gamebird feed *ad libitum* for 4 weeks before the first feeding trial (Barras et al. 1996). Fresh water and grit were provided *ad libitum* during the pre-experimental period. All protocols for this research were approved by the Texas A&M University-Kingsville Animal Care and Use Committee (# 2007-10-26).

We randomly selected 30 of the 125 bobwhites (15 males and 15 females) for the feeding trials and randomly selected 6 (3 males and 3 females) of those 30 birds for each of 5 experimental groups. We measured and recorded body mass of each bobwhite before assigning them to pens. Birds were housed individually in 1.5 × 1.8 × 2.1-m pens, alternating male and female by pen, and consecutively by pen, according to group assignment. Pens were cleaned daily and disinfected with a bleach solution weekly.

Experimental Period

Feed Preference.—We used a Latin rectangle design for each of 3 blocks (repetitions in time) in which each group of 6 birds experienced each treatment once in each block (Barras et al. 1996). We provided each of 5 groups of bobwhites with 5 randomly assigned, single-offering treatments (5 diets × 5 groups of bobwhites × 3 24-hr repetitions in time) and 5 randomly assigned, multiple-offering treatments once for each block (5 combinations of 4 feeds × 5 groups of bobwhites × 3 repetitions in time). Single-offering treatments consisted of 25 g of 1 feed type. The subsequent multiple-offering treatment was comprised of 25 g of each of the 4 feed types not offered during the previous single-offering treatment. We placed each of the food containers used during the multiple-offerings in the pens spaced evenly apart to provide unhindered availability and access from all sides of the container.

We alternated single and multiple-offerings daily (24 hrs). Maintenance rations to prevent malnutrition were provided to all groups upon collection of multiple-offerings for 24 hrs, after which the next treatment was provided. Each group received a different treatment during each trial (24-hr feeding period). We provided feed in 3.5 × 12.5 × 12.5-cm plastic containers. We offered treatments at 0700 hrs during each feeding period. We collected all remaining feed after 24 hrs elapsed from the time feed was provided and stored it for reweighing. Subsequent treatments were offered immediately following the collection. The feed that was collected after treatment offerings was reweighed and differences from the original mass were recorded, providing the amount consumed. We weighed each bird weekly to monitor body mass and to protect against malnutrition (Barras et al. 1996). Any loose bird waste was collected and removed during collection of feed. The floors of each pen were cleaned with water and a mild bleach solution during collection times every 7 days from the start of the feeding trials.

A graduated cylinder (mL), fine sand, and feeds provided in the experiment were used to convert mass of seed to volumes (Inglis and Barstow 1960). We weighed

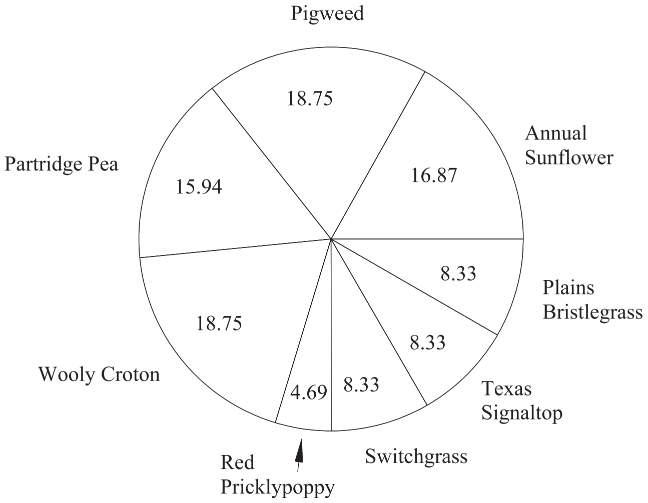

Fig. 1. Percentage of each seed species by mass (g) in a native seed mix fed during northern bobwhite feeding preference trials.

10 samples of each feed to obtain samples of 1 g each to calculate means for the 10 sample volumes of each feed to calculate average volume for 1 g of each species. The graduated cylinder was filled with 10 mL of sand and a 1-g sample of feed was placed in the graduated cylinder. The sand and feed were thoroughly mixed to ensure the sand occupied all interstitial space. The difference between the total volume of the sand and feed mixture and the initial 10 mL of sand was recorded. We repeated this process 9 times for a total of 10 volumes for each feed. We converted the mass of feed consumed in each feeding trial using the corresponding 1-g conversion factors and statistically compared volumes consumed. Volumes are expressed as cubic centimeters (cc) (1 mL = 1 cc).

We analyzed data with a repeated measures analysis of variance using the PROC MIXED procedure in SAS Version 9.1 (SAS Institute 2006). The dependent variable was daily consumption of food (g and cc) and the independent variable was diet (single feed or combinations of seeds of 4 feeds). Diet was the fixed factor and the birds were random factors. Tukey's Studentized Range (HSD) test was used to compare consumption means (SAS Institute 2006).

We measured gross energy, fat content, protein, and acid detergent fiber (ADF) for each feed. We randomly selected 25 subsamples (5 g) of feed from each source (bag) and thoroughly mixed each one. We ground the subsamples from each feed and thoroughly mixed the ground contents. We randomly took subsamples (5 g) of the mixed, ground contents until we had 50 g of each feed and then oven-dried the samples for the assays. Duplicates for each feed were tested in each assay and the mean was used. Gross energy of each feed was obtained using a Parr oxygen bomb calorimeter (Parr Instrument Company, Moline, IL, USA). Fat content was measured using an ANKOM XT10 Extractor© (Ankom 2010). Protein and mineral content (Appendix) were measured by the Soil, Water, and Forage Testing Laboratory of the Department of Soil and Crop Sciences of the Texas AgriLife Extension Service in College Station, Texas, USA (Soil, Water, and Forage Testing Laboratory 2010). Acid detergent fiber (ADF) was measured following Goering and Van Soest (1970). Inferences regarding chemical composition of each feed are limited to those feeds used in this study because only one source of each feed was used.

Body Mass Change.—We examined body mass changes of birds fed exclusive diets of each feed type after preference trials were completed. We randomly selected 60 birds, 30 males and 30 females, not used in the previous preference trials for use in this experiment. We randomly assigned 2 birds of the same gender to each of 30 pens and weighed each bird before pen assignment. We randomly assigned each pen with a feed type so there were 6 pens assigned to each of the 5 treatments. Each pen received the assigned diet twice daily. The first portion was provided *ad libitum* at 0700 hrs and removed at 0900 hrs. The second portion was provided *ad libitum* at 1700 hrs and removed at 1900 hrs. We provided fresh water *ad libitum* daily. We weighed each bird every third day after the start of the feeding, until 12 masses were recorded for each bird. We calculated percent difference in mass from the previous mass recorded for each bird. Number of eggs laid by each treatment group was recorded.

We analyzed body mass change data with analysis of variance using the PROC MIXED procedure in SAS Version 9.1 (SAS Institute 2006). The dependent variable in analyses was overall body mass change and the independent variable was diet. Tukey's Studentized Range (HSD) test was used to compare treatment means (SAS Institute 2006).

RESULTS

Relative Preference of Agricultural Feeds Based on Mass

Sorghum was the most highly consumed feed for the single and multiple offering experiments, based on mass, with 81 and 193% greater consumption, respectively for single and multiple offering experiments, than the second most consumed feed, the native seed mix (Figs. 2, 3). Consumption of sorghum was 109% greater than corn consumption, 149% greater than Quail Breeder 16™ consumption, and 373% greater than soybean consumption for single-offering experiments. Quail Breeder 16™ and soybeans were the least consumed feeds while native mix and corn were intermediate in consumption; mean consumption of these 2 feeds was similar for single-offering experiments. Consumption of sorghum was 285% greater than corn consumption, and >1,000% greater than Quail Breeder 16™ and soybean consumption for multiple-offering experiments. Quail Breeder 16™ and soybeans were the least consumed feeds, while native mix and corn were intermediate in consumption; mean consumption of these 2 feeds was similar for multiple-offering experiments.

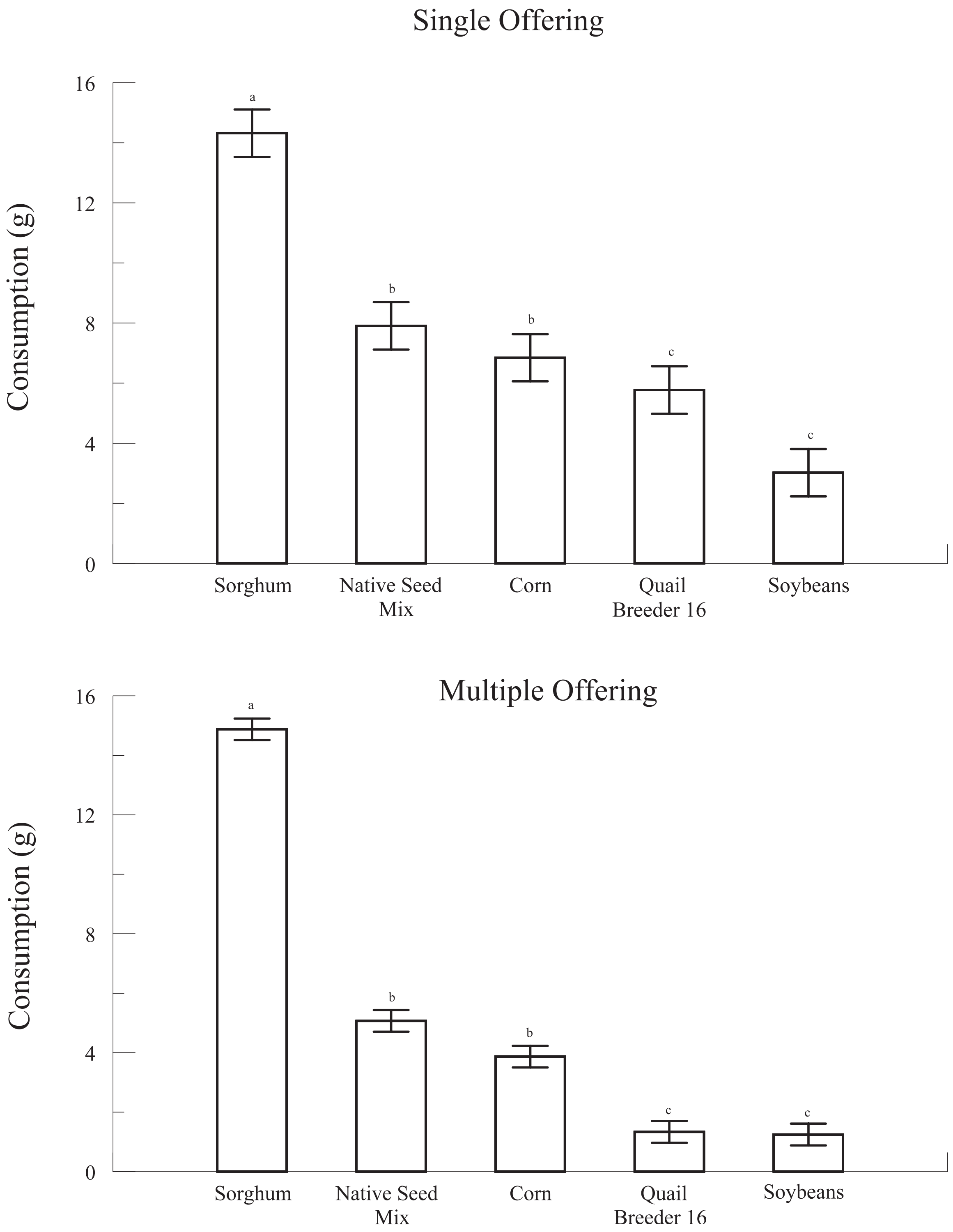

Fig. 2. Mass (g) (mean ± 95% confidence intervals) of sorghum, native mix, corn, Quail Breeder 16™, and soybeans eaten by 30 northern bobwhites during 3 single (top) and 3 multiple-offering (bottom) feeding trial periods between 26 November 2007 and 8 January 2008, Kingsville, Texas, USA. Means with unlike letters differ ($P \leq 0.05$) based on Tukey's test.

Relative Preference of Agricultural Feeds Based on Volume

Sorghum and native mix were the most highly consumed feeds when comparing diets based on volume for single-offering experiments, while soybeans were least consumed (Figs. 4, 5). Consumption of the native mix was 57% greater than Quail Breeder 16™, 66% greater than corn, and 329% greater than soybeans for single-offering experiments. Quail Breeder 16™ and corn were intermediate in consumption and mean consump-

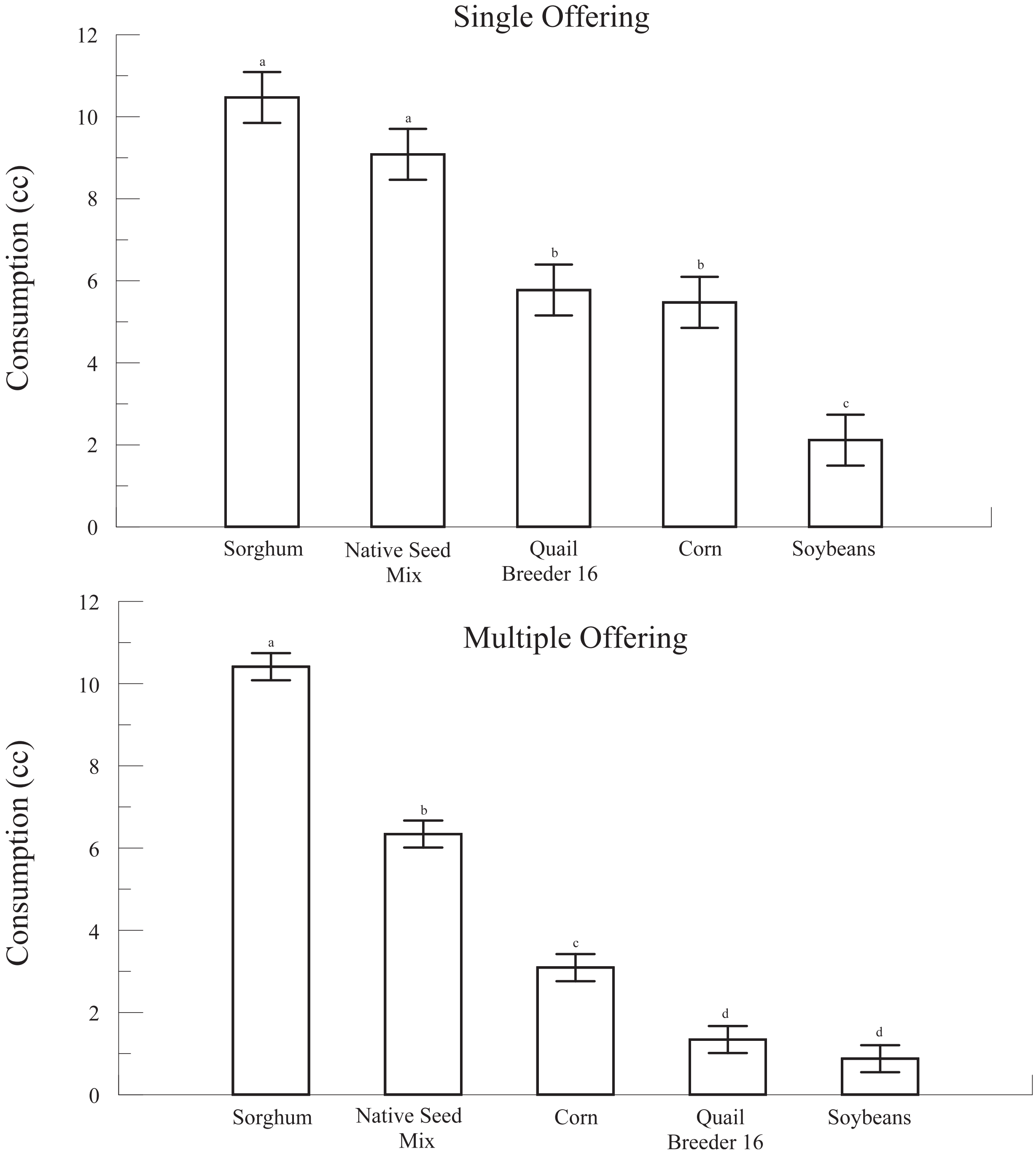

Fig. 3. Volume (cc) (mean ± 95% confidence intervals) of sorghum, native mix, corn, Quail Breeder 16™, and soybeans eaten by 30 northern bobwhites during 3 single (top) and 3 multiple-offering (bottom) feeding trial periods between 26 November 2007 and 8 January 2008, Kingsville, Texas, USA. Means with unlike letters differ ($P \leq 0.05$) based on Tukey's test.

tion of these species was similar for single-offering experiments. Sorghum was the most highly consumed feed when comparing diets based on volume for multiple-offering experiments. Consumption of sorghum was 64% greater than native mix, 237% greater than corn, 677% greater than Quail Breeder 16™, and 1,089% greater than soybeans for multiple-offering experiments. Native mix and corn were intermediate in consumption, and soybeans and Quail Breeder 16™ were least consumed feeds.

Nutritional Quality of Diets

Protein ranged from 8% in corn to 40% in soybeans (Table 1). Fat content ranged from 9% in Quail Breeder 16™ to 19% in soybeans. ADF ranged from 24% in soybeans to 29% in the native seed mix. Gross energy

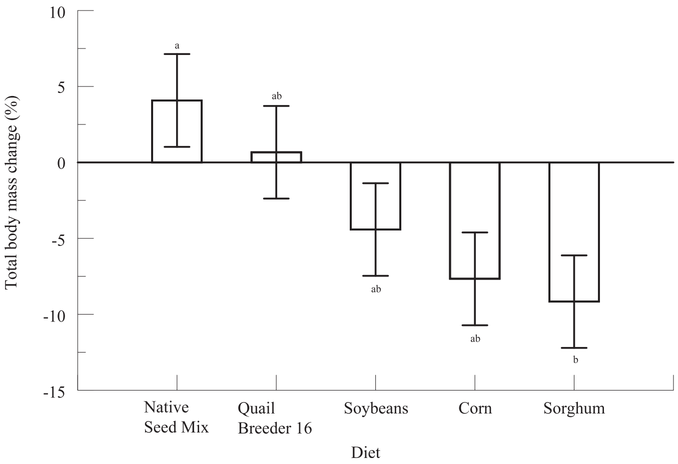

Fig. 4. Mean total body mass change (%) of 60 northern bobwhites fed exclusive diets of corn, soybeans, sorghum, a native seed mix, and Quail Breeder 16™ from 1 March to 3 April 2008, Kingsville, Texas, USA. Means with the same letter did not differ ($P \leq 0.05$) based on Tukey's test.

ranged from 14.9 kJ/g in Quail Breeder 16™ to 21 kJ/g in soybeans.

Body Mass Changes of Bobwhites Fed Exclusive Diets and Eggs Laid

Only mean body mass change for the native seed mix and sorghum differed significantly (Fig. 4). Body mass changes for bobwhites offered each treatment followed similar trends (Fig. 5). Body mass of birds in all treatments initially decreased, but increased by the second week after the experiment was initiated. Body mass then decreased but continued to increase after the third week of the experiment. Bobwhites fed exclusive diets of the native seed mix and the Quail Breeder 16™ increased in body mass compared to the first weighing period. Bobwhites fed exclusive diets of corn, sorghum, and soybeans weighed less overall than at the first weighing period. Fifteen eggs were laid for all diet treatment groups combined. Birds fed Quail Breeder 16™ laid 7 eggs while those fed the native mix laid 0. Birds fed soybeans, corn, and sorghum laid 3, 3, and 2 eggs, respectively.

DISCUSSION

Quail Breeder 16™ pellets were low to moderate in diet preference based on consumption. Lower relative preference of Quail Breeder 16™ may be explained, in part, based on its nutrient content if bobwhites in our study selected Quail Breeder 16™ to meet their nutritional requirements. Nonbreeding adult bobwhites need to consume about 250 kJ/day of metabolizable energy (ME) (Case and Robel 1974) and 11–12% protein (Nestler

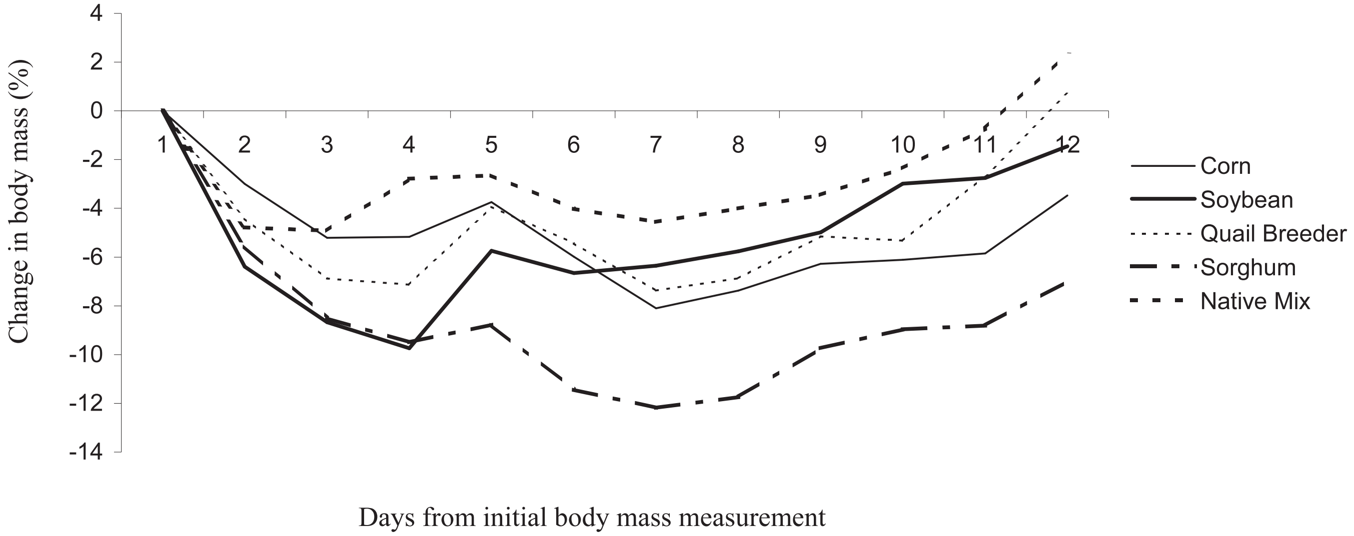

Fig. 5. Mean body mass change (%) over time for 5 groups of 12 northern bobwhites fed exclusive diets of corn, soybeans, sorghum, a native seed mix, and Quail Breeder 16™ from 1 March to 3 April 2008, Kingsville, Texas, USA.

Table 1. Protein, fat, acid detergent fiber (ADF), and gross energy for sorghum, corn, a native seed mix, soybeans, and Quail Breeder 16™.

Diet	Protein (%)	Fat (%)	ADF (%)	Gross energy (kJ/g)
Sorghum	10	11	27	16.32
Corn	8	12	26	16.74
Native seed mix	22	11	29	19.83
Soybeans	40	19	24	21.00
Quail Breeder 16™	18	9	25	14.89

1949) at 15 °C. Quail Breeder 16™ meets this protein demand, but contains the lowest gross energy value of all diets offered. A bobwhite would need to consume ~ 17 g/day of Quail Breeder 16™ even if all of the gross energy of Quail Breeder 16™ could be metabolized. Quail Breeder 16™ had the lowest gross energy and bobwhites likely consumed some other feed types in greater quantity to meet energy demands.

Bobwhite preferences for the other feeds in our experiment may be explained in part by their nutrient content. Soybeans were least preferred, based on consumption, but overall had the highest protein, fat, and gross energy. Bobwhites assimilated only 45% of energy consumed in soybeans in previous feeding trials (Robel and Arruda 1986). Bobwhites in the same study assimilated nearly 85% of energy consumed from sorghum. Similarly, bobwhites assimilated 86% of energy consumed from sorghum and 68% of energy consumed from soybeans (Robel et al. 1979). Metabolic efficiency (ME) was greater for sorghum than soybeans, but ME was greater in soybeans because gross energy was greater in soybeans (Robel et al 1979, Madison and Robel 2001). Bobwhites consumed more sorghum than soybeans (9%) in a similar study (Madison and Robel 2001). If bobwhites also exhibited greater metabolic efficiency consuming sorghum than soybeans in our study, it may explain why sorghum consumption was greater than soybean consumption based on mass for multiple-offerings.

The native seed mix was also relatively nutritious, but contained the greatest ADF. Perhaps more energy was needed to soften the native seed mix while in the crop than with other feeds, requiring bobwhites to consume more of it to meet energy demands. The relatively low nutritional value of corn may be a reason why consumption of this feed type was low to moderate, because bobwhites may have needed to consume more corn than other diets to meet energy requirements.

Palatability and relative size of each feed type may also affect preference. Sorghum was the most highly preferred food by bobwhites of 53 different foods (Michael and Beckwith 1955). The authors indicate that differences in palatability are important in food selection and olfactory senses of bobwhites aid in detecting palatability. Short-billed (mean bill length < 9.6 mm) species of North American sparrows (*Melospiza georgiana*, *Spizella arborea*, and *S. pusilla*) consumed more small seeds than large seeds (Willson 1971). All species (*Cardinalis cardinalis, Passerella iliaca, Melospiza melodia, M. georgiana, Zonotrichia albicollis, Junco hyemalis, Spizella arborea,* and *S. pusilla*) studied (mean bill length up to 14.2 mm) selected mostly small seeds (Willson 1971). Bobwhites 17 months of age and older have bill lengths ranging from 7.4 to 9.2 mm (Thompson and Robel 1968). The relatively large size of soybeans, corn, and Quail Breeder 16™ compared to sorghum and the native seed mix, may have caused bobwhites to choose diets comprised of smaller seeds. Sorghum seeds were larger than most of the seeds in the native mix, yet generally smaller than those of the other diets, resulting in a higher rate of intake efficiency.

Two parts of this study addressed the nutritional aspect of feed types used in the preference studies. First were laboratory analyses of nutrition, and second was the experiment in body mass change. Changes in body mass of bobwhites fed exclusive diets are likely due to the nutritional characteristics of each diet. Bobwhites fed the native seed mix and Quail Breeder 16™ exhibited an overall increase in body mass, while bobwhites fed sorghum exhibited the greatest overall decrease in body mass at the end of the study period. The native seed mix and Quail Breeder 16™ were the most nutritious diets based on our laboratory analyses. Birds offered the relatively low in nutrition corn and sorghum diets had the highest decreases in body mass. Factors other than nutrition that could have affected body mass changes include competition within pens, differing stress levels of birds, pen location, and initial overall health of birds studied. However, bobwhites were limited to 2 birds per pen and all birds used were in good initial general body condition to reduce potential variability of mass changes due to these other factors.

Our findings that soybeans, corn, and sorghum produced negative body mass changes at the conclusion of our study are consistent with previous research. Bobwhites fed exclusive diets of soybeans (Robel and Arruda 1986, Madison and Robel 2001), and corn and sorghum (Michael and Beckwith 1955) also had an overall decrease in body mass. An exclusive sorghum diet fed to bobwhites (Robel and Arruda 1986) resulted in an overall positive change in body mass, although it was only a 1-g increase over a 3-day period for 5 birds. Corn and grain sorghum are the most commonly supplemented feeds in south Texas for bobwhites (Brennan 2007:291), but these feeds do not possess adequate calcium, protein, or phosphorus for laying hens (Guthery 1986:53).

Female bobwhites fed only Quail Breeder 16™ laid 7 eggs during the 34-day body mass change study, which was 1 fewer than all other diets combined. This suggests Quail Breeder 16™ provides ample nutrition for the laying requirements of bobwhite hens in captivity. Egg production and differences in egg production among treatments may have been due, at least in part, to captivity bias (Lambrechts et al. 1999). Bobwhites fed only Quail Breeder 16™ had an overall increase in mass by the end of the 34-day mass change study, even with the increased energy demands of egg production for those hens that laid eggs. Hen bobwhites were likely carrying some of these eggs during weighing intervals, and body mass changes due to increased energy demands for egg production may be partially offset by the increased body mass due to the eggs. Female bobwhites fed soybeans, corn, and sorghum also laid at least 2 eggs per treatment group, and changes in body mass may have also been due to additional mass of eggs in these birds when weighed. Fresh mass of bobwhite eggs range from 8.2 to 8.8 g (Case and Robel 1974). Ovary mass in bobwhites can also increase during reproduction and has been shown to be affected by protein and energy in diets (Giuliano et al. 1996). Mean ovary mass for female bobwhites fed a high quality diet was 3% of total body mass (Giuliano et al. 1996). The effect on body mass could be significant for a 167-g hen with a 5-g ovary and an egg just prior to laying.

MANAGEMENT IMPLICATIONS

Providing Quail Breeder 16™ to supplement bobwhite nutrition when food availability is limiting could potentially increase reproduction in wild bobwhites, if they consume it in the wild. Corn, sorghum, and the native seed mix were generally more highly preferred than Quail Breeder 16™ in our study, but quail may select Quail Breeder 16™ in the wild to acquire minerals not highly available in the other 2 feeds and native food sources. Only 8 species of seeds were used in the native seed mix, whereas south Texas habitats have a greater variety of species of seed producing plants for bobwhites (Wood 1985). Bobwhites may be able to acquire nutrients or minerals lacking in the 8 native seeds used in these trials with a greater variety of foods available in the wild. Managing landscapes in South Texas to produce diverse native plant communities that provide bobwhites with ample nutritious food sources as well as the nesting, loafing, and protective cover they require, should take priority over providing supplemental feeding.

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LITERATURE CITED

Ankom. 2010. Procedures. Ankom Technologies, Macedon, New York, USA. www.ankom.com

Barras, S. C., R. M. Kaminski, and L. A. Brennan. 1996. Acorn selection by female wood ducks. Journal of Wildlife Management 60: 592–602.

Brennan, L. A., (ed.). 2007. Texas quails: ecology and management. Texas A&M University, College Station, USA.

Campbell-Kissock, L., L. H. Blankenship, and J. W. Stewart. 1985. Plant and animal foods of bobwhite and scaled quail in southwest Texas. Southwestern Naturalist 30:543–553.

Case R. M., and R. J. Robel. 1974. Bioenergetics of the bobwhite. Journal of Wildlife Management 38:638–652.

DeMaso, S. J., M. J. Peterson, J. R. Purvis, N. J. Silvy, and J. L. Cooke. 2002. A comparison of two quail abundance indices in Texas. Proceedings of the National Quail Symposium 5:206–212.

Doerr, T. B. 1988. Effects of supplemental feeding on northern bobwhite populations in South Texas. Thesis. Texas A&M University-Kingsville, USA.

Doerr, T. B., and N. J. Silvy. 2002. Effects of supplemental feeding on northern bobwhite populations in South Texas. Proceedings of the National Quail Symposium 5:233–240.

Frye, O. E. 1954. Studies of automatic quail feeders in Florida. Transactions of the North American Wildlife Conference 19: 298–315.

Giuliano, W. M., R. S. Lutz, and R. Patiño. 1996. Reproductive responses of adult female northern bobwhite and scaled quail to nutritional stress. Journal of Wildlife Management 60:302–309.

Goering, H. K., and P. J. Van Soest. 1970. Forage fiber analyses (apparatus, reagents, procedures, and some applications). USDA, Agricultural Research Service, Agriculture Handbook 379.

Guthery, F. S. 1986. Beef, brush and bobwhites: quail management in cattle country. Caesar Kleberg Wildlife Research Institute, Texas A&I University, Kingsville, USA.

Guthery, F. S., T. L. Hiller, W. H. Puckett Jr., R. A. Baker, S. G. Smith, and A. R. Ryba. 2004. Effects of feeders on dispersion and mortality of bobwhites. Wildlife Society Bulletin 32:1248–1254.

Inglis, J. M., and C. J. Barstow. 1960. A device for measuring the volume of seeds. Journal of Wildlife Management 24:221–222.

Kane, A. H. 1988. Effects of management on bobwhite habitat and density in southern Texas. Thesis. Texas A&I University, Kingsville, USA.

Lambrechts, M. M., P. Perret, M. Maistre, and J. Blondel. 1999. Do experiments with captive non-domesticated animals make sense without population field studies? A case study with blue tits' breeding time. Proceedings of the Royal Society of London, Series B 266:1311–1315.

Larson, J. A., T. E. Fulbright, L. A. Brennan, F. Hernández, and F. C. Bryant. 2010. Texas bobwhites: a guide to their foods and habitat management. University of Texas Press, Austin, USA.

Lehmann, V. W., and H. Ward. 1941. Some plants valuable to quail in southwestern Texas. Journal of Wildlife Management 5:131–135.

Madison, L. A., and R. J. Robel. 2001. Energy characteristics and consumption of several seeds recommended for northern bobwhite plantings. Wildlife Society Bulletin 29:1219–1227.

Michael, V. C., and S. L. Beckwith. 1955. Quail preference for seed of farm crops. Journal of Wildlife Management 19:281–296.

Nestler, R. B. 1949. Nutrition of bobwhite quail. Journal of Wildlife Management 13:342–358.

Robel, R. J., and S. M. Arruda. 1986. Energetics and weight changes of northern bobwhites fed 6 different foods. Journal of Wildlife Management 50:236–238.

Robel, R. J., R. M. Case, A. R. Bisset, T. M. Clement Jr., and A. D. Dayton. 1979. Metabolizable energy of important foods of bobwhites in Kansas. Journal of Wildlife Management 43:982–987.

SAS Institute. 2006. Version 9.1. SAS Institute Inc., Cary, North Carolina, USA.

Soil, Water, and Forage Testing Laboratory. 2010. Methods and method references. AgriLife Extension, Texas A&M University System, College Station, USA. soiltesting.tamu.edu/webpages/swftlmethods1209.html

Thompson, M. P., and R. J. Robel. 1968. Skeletal measurements and maceration techniques for aging bobwhite quail. Journal of Wildlife Management 32:247–255.

Townsend III, D. E., R. L. Lochmiller, S. J. DeMaso, D. M. Leslie, A. D. Peoples, S. A. Cox, and E. S. Parry. 1999. Using supplemental food and its influence on survival of northern bobwhite (*Colinus virginianus*). Wildlife Society Bulletin 27:1074–1081.

Willson, M. F. 1971. Seed selection in some North American finches. Condor 73:415–429.

Wood, K. N. 1985. Bobwhite foods and nutrition in the Rio Grande Plain of Texas. Thesis. Texas A&I University, Kingsville, USA.

APPENDIX. Mineral content (% and micrograms per milliliter [ug/ml]) of soybeans, sorghum, corn, Quail Breeder 16™, and a native seed mix used in a supplemental feed preference study with northern bobwhites.

Diet	Phosphorus (%)	Potassium (%)	Calcium (%)	Magnesium (%)	Sodium (ug/ml)	Zinc (ug/ml)	Iron (ug/ml)	Copper (ug/ml)	Manganese (ug/ml)
Soybeans	0.76	1.82	0.22	0.24	1,123	53	75	10	31
Sorghum	0.33	0.37	0.05	0.15	1,004	26	49	3	24
Corn	0.27	0.39	0.04	0.09	996	21	36	3	16
Quail Breeder 16™	0.77	0.87	4.04	0.18	2,264	128	94	22	208
Native seed mix	0.45	0.62	0.4	0.27	1,139	52	66	11	59

EFFECTS OF CARBOHYDRATE-BASED AND PROTEIN-CARBOHYDRATE RATIONS ON WILD BOBWHITE NESTING AND HARVEST DEMOGRAPHICS

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ABSTRACT

Northern bobwhite (*Colinus virginianus*) reproduction is a nutrient-intensive process. Arthropods are essential for breeding bobwhite hens and their offspring. Traditional supplemental feeding programs use corn and milo and typically neglect the protein needs of bobwhites. Commercial bobwhite rations are widely available but are seldom used in feeding programs due to high cost and lack of an appropriate supplement for field use. We compared the effect of a protein-carbohydrate ration (PC) to the effects of a carbohydrate only ration (CO) on: (1) bobwhite hen nesting demographics (clutch size, ordinal clutch initiation date, Mayfield nest survival), and (2) fall relative abundance (coveys moved/hr hunting). Nesting parameters for bobwhites based on a sample of 60 hens during the 2008 breeding season in South Texas were statistically similar based on overlap of 95% confidence intervals for both the PC and CO supplements. Mayfield nest success was high for both the PC ration (75.2%) and the CO ration (73.1%). Coveys moved during hunting (4.17 ± 14 coveys/hr in pastures with CO feed and 4.2 ± 12.5 coveys/hr in pastures with PC feed) did not differ during the 2008–2009 hunting season. The 2009 nesting season was a failure because all study animals died due to drought. Weekly Kaplan-Meier survival estimates of bobwhite hens were 6 times higher in 2008 than in 2009. The PC ration in our study provided no benefit to bobwhite populations or enhancement of wild bobwhite reproductive parameters over the CO ration. The additional cost of using PC over CO is not justified based on our results.

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Key words: *Colinus virginianus*, hens, nest success, northern bobwhite, protein, supplemental feed

INTRODUCTION

Northern bobwhite reproduction is a nutrient-intensive process. A diet consisting of $>$ 24% protein and $>$ 2.8 kcals of metabolizable energy (ME) is required for optimal reproduction in captive hens (Nestler et al. 1944b, Nestler 1949, Giuliano et al. 1996). Breeding female bobwhites tend to have higher daily energetic requirements and protein requirements than both non-breeding females and males (Guthery 1999, 2002). Hens meet their nutritional needs during the breeding season by consuming arthropods, gastropods, forbs, and seeds (Wood et al. 1986, Brennan and Hurst 1995). In South Texas, 54% ($n = 11$ crops) of a bobwhite diet was arthropods with the remainder consisting of gastropods, seeds, and fruits (Campbell-Kissock et al. 1985). The diet shifted to high-protein, green vegetation (72%; $n = 91$ crops) during late winter.

Arthropods are essential for reproduction in many Galliformes (Potts 1986), especially bobwhites. Arthropods contain $>$ 55% crude protein and $>$4.0 kcal ME/g (Bell 1990), and are the primary food source for bobwhite chicks during their first 30–60 days of life (Handley 1931, Hurst 1972). Arthropod abundance is positively related to increasing vegetation diversity, biomass, and rainfall

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(Varley et al. 1973). Bobwhite hens meet their protein needs through arthropod consumption, and low arthropod abundance can potentially reduce survival and reproduction.

Bobwhites with nutritional deficiencies in captivity produce fewer offspring than those without nutritional deficiencies. Hen bobwhites provided with 23% protein in captivity produced twice as many eggs as hens provided with 13% protein (Nestler et al. 1944b). Bobwhite hens with deficiencies in either fat or crude protein have decreased egg production (Giuliano et al. 1996). Nutritionally complete rations have been developed and used with success on game bird farms for more than 65 years (Nestler et al. 1944a, Fay 1963, McEwen et al. 1969). Studies of captive bobwhites have documented high reproduction by quail fed a complete ration (Giuliano et al. 1996, Radomski 1999), but the effect of this ration on wild bobwhite populations has not been reported.

Traditional supplemental feeding programs typically neglect the protein needs of bobwhites. Corn and milo are commonly distributed by bobwhite hunting operations in South Texas to facilitate harvest (Haines et al. 2004). Some managers believe providing these grains allows bobwhite hens to be in better body condition for reproduction (W. E. Palmer, unpublished data, Tall Timbers Research Station, http://www.talltimbers.org/gb-suppfeed.html). However, neither grain has sufficient protein for bobwhite body maintenance, much less optimal reproductive effort (Nestler et al. 1944b). Commercial bobwhite rations are widely available but are seldom used in feeding programs due to high cost.

Our objectives were to compare the effects of the PC ration to the effects of the CO ration on (1) hen nesting demographics (clutch size, ordinal clutch initiation date, percent hens nesting, nest attempts per hen, nesting season length, and Mayfield nest success), and (2) fall relative abundance (coveys moved/hr hunting). We hypothesized that: (1) bobwhite hens with access to PC would have greater clutch size, earlier ordinal clutch initiation dates, nest more readily (higher proportion of hens nesting), higher nest attempts per hen, longer nesting season, and higher Mayfield nest success than hens with access to the CO ration, and (2) pastures supplied with the PC ration would produce greater coveys moved per hour during fall hunts than pastures supplied with the CO ration.

STUDY AREA

We conducted our study during 2008 and 2009 on a private ranch, 10 km west of Falfurrias, Texas. The study area consisted of 800 ha of chaparral brush vegetation typical of the South Texas Plains ecoregion (Gould 1975). The study area was divided into 4, 200-ha pastures. Each pasture was buffered by a 200-m strip between each pasture. Each set of pastures (CO and PC) was 7 km from the other. Each pasture was randomly assigned an experimental feed type resulting in 2 pastures broadcast with CO and 2 pastures broadcast with PC. The primary vegetation community was mixed brush containing mesquite (*Prosopis glandulosa*), huisache (*Acacia farnesiana*), granjeno (*Celtis pallida*), and prickly pear (*Opuntia* spp.). The dominant grass species was seacoast bluestem (*Schizachyrium scoparium var. littorale)*. Soils on the site range from deep sand to sandy loam. The site received 42.2 cm of precipitation in April–August 2008 and 10.6 cm in April–August 2009 (U.S. Department of Commerce 2010). This site was a former livestock production ranch but has been operated as a private bobwhite hunting enterprise business since 1997.

METHODS

Ranch employees used a truck-mounted broadcast spreader to distribute feed (provided by the ranch) along feed roads spaced 450 m apart. Supplemental feed was broadcast year-round at 1-week intervals and distributed at a rate of 10 kg/ha on all pastures. Ranch employees distributed corn and milo on all surrounding pastures. We used the CO ration as a control to reduce emigration of bobwhite from the study pastures. Feed distributed on the CO sites for both years was a mix of 50% corn and 50% milo. We used a 16% protein formulated feed ration (Quail Breeder 16; Lyssy and Eckles Feed Co., Poth, TX, USA) on the PC pastures during 2008, and a 24% protein pellet (Appendix) during 2009. We used a crossover study design in which CO pastures during year 1 became the PC pastures during year 2 to mitigate potential site-specific variation. Continuous predator trapping (snares and box traps) conducted by ranch employees occurred throughout the ranch during both years of the study and was a normal ranch procedure since 1997. Ordinal clutch initiation date (number of days in a year from 1 Jan), clutch size, and nest fate were recorded for each nest. We also recorded the number of clutch laying attempts per hen, number of hens nesting per season, and nesting season length. We calculated Mayfield (1975) nest success for CO and PC pastures. Hunting guides collected data on coveys moved per hunt and the age class (juvenile or adult) of each harvested bird for the 2008–2009 and 2009–2010 hunting seasons.

Trapping and Telemetry

We trapped bobwhite hens from March to July using standard funnel traps (Stoddard 1931) baited with milo. We fit hens that had a mass > 150 g (Hernández et al. 2004) with a 5–6 g necklace-style radio package (American Wildlife Enterprises, Monticello, FL, USA) and an aluminum leg band. We monitored bobwhite hens using a 3-element Yagi antenna and a hand-held receiver (Communications Specialists, Orange, CA, USA). We located each radio-marked hen and marked the location with a hand-held Global Positioning System (GPS) unit a minimum of 2 times per week. We maintained a sample size of 15 hens per pasture ($n = 60$ hens) throughout the breeding season (Apr–Aug) and trapped as needed to replace deceased birds. Once a hen was located in the same place for > 2 consecutive tracking periods, we located her nest and recorded the UTM coordinates with a GPS. We removed transmitters from all surviving

Table 1. Bobwhite nesting parameters (Mean, 95% CI) on pastures supplied with a protein-carbohydrate (PC) ration and pastures supplied with a carbohydrate-only (CO) ration in Brooks County, Texas, USA, March–August 2008.

	Carbohydrate-only			Protein-carbohydrate		
	n	mean	95% CI	*n*	mean	95% CI
Clutch size (# eggs)	39[a]	11.7	10.7–12.7	35[a]	11.9	11.4–12.4
Clutch initiation (ordinal day)	39[a]	195	188–202	35[a]	193	185–200
Mayfield nest survival (%)	39[a]	73.1	73.1–73.2	35[a]	75.3	75.2–75.3
Nest attempts per hen (# nests)	30[b]	1.46	1.27–1.66	30[b]	1.43	1.23–1.62
Proportion of hens that nested (%)	30[b]	100		30[b]	100	

[a] Number of nests per feed type.

[b] Number of hens per feed type.

bobwhite hens in October and trapped new bobwhites in 2009.

Statistical and Survival Analyses

We pooled like feed type data for ordinal clutch initiation date (number of days from 1 Jan), clutch size, Mayfield nest survival, proportion of hens nesting, number of nests per hen, and coveys moved/hr due to relatively low sample size ($n = 30$ hens per feed type). We calculated means and 95% confidence intervals for each variable (excluding Mayfield nest survival) in R 2.10.0 (R Core Development Team 2012) and compared between feed types. Mayfield nest survival estimates and 95% confidence intervals (Johnson 1979) were calculated by hand and compared between feed types. There were no recaptured bobwhite hens in 2009 from 2008. We pooled all hens by year to compare weekly hen survival for 2008 and 2009. We calculated Kaplan-Meier survival estimates for 1 April 2008–30 June 2008 and 1 April 2009–30 June 2009 using the known fate platform in Program MARK (White and Burnham 1999). We pooled like feed type data for hunting parameters for 2008. Pastures were not hunted in 2009 due to a perceived decline in bobwhite abundance by the ranch employees.

RESULTS

Nesting Parameters

Nesting parameters (clutch size, clutch initiation date, nest attempts per hen, and number of hens nesting) were similar based on 95% confidence intervals for both the PC and CO pastures during 2008 (Table 1). All radio-marked hens ($n = 60$, 100%) had $>$ 1 nesting attempt, 45% ($n = 14$ on CO pastures, $n = 13$ on PC pastures) had $\geq$ 2 nesting attempts, and 3% ($n = 2$ on CO pastures, $n = 0$ on PC pastures) had $\geq$ 3 nesting attempts during 2008. Mayfield nest success was $>$ 71% for both feed types and was 2% higher in pastures with PC. Mayfield nest success did statistically differ between pastures, but this difference is not biologically meaningful. Hens in PC pastures had a nesting season length of 131 days and hens in CO pastures had a nesting season length of 123 days during 2008. No radiomarked hens ($n = 60$) attempted to nest, regardless of feed type, during 2009. Proportion of nests depredated was the same between feed types (26% in CO pastures, 26% in PC pastures).

Harvest and Survival Parameters

The number of coveys moved/hour hunting did not differ between feed types, during the 2008–2009 hunting season. The mean number of coveys moved/hr (± 95% CI) was slightly higher (4.17 ± 14 coveys/hr in pastures with CO feed and 4.20 ± 12.5 coveys/hr) in pastures with PC feed. The mean (± SE) number of hours hunted per pasture was 6.50 ± 0.35. Kaplan-Meier survival estimates were statistically different between 2008 and 2009 (Fig. 1). Hen survival from 1 April to 30 June during 2008 was 6 times greater than survival from 1 April to 30 June during 2009. All radio-marked bobwhites in our study during 2009 died by 7 July. We could not identify sources of mortality for all hens but the majority (63% of the mortality) was from avian (2/3 of the total predation) and mammalian (1/3 of the total predation) predators.

DISCUSSION

Nesting Parameters and Survival

Supplemental feed has not been documented to consistently increase wild bobwhite reproductive param-

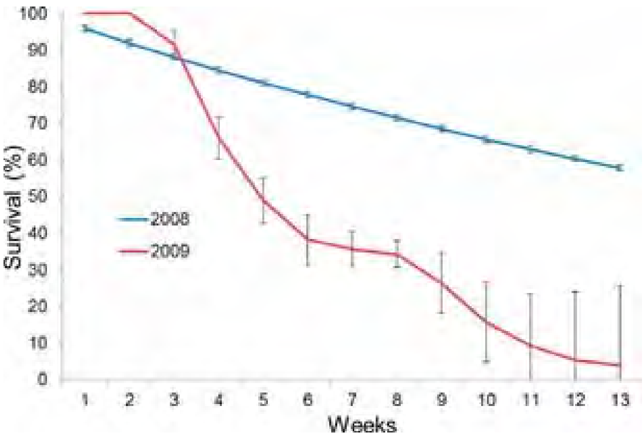

Fig. 1. Kaplan-Meier weekly survival estimates (± SE) of 60 radio-marked bobwhite hens from 1 April to 30 June 2008 and 2009 on a private ranch in Brooks County, Texas, USA.

eters (Guthery 1997, 2002). This observation was supported by our findings in 2008, and especially 2009 (i.e., none of our radiomarked birds attempted to nest). Our hypotheses—bobwhite hens with access to PC will have higher clutch size, earlier nesting dates, fewer attempts to nest, and higher nest survival than hens with access to the CO ration—were not supported by our data. We would expect, assuming nest initiation is solely nutrition-based and the PC ration improved the bobwhite hens' nutritional status prior to reproduction (by supplementing protein needs), (1) nesting to occur earlier than in pastures supplied with CO, and (2) the PC ration would ameliorate the impact of drought conditions on the vegetation community in 2009, which should have helped some bobwhites reach reproductive condition. Increasing reproductive parameters through application of a protein-carbohydrate ration was demonstrated for bobwhites during the 1999 breeding season in Florida (W. E. Palmer, unpublished data, Tall Timbers Research Station, http://www.talltimbers.org/gb-suppfeed.html). Broadcasting milo year-round and supplementing the regimen with a complete bobwhite pelleted ration during the breeding season resulted in clutch initiation 1 month earlier and 3 times better nest productivity, despite a small sample size ($n = 15$ hens); however, these results have yet to be published in peer-reviewed literature. We observed essentially no difference in our study between feed types in any reproductive parameter measured. Nest survival was slightly ($\sim$2%) higher in PC pastures than in CO pastures, but the difference is likely not biologically significant.

Bobwhite clutch size was similar in CO pastures supplied with supplemental milo and experimental pastures supplied with the PC ration. A lack of change in clutch size is consistent with other literature documenting an average clutch size of 12–14 eggs (range = 7–28 eggs/clutch; Stoddard 1931, Simpson 1972, Klimstra and Roseberry 1975, Brennan 1999). The current theory of clutch size has evolved from consensus on 4 potential hypotheses (physiology, natural selection, food limitation, and predation mitigation) into a deluge of proximate hypotheses (Lack 1947, 1954; Cody 1966; VanderWerf 1992). There has been a general agreement on Lack's third hypothesis (1954: 22), which suggests clutch size is selected for by the largest brood size for which the parents can provide food; however, some feel this is counterintuitive. Bobwhites have precocial, nidifugous chicks (Stoddard 1931, Brennan 1999), and parental investment is more intensive during egg production and development (Winkler and Walters 1983) than during brood rearing; under this hypothesis, more available crude protein may not increase clutch size.

Annual bobwhite productivity in South Texas is more heavily influenced by weather and usable space (Guthery et al. 2001, 2002; Hernández et al. 2002, 2005) than by nutrition. Nest success is a component of annual productivity, and it is likely influenced by the same factors as annual productivity (i.e., heat loads, annual precipitation, nesting cover, escape cover, etc.). Hernández et al. (2005) found that 100% of radio-marked hens nested ($n = 15$ hens) during a wet year (93 cm annual precipitation), but during a dry year (51 cm annual precipitation) $\sim$52% of radio-marked hens nested ($n = 19$ hens). Less precipitation occurred during our study—17% less during 2008 and 79% less during 2009—than the dry year documented by Hernández et al. (2005). However, the proportion of hens nesting in our study during 2008 was 2 times greater than the proportion of hens nesting documented by Hernández et al. (2005). Weather is strongly linked to bobwhite productivity (Kiel 1976, Giuliano et al. 1999, Guthery et al. 2002) and may have negated marginal benefit provided by the PC feed. The 2008 bobwhite nesting season length was 2 times longer than the dry year nesting season documented by Hernández et al. (2005); this is likely due to the abundant precipitation during July and August after the 2008 drought ceased. The nesting rate during the 2008 nesting season was most similar to rates documented by Hernández et al. (2005) during the dry year. The study area was in exceptional drought for all of 2009 (Fig. 2). The drought for South Texas was the worst since the historic drought of the 1950s and the worst drought in climate record history in the 3 neighboring counties (Rosencrans 2009).

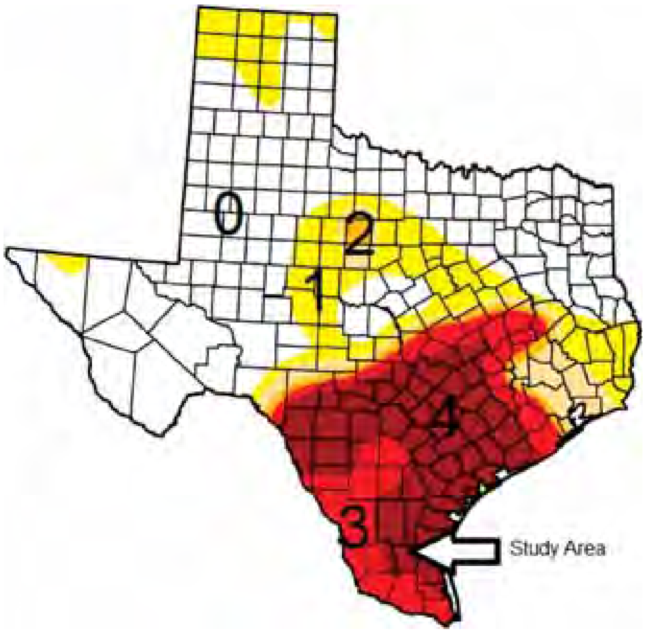

Fig. 2. Study area and severity of the 2009 Texas drought (Rosencrans 2009). The arrow points to the study area. Drought intensity ranges on a scale from 0 to 4: 0 = abnormally dry areas, 1 = moderate drought, 2 = severe drought, 3 = extreme drought, and 4 = exceptional drought.

Acknowledging our relatively small sample size ($n = 60$ hens) and short study duration (2 nesting seasons), we reported one of the highest Mayfield nest success percentages ($> 70\%$) for bobwhites. Nest success ($n = 793$ nests) was 33% (Roseberry and Klimstra 1984) in Illinois while nest success ($n = 54$ nests) in Florida was 45% (DeVos and Mueller 1993). We cannot rule out the potential effect of predator trapping in all 4 pastures;

however, we attribute the high overall nest success to the ample amount of usable space on the study site. The vegetation community was dominated by a variety of grasses and forbs with interspersed mesquite and huisache, and was managed solely for bobwhite hunting. Simulation modeling has shown that improving habitat quality (increasing usable space) rather than increasing predator control is an effective way to increase nest success of bobwhites in South Texas (Rader et al. 2011). Nest loss to predators in our study (26%) was lower than all of the reported values (37–91%) documented by Rollins and Carroll (2001).

Hunting Parameters

Supplemental feed can facilitate hunting success by localizing coveys and increasing roadside bobwhite density (Guthery 2000, Guthery et al. 2004, Haines et al. 2004). Our hypothesis—pastures with PC ration will have more coveys moved per hour during fall hunts than pastures with the CO ration applied—was not supported by our data. Coveys moved per hour was the same between feed types in our study, suggesting the commercial pellet localizes coveys with the same efficacy as traditional grains at a much higher financial cost ($0.78 USD/kg CO ration vs. $2.22 USD/kg for the PC ration). Our estimates of mean coveys moved per hour are 4 times higher than documented by Palmer et al. (2002) and result in a covey rise about every 15 min of hunting. The large 95% confidence intervals are likely due to the low number of hunts (2) on each study area.

There are at least 3 possible reasons explaining the lack of effect in bobwhite reproduction in pastures provided with the PC ration. First, bobwhite hens may not have consumed the PC ration during either year. Anecdotal hunting data show that ~95% of all harvested bobwhites from pastures supplied with the PC ration had that ration in their crops and gizzards; however, we were unable to quantify how much feed was consumed by each hen during the breeding season. Diets of bobwhites differ between seasons (Wood et al. 1986), but we assumed bobwhite hens consume an equal proportion of PC ration in the breeding season and in the hunting season. Second, the bobwhite hens were consuming the supplemental feed, but the PC ration nutrient levels were likely poor in comparison to wild arthropods. We would have expected some sort of biologically-significant effect on nesting demographics in 2 years of drought from the supplemental PC ration. There was no effect in either year. Hens did not survive sufficiently long to nest during the 2009 nesting season. Hens likely would have remained alive throughout the season and nested during times of drought if the feed was effective. Third, the short time frame of our study (2 years) may have limited the ability of the researchers to detect potential differences between the CO and PC feed. A long-term study with a larger sample size and true replication during wet and dry years to evaluate the effects of the protein feed would allow researchers to examine whether the PC ration would provide a benefit to bobwhite populations.

MANAGEMENT IMPLICATIONS

Using the PC ration to enhance wild bobwhite reproductive parameters was ineffective based on our results. Our data did not suggest the PC ration provided no benefit to bobwhite populations over the CO ration. The additional cost of using PC ration over CO is not justified based on our results.

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LITERATURE CITED

Bell, G. P. 1990. Birds and mammals on an insect diet: a primer on diet composition analysis in relation to ecological energetics. Studies in Avian Biology 13: 416–422.

Brennan, L. A. 1999. Northern bobwhite (*Colinus virginianus*). The birds of North America. Number 397.

Brennan, L. A., and G. A. Hurst. 1995. Summer diet of northern bobwhite in eastern Mississippi: implications for habitat management. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Management Agencies 49:516–524.

Campbell-Kissock, L., L. H. Blankenship, and J. W. Stewart. 1985. Plant and animal foods of bobwhite and scaled quail in southwest Texas. Southwestern Naturalist 30:543–553.

Cody, M. L. 1966. A general theory of clutch size. Evolution 20:174–184.

DeVos, T., and B. S. Mueller. 1993. Reproductive ecology of northern bobwhite in north Florida. Proceedings of the National Quail Symposium 3:83–90.

Fay, L. D. 1963. Recent success in raising ruffed grouse in captivity. Journal of Wildlife Management 26:642–647.

Giuliano, W. M., R. S. Lutz, and R. Patino. 1996. Reproductive responses of adult female northern bobwhite and scaled quail to nutritional stress. Journal of Wildlife Management 60:302–309.

Giuliano, W. M., R. S. Lutz, and R. Patino. 1999. Influence of rainfall on northern bobwhite and scaled quail abundance and breeding success. Texas Journal of Science 51:231–240.

Gould, F. W. 1975. Texas plants–a checklist and ecological summary. Miscellaneous Publication 585. Texas Agricultural Experiment Station, College Station, USA.

Guthery, F. S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 61:291–301.

Guthery, F. S. 1999. Energy-based carrying capacity for quails. Journal of Wildlife Management 63:664–674.

Guthery, F. S. 2000. On bobwhites. First edition. Texas A&M University Press, College Station, USA.

Guthery, F. S. 2002. The technology of bobwhite management: the theory behind the practice. First edition. Iowa State University Press, Ames, USA.

Guthery, F. S., C. L. Land, and B. W. Hall. 2001. Heat loads on reproducing bobwhites in the semiarid subtropics. Journal of Wildlife Management 65:111–117.

Guthery, F. S., J. J. Lusk, D. R. Synatzske, J. Gallagher, S. J. DeMaso, R. R. George, and M. J. Peterson. 2002. Weather and age ratios of northern bobwhites in South Texas. Proceedings of the National Quail Symposium 5:99–105.

Guthery, F. S., T. L. Hiller, W. H. Puckett Jr., R. A. Baker, S. G. Smith, and A. R. Rybak. 2004. Effects of feeders on dispersion and mortality of bobwhites. Wildlife Society Bulletin 32:1248–1254.

Haines, A. M., F. Hernández, S. E. Henke, and R. L. Bingham. 2004. Effects of road baiting on home range and survival of northern bobwhites in southern Texas. Wildlife Society Bulletin 32:401–411.

Handley, C. O. 1931. Food of the young. Pages 113–165 *in* H. L. Stoddard, ed. The bobwhite quail: its habits, preservation and increase. Charles Scribner's Sons, New York, USA.

Hernández, F., F. S. Guthery, and W. P. Kuvlesky Jr. 2002. The legacy of bobwhite research in South Texas. Journal of Wildlife Management 66:1–18.

Hernández, F., J. A. Arredondo, F. Hernández, D. G. Hewitt, S. J. DeMaso, and R. L. Bingham. 2004. Effects of radiotransmitters on body mass, feed consumption, and energy expenditure of northern bobwhites. Wildlife Society Bulletin 32:394–400.

Hernández, F., F. Hernández, J. A. Arredondo, F. C. Bryant, L. A. Brennan, and R. L. Bingham. 2005. Influence of precipitation on demographics of northern bobwhites in southern Texas. Wildlife Society Bulletin 33:1071–1079.

Hurst, G. A. 1972. Insects and bobwhite quail brood habitat management. Proceedings of the National Bobwhite Quail Symposium 1:65–82.

Johnson, D. H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96:651–661.

Kiel, W. H. 1976. Bobwhite quail population characteristics and management implications in South Texas. Transactions of the North American Wildlife and Natural Resources Conference 41: 407–420.

Klimstra, W. D., and J. L. Roseberry. 1975. Nesting ecology of the bobwhite in southern Illinois. Wildlife Monographs 41.

Lack, D. 1947. The significance of clutch size. Ibis 89:302–352.

Lack, D. 1954. The natural regulation of animal numbers. Oxford University Press, Ely House, London, United Kingdom.

Mayfield, H. F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456–466.

McEwen, L. C., D. B. Knapp, and E. A. Hilliard. 1969. Propagation of prairie grouse in captivity. Journal of Wildlife Management 33:276–283.

Nestler, R. B. 1949. Nutrition of bobwhite quail. Journal of Wildlife Management 13:342–358.

Nestler, R. B., L. Llewellyn, and M. Benner. 1944a. Wartime diet for growing bobwhite quail. Journal of Wildlife Management 8:211–218.

Nestler, R. B., W. W. Bailey, M. J. Rensberger, and M. Y. Benner. 1944b. Protein requirements of breeding bobwhite quail. Journal of Wildlife Management 8:284–289.

Palmer, W. E., S. D. Wellendorf, L. A. Brennan, W. R. Davidson, and F. E. Kellogg. 2002. Hunting success and northern bobwhite density on Tall Timbers Research Station; 1970–2001. Proceedings of the National Bobwhite Quail Symposium 5: 213–216.

Potts, G. R. 1986. The partridge: pesticides, predation and conservation. Sheridan House, London, United Kingdom.

Rader, M. J.**,** L. A. Brennan, F. Hernández, and N. J. Silvy. 2011. Simulating northern bobwhite population responses to nest predation, habitat and weather. Journal of Wildlife Management 75:582–587.

Radomski, A. A. 1999. Physiological ecology of northern bobwhite reproduction. Dissertation. Texas A & M University–Kingsville, USA.

R Development Core Team. 2012. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. www.R-project.org/

Rollins, D. R., and J. P. Carroll. 2001. Impacts of predation on northern bobwhite and scaled quail. Wildlife Society Bulletin 29:39–51.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, USA.

Rosencrans, M. 2009. U.S. drought monitor: Texas summer drought of 2009. National Weather Service, Climate Prediction Center, Camp Spring, Maryland, USA.

Simpson, R. C. 1972. A study of bobwhite quail nest initiation dates, clutch sizes, and hatch sizes in southwest Georgia. Proceedings of the National Bobwhite Quail Symposium 1: 199–204.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. C. Scribner's Sons, New York, USA.

U.S. Department of Commerce, National Atmospheric and Oceanic Administration. 2010. National Climatic Data Center, Louisiana State University, Baton Rouge, USA. www.ncdc.noaa.gov

VanderWerf, E. 1992. Lack's clutch size hypothesis: an examination of the evidence using meta-analysis. Ecology 73:1699–1705.

Varley, G. C., G. R. Gradwell, and M. P. Hassell. 1973. Insect population ecology: an analytical approach. University of California Press, Berkeley, USA.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 (Supplement):120–138.

Winkler, D. W., and J. R. Walters. 1983. The determination of clutch size in precocial birds. Current Ornithology 1:33–68.

Wood, K. N., F. S. Guthery, and N. E. Koerth. 1986. Spring-summer nutrition and condition of northern bobwhites in South Texas. Journal of Wildlife Management 50:84–88.

APPENDIX. Feed ingredient information for a new, commercially available quail supplement (Quail Breeder 16 [denoted PC in 2008 field trial]; Quail Breeder 24 [denoted PC in 2009 field trial]) during field trials in 2008–2009 in Brooks County, Texas, USA.

	Feed type	
	Quail Breeder 16	Quail Breeder 24
Crude protein, % (min)	16.0	24.0
Lysine, % (min)	1.0	1.0
Methionine, % (min)	0.7	0.7
Crude fat, % (min)	3.0	3.0
Calcium, % (Ca) (min)	1.0	1.0
Calcium, % (Ca) (max)	1.2	1.2
Phosphorus, % (P) (min)	1.0	1.0
Salt, % (Na Cl) (min)	0.3	0.3
Salt, % (Na Cl) (max)	0.5	0.5

CONSTRUCTION OF SPECIES-SPECIFIC PCR PRIMERS FOR DETECTION OF COCCIDIA PARASITES IN CAPTIVE-REARED NORTHERN BOBWHITES*

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ABSTRACT

Captive rearing and subsequent release of game birds, including northern bobwhites (*Colinus virginianus*), has become common in certain areas. In this practice, bobwhites are often raised in confinement to 'flight ready' and subsequently released for hunting. It is estimated that 30–40 million bobwhites are raised in captivity annually and some farms in the USA produce upwards of 1 million birds annually for this market. Raising game birds in these densities greatly facilitates the transmission of pathogenic organisms. Coccidiosis has been previously identified as an important disease in captive bobwhites and infection can lead to weight loss, diarrhea, poor feather growth, dehydration and, in severe cases, death. *Eimeria lettyae, E. colini,* and *E. dispersa* are the three described coccidia species from bobwhites. We investigated the prevalence and distribution of species of coccidia in captive bobwhite facilities throughout the United States. We collected litter or intestinal samples from 31captive bobwhite facilities originating from 13 states. Species-specific PCR primers were constructed against the internal transcribed spacer region 1 (ITS-1) of the ribosomal RNA gene of the various *Eimeria* spp. to aid in parasite detection and distinction. Primers were used to detect the specific *Eimeria* spp. in the collected samples. All 31 samples were positive for coccidia. Results of the primer survey disclosed *E. lettyae, E. dispersa*, and an unidentified *Eimeria* sp. in 20 (64.5%), 22 (72%), and 29 (93.5%) of the samples, respectively. Thirteen (41.9%) samples had 3 *Eimeria* spp. detected, 14 (45.2%) samples had 2 spp. detected, and 4 (12.9%) samples had 1 sp. detected. Flock age or geographical location was not associated with the presence of any particular *Eimeria* spp. To our knowledge, this is the first study of coccidia in captive bobwhites. Previous studies of *Eimeria* spp. in wild northern bobwhite are rare and disclosed variable prevalence rates ranging from 0 to 36%; no efforts were made to distinguish the coccidia species in these studies It would be helpful to use the species-specific primers constructed in this study to examine the prevalence and distribution of the *Eimeria* spp. in wild bobwhites from throughout their range to investigate the potential for captive-raised bobwhites to be a source of coccidiosis for wild bobwhites.

* Developed from Gerhold, R. W., L. R. McDougald, and R. B. Beckstead. 2011. Construction of pcr primers to detect and distinguish *Eimeria* spp. in northern bobwhites and a survey of *Eimeria* on gamebird farms in the United States. Journal of Parasitology 97: 892–895.

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HABITAT SELECTION BY NORTHERN BOBWHITE BROODS IN PINE SAVANNA ECOSYSTEMS

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ABSTRACT

Habitat for northern bobwhite (*Colinus virginianus*) broods is a critical component of bobwhite management. Research within pine (*Pinus* spp.) savannas has provided contradictory results regarding the value of macro-habitats with studies demonstrating selection for annually-disked fallow fields and others showing avoidance of fields and selection for burned pine savannas. Field establishment (up to 30% of a property) is a published management recommendation for bobwhites in pine savannas but there are significant annual costs with fallow-field management; information on factors that influence habitat selection by broods can improve management recommendations and facilitate weighing costs/benefits. We examined 2nd and 3rd order habitat selection by 466 broods on 3 sites during 1999–2009. All sites had similar macro-habitats (e.g., pine savanna, fallow fields, hardwood drains) but differed in soil characteristics and species composition of ground vegetation. Annually-disked fields were preferred by broods in most years on sites with predominantly grass and hardwood scrub ground vegetation. Rainfall mediated use of hardwood drains and burned upland pine savannas; hardwood drains were used more during droughts whereas burned pine savannas were used more with increased rainfall. Burned upland pine savanna was preferred on higher fertility sites in 9 of 10 years at the 3rd order level, fields were avoided or used according to availability in 8 of 10 years, and drains were avoided. Managers should consider how soil, weather, and vegetation community in pine savannas influences habitat use by bobwhite broods when identifying the value of different macro-habitats. Field establishment may or may not provide brood habitat depending on site.

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Key words: broods, chicks, *Colinus virginianus,* fields, fire, habitat use, northern bobwhite, pine, savanna

INTRODUCTION

High survival of chicks is critical to sustaining populations of northern bobwhites on managed lands; thus, creating habitat for broods is an important management consideration (Stoddard 1931, Hurst 1972, DeVos and Mueller 1993). Inadequate brood habitat, and resulting low chick survival, in bobwhite management (Burger 2001) is considered a major potential limiting factor for populations (Yates et al. 1995, Sandercock et al. 2008). Habitat for bobwhite chicks is enhanced by insect-rich herbaceous/shrub plant communities that provide cover while maintaining an open structure at ground level to facilitate foraging (Stoddard 1931, Taylor and Guthery 1994, Taylor et al. 1999). Broods also require loafing and roosting areas typically provided by woody plants, such as shrubs and vines (Taylor and Guthery 1994). Researchers in pine savanna ecosystems have shown broods select for annually-disked fields composed of annuals, such as common ragweed (*Ambrosia artemisiifolia*) or showy partridge pea (*Chamaecrista fasciculata*) (Yates et al. 1995, Carver et al. 2001). Maintaining up to 30% of pine woodlands in 1–2 ha annually-disked agricultural fields is a recurring management recommendation (Yates et al.

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1995, Michener et al. 2000, Burger 2001:139). Conversely, researchers have also found burned woodlands provide suitable brood habitat in pine savanna ecosystems (Carver et al. 2001, Hammond 2001). Creating and maintaining fields is expensive and managers should be confident fields are necessary prior to including them in land management strategies.

Vegetation types that provide suitable brood habitat for bobwhites in pine savannas may be related to soil fertility, previous land use history, timber density, and fire frequency which in turn affect groundstory plant community composition and structure (Glitzenstein et al. 2012). Information on brood habitat selection on sites that differ in respect to these properties may provide insight into habitat characteristics bobwhites select and management actions that provide suitable brood habitat under different site conditions. Rainfall interacts with soil fertility and influences plant growth after disturbance which may affect macro-habitat selection by broods. We studied brood habitat selection on 3 sites with similar habitat management practices but distinctly different 'old field' plant communities to understand the role of site-specific characteristics and precipitation on brood habitat over 4 to 10 years.

STUDY AREA

We conducted field research on Tall Timbers Research Station (TTRS), Pineland Plantation, and Sehoy Plantation. TTRS (1,568 ha) is in Leon County, Florida, and had a loblolly pine (*Pinus taeda*) and shortleaf pine (*P. echinata*) mature overstory (66%) intermixed with hardwood drains and hammocks (21%), and fallow fields (13%) 0.4 to 1.2 ha in size. Ground story communities were about equal proportions of grasses, forbs, and shrubs typical of 'old-field' plant communities (Carver et al. 2001). Herbaceous ground cover was a mix of warm season grasses and a diverse legume and forb community (Hammond 2001). Soils on TTRS are of the Fuquay-Orangeburg-Faceville series which are characterized as well-drained, moderately-fertile, fine-loam soils with varying levels of sand and clay. These soils are considered well-suited to agriculture, forestry, and pasture. Fallow fields were annually-disked in January to produce ragweed, partridge pea, and other annuals (hereafter annually-disked fields) or were undisturbed for up to 3 years to encourage development of grasses and blackberry (*Rubus* spp.). Some fallow fields were planted to longleaf pine (*P. palustris*) during the study but had vegetation characteristics similar to fallow fields and were classified as fallow fields.

Pineland Plantation in Baker County, Georgia was ~ 5,630 ha of a mixture of upland pine forests, primarily slash pine (*P. elliotti*) with intermittent live oaks (*Quercus* spp.). Each year ~ 50% of the study area was burned. Soils on Pineland are primarily Orangeburg-Lucy-Grady and Norfolk-Wagram-Grady complexes typified as sandy-loam, moderately permeable with low natural fertility. Twenty percent of the site was annually-disked fields composed primarily of ragweed. Field management has varied over the study period. Fields were harrowed in September and October, harrowed again in February, and fertilized in April to maximize growth of ragweed. Fields were no longer fertilized beginning in 2006, but some were deep plowed to break a hardpan and bring clay content to the surface to help hold moisture and promote plant vigor.

Sehoy Plantation was in northern Bullock County and southern Macon County in east-central Alabama. The study area was ~ 972 ha and was involved in an intensive quail management program for > 10 years. Soils associated with upland pine woodlands are primarily Black Belt clayey soils. Hardwood drains were associated with poorly-drained clayey and loamy soils. Loamy terrace soils were found in transitional areas between the upland and hardwood habitats. Soils are generally of low fertility and acidic with poor suitability for pasture or cultivated crops. Pine forests covered 70% of the area and were of shortleaf, longleaf, loblolly, and slash pines. Ground story communities were primarily broomsedge (*Andropogon virginicus*) as well as a variety of other bunch grasses (*Andropogon* spp.). Other evident herbaceous plants included crown grasses (*Paspalum* spp.), partridge pea, butterfly pea (*Clitoria mariana*), and a variety of *Desmodium* species. Annually-disked fields ranging from ~ 0.5 to 3 ha were composed of ragweed and made up 16% of the site. Hardwood drains (4%) were thinned prior to the study with ~ 90% of hardwoods removed. These drainages were burned each year to maintain a rich herbaceous ground cover.

METHODS

Field Procedures

Bobwhites were captured in January and March using standard walk-in funnel traps (Stoddard 1931). We assigned gender and age class, weighed each captured bobwhite, and attached a uniquely-numbered aluminum leg band (National Band and Tag Co., Newport, KY, USA). We selected 2–3 bobwhites from each captured covey to be fitted with a 6-g radio transmitter (American Wildlife Enterprises, Monticello, FL, USA and Holohil Systems Limited, Carp, ON, Canada). Trapping, handling, and marking procedures were consistent with Palmer and Wellendorf (2007) and followed the guidelines of the Tall Timbers Research Inc. Institutional Animal Care and Use Committee Permit (# GB2001-01).

Radio-marked bobwhites were located 5 times per week during the nesting season (15 Apr-1 Oct) to locate nests. We documented nesting when locations were unchanged for 2 consecutive days. Broods were located once per day after hatching until 21 days of age. Only data through 14 days of age were analyzed on Sehoy. We located radio-marked individuals with broods using homing procedures (White and Garrott 1990) and plotted locations on detailed landcover maps developed in ArcGIS (ESRI, Redlands, CA, USA). The precision of calculated locations to actual coordinates of radio-marked bobwhites was not formally tested; we thoroughly trained technicians on use of the homing technique to ensure locations were defined within at least a 30-m^2 area. We verified the correct macro-habitat landcover type (e.g., burned upland, unburned upland, field, hardwood drain) was assigned to the location.

We recorded daily rainfall totals on Pineland and TTRS but not Sehoy. We summed rainfall totals for April through June and compared these rainfall totals to habitat selection ratios for broods on these study areas.

Statistical Analyses

We computed a fixed-kernel home range for broods on TTRS and Pineland using a bivarate normal (Gaussian) kernel density estimator (HRT: Home Range Tools for ArcGIS; Version 1.1; Rogers et al. 2007) in ArcGIS 9.3. Bandwidth (*h*) was calculated for all broods using a least-squares cross-validation procedure (LSCV) for each year (Calenge 2006). Home ranges that did not converge were removed from further analysis. We estimated the median h_{lscv} value for all remaining home ranges for each year and this value was used as the bandwidth value for all home range calculations (Kenward 2001). We used a grid cell size of 10 m for the raster portion of the kernel home range procedure, which we estimated to be an appropriate scale for bobwhites, considering location resolution. We calculated a 95% volume contour from the grid that was produced, which was used in the habitat use analysis. Quail home ranges were calculated using the minimum convex polygon (MCP) method on Sehoy (Crouch 2010). We recognize that home ranges estimated using fixed-kernel method for broods on Pineland and TTRS may be larger than MCP used for broods on Sehoy (Kenward 2001). We do not believe differences in home range methodology among sites posed an issue for our study comparing habitat selection within study areas.

We categorized major habitat types on each study area to include pine woodlands burned that year, pine woodlands burned the previous year, hardwood drains, and annually-disked fields. Additional habitats on TTRS included marsh and fallow fields that were not annually disked. We followed Neu et al. (1974) using Resource Selection for Windows (Leban 1999). Second and 3rd order selection (Johnson 1980) were used to compare habitat use and availability for each year. We calculated habitat availability each year for 2nd order analysis by creating a 200-m buffered MCP polygon that encompassed all radio-marked bobwhite locations for that year. The buffered MCP was intersected with the annual landcover map to generate an overall proportion for each habitat. Second-order habitat use was defined as the proportion of each habitat type within the individual home ranges. Habitat use for 3rd order analysis was the proportion of telemetry locations within each habitat type; habitat availability was defined as the proportion of each habitat type inside the home range polygon of each brood (Neu et al. 1974). Second order analysis compared home range selection to available habitat for each individual brood and 3rd order analysis compared use of habitats to their availability within home ranges to measure habitat preference (Johnson 1980). Chi-square goodness-of-fit tests were calculated for both 2nd and 3rd order selection (Neu et al. 1974).

RESULTS

We monitored habitat use of 466 broods on 3 study sites during 1999–2009. Broods on Pineland Plantation ($n = 167$) used fields (43% of brood locations) more than pine woodlands burned that year (30% of locations) or burned the previous year (23% of locations). Annually-disked fields on Pineland were selected by broods in 8 of 9 years at the 2nd and 3rd order and used equal to availability in 1 year. Upland pine woodlands burned the previous year were avoided in 7 of 9 years at the 2nd order and used equal to availability in 2 years. Upland pine woodlands burned the previous year were avoided in 7 of 9 years at the 3rd order, selected in 1 year, and used equal to availability in 1 year. Burned pine woodlands were used less than available in 4 of 9 years and selected in 2 years at the 2nd order. Burned pine woodlands were selected in 1 of 9 years and used less than available in 6 years at the 3rd order. Amount of rainfall during April through June on Pineland was positively correlated with use of pine woodlands burned that year ($r = 0.59$, $P = 0.09$) but not use of fields ($r = -0.08$, $P = 0.83$). Brood use of pine woodlands burned that year in 2007, a severe drought year, was lowest (9% of locations) relative to other years (range = 15 to 54% use). Broods used pine woodlands burned the previous year more in 2007 (54% of brood locations) compared to other years (range = 4 to 32% use).

Broods on TTRS ($n = 240$) used pine woodlands burned that year (52% of brood locations) most followed by pine woodlands burned the previous year (27% of locations), annually-disked fields (6.2% of locations), fallow fields (5.8% of locations), and drains (2.9% of locations). Broods selected annually-disked fields in 3 of 10 years and used fields equal to availability in 7 years at the 2nd order. Broods selected annually-disked fields in 2 of 10 years and used fields equal to availability in 6 years at the 3rd order. Pine woodlands burned that year were selected in 7 of 10 years, avoided in 1 year, and used equal to availability in 2 years at the 2nd order. Pine woodlands burned that year were selected in 9 of 10 years and used equal to availability in 1 year at the 3rd order. Pine woodlands burned the previous year were avoided in 4 of 10 years and selected in 2 years at the 2nd order. Pine woodlands burned the previous year were avoided in 5 of 10 years and selected in 2 of 10 years at the 3rd order. The 2007 year had a severe drought and pine woodlands burned the previous year were selected at both the 2nd and 3rd orders. Hardwood drains were avoided in all years, except at the 2nd order in 2007 when they were used equal to their availability. Fallow fields with and without pines were selected in 6 of 10 years at the 2nd order and in 1 of 10 years at the 3rd order. Amount of rainfall was not correlated with use of fields or pine woodlands burned that spring; however, the selection ratio of hardwood drains was negatively correlated with rainfall ($r = -0.56$, $P = 0.09$).

Broods on Sehoy Plantation ($n = 59$) used annually-disked fields (37% of brood locations) most followed by pine woodlands burned the previous year (29% of locations), pine woodlands burned that year (15% of locations), and drains (14% of locations). Broods selected annually-disked fields in 3 of 4 years at the 2nd and 3rd orders. Pine woodlands burned that year were avoided in 3 of 4 years at the 2nd order and 2 of 4 years at the 3rd order. Pine woodlands burned the previous year were avoided in 1 of 4 years at the 2nd order and 3 of 4 years at the 3rd order of selection. Drains were selected in 2006 which was a severe drought year on the study area.

DISCUSSION

Habitat use and selection was variable among sites and largely consistent from year to year within sites. Differences in brood habitat selection across years but within sites were related to rainfall accumulation for a given year. Brood habitat was characterized by areas with abundant herbaceous vegetation, abundant insects, ample (20–50%) bare ground, and well dispersed woody shrubs for loafing, thermal protection, and roosting (DeVos and Mueller 1993, Burger 2001). Different soil types and vegetation communities can produce suitable brood habitat. Thus, macro-habitat selection is likely to vary depending on the suitability of the micro-habitat within a site. Suitable micro-habitat conditions on soils of moderate fertility at TTRS were provided by pine woodlands burned the same year rather than annually-disked fields. Higher clay content and fertility of the soils allowed for a relatively quick resurgence of the groundstory community after fires. Areas burned in March were used by June broods and those burned later in spring were used by broods during late summer. Broods preferred more floristically-diverse open pine woodlands and used this habitat for foraging, loafing, and roosting habitat (Hammond 2001). Preference for upland pine forests over annually-disked fields has also been observed on other properties in the Red Hills region (Hammond 2001). Brood habitat is not limiting in this landscape and the addition of fields would likely reduce the amount of useable space and potentially have a negative effect on bobwhite populations (Guthery 1997).

Annually-disked fields on sites with lower soil fertility, such as Pineland and Sehoy, were highly selected in all years except during severe drought in 2006 on Sehoy when frequently-burned hardwood drains were preferred. There is evidence that bobwhite abundance on these types of soils increases with increasing amount (up to 30%) of area in fields (Michener et al. 2000). Pine woodlands burned the same year were less suitable for broods likely due to the lower overall herbaceous groundstory. The lower soil fertility and greater sand content made these soils more drought prone and lengthened the time needed for regrowth of the understory following burning in March or April. This is supported by the correlation between early spring and summer rainfall and use of burned pine woodlands. Increased use of pine woodlands burned the same year with increasing rainfall suggests that as cover increased, so did the suitability of pine forests for bobwhite broods. Rainfall may also increase insect availability in burned pine woodlands (Wolda 1978).

Bobwhite broods on both TTRS and Sehoy Plantation shifted habitat use during periods of drought (2006 on Sehoy and 2007 on TTRS). Bobwhites shifted habitat use during periods of drought to drains or pine woodlands burned the previous year (i.e., 1 year roughs). The use of pine forests burned the previous year on Pineland Plantation also increased and use of pine forests burned that same spring was the lowest recorded during the 2007 drought. We also observed bobwhites selecting for hardwood drains and wet-weather ponds, over traditional brood habitats during the 1998 drought (Hammond 2001). Managing a diversity of macro-habitat types using fire or mechanical disturbance may be important to bobwhites during periods of stress.

MANAGEMENT IMPLICATIONS

Managers developing habitat for northern bobwhites in pine savanna ecosystems should consider how soils, vegetation community, and weather may affect the suitability of frequently-burned habitats for broods. Annually-burned woodlands on sites with moderately fertile soils supporting diverse ground cover including annual and perennial forbs, grasses, and shrubs may be the most suitable habitat. Increasing abundance of fields given these habitat conditions may actually reduce bobwhite nesting, brooding, and winter habitat provided by frequently-burned pine woodlands resulting in lower bobwhite densities. Conversely, on areas with lower fertility due to sand or acidic soil chemistry, often dominated by grasses and shrubs and relatively few forbs and legumes, annually-disked fields can be a vitally important component of brood habitat. Fields managed as brood habitat fill an important gap in the annual habitat needs for bobwhites and result in higher bobwhite densities over time. However, even when annually-disked fields are provided, our study indicates burned woodlands and hardwood drains still serve as critical habitat components, such as providing shrubs for roosting as well as additional foraging habitats. Our study also indicated that frequently burned drains can be important brood habitat during drought periods. A diversity of habitat types that are frequently burned, or disked, provides the range of habitats needed to sustain bobwhites across years and under differing weather regimes.

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LITERATURE CITED

Burger Jr., L. W. 2001. Ecology and management of northern bobwhite. Pages 122–146 *in* J. G. Dickson, ed. Wildlife of southern forests: habitat and management. Hancock House Publishers, Blaine, Washington, USA.

Calenge, C. 2006. The package *adehabitat* for the R software; a tool for the analysis of space and habitat use by animals. Ecological Modeling 197:516–519.

Carver, A. V., L. W. Burger Jr., W. E. Palmer, and L. A. Brennan. 2001. Vegetation characteristics in seasonal-disked fields and at bobwhite brood locations. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 55:436–444.

Crouch, T. L. 2010. Brood habitat use and availability and daily and seasonal covey movements of northern bobwhites in east-central Alabama. Thesis. Auburn University, Auburn, Alabama, USA.

DeVos, T., and B. S. Mueller. 1993. Reproductive ecology of northern bobwhite in north Florida. Proceedings of the National Quail Symposium 3:83–90.

Glitzenstein, J. S., D. R. Streng, R. E. Masters, K. M. Robertson, and S. M. Hermann. 2012. Fire-frequency effects on vegetation in north Florida pinelands: another look at the long-term Stoddard Fire Research Plots at Tall Timbers Research Station. Forest Ecology and Management 264:197–209.

Guthery, F. S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 61:291–301.

Hammond, A. D. 2001. Ecology and management of northern bobwhite broods in a longleaf pine-wiregrass ecosystem. Thesis. Mississippi State University, Starkville, USA.

Hurst, G. A. 1972. Insects and bobwhite quail brood habitat management. Proceedings of the National Quail Symposium 1:65–82.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65–71.

Kenward, R. E. 2001. A manual for wildlife radio tagging. Academic Press, London, United Kingdom.

Leban, F. A. 1999. Resource selection for Windows. University of Idaho, Moscow, USA.

Michener, W. K., J. B. Atkinson, D. G. Edwards, J. W. Hollister, P. F. Houhoulis, P. M. Johnson, and R. N. Smith. 2000. Habitat characteristics of northern bobwhite quail-hunting party encounters: a landscape perspective. Proceedings of the National Quail Symposium 4:173–182.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization- availability data. Journal of Wildlife Management 38:541–545.

Palmer, W. E., and S. D. Wellendorf. 2007. Effects of radio-transmitters on northern bobwhite survival. Journal of Wildlife Management 71:1281–1287.

Rodgers, A. R., A. P. Carr, H. L. Beyer, L. Smith, and J. G. Kie. 2007. HRT: home range tools for ArcGIS. Version 1.1. Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario, Canada.

Sandercock, B. K., W. E. Jensen, C. K. Williams, and R. D. Applegate. 2008. Demographic sensitivity of population change in northern bobwhite. Journal of Wildlife Management 72:970–982.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner's Sons Publishers, New York, USA.

Taylor, J. S., and F. S. Guthery. 1994. Components of northern bobwhite brood habitat in southern Texas. Southwestern Naturalist 39:73–77.

Taylor, J. S., K. E. Church, and D. H. Rusch. 1999. Microhabitat selection by nesting and brood-rearing northern bobwhite in Kansas. Journal of Wildlife Management 63: 686–694.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press Inc., San Diego, California, USA.

Wolda, H. 1978. Seasonal fluctuations in rainfall, food, and abundance in tropical insects. Journal of Animal Ecology 47:369–381.

Yates, S. W., D. C. Sisson, H. L. Stribling, and D. W. Speake. 1995. Northern bobwhite brood habitat use in south Georgia. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:498–504.

ARTHROPOD CONSUMPTION BY NORTHERN BOBWHITE CHICKS IN MANAGED TALL FESCUE MONOCULTURES

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ABSTRACT

An extensive amount of Conservation Reserve Program (CRP) habitat for northern bobwhite (*Colinus virginianus*) has been lost to planting of tall fescue (*Schedonorus phoenix*). We conducted foraging trials using human-imprinted bobwhite chicks ($n = 288$) and collected terrestrial arthropods using a customized yard vacuum to assess the effects of 3 USDA mid-contract management (MCM) cost-share practices on chick foraging rates and arthropod prey selection in 36 tall fescue-dominated CRP fields in Illinois during 2008. We applied fall strip disking, fall glyphosate spraying, and fall glyphosate spraying followed by spring legume interseeding in alternating strips to 33% of each treatment field on a 3-year rotation. Glyphosate and glyphosate-interseeding treatments provided greater brood habitat benefits for bobwhite chicks than disking and control fields. Chicks consumed a greater abundance ($P < 0.0001$) and biomass ($P = 0.0017$) of arthropods in managed fields than in unmanaged fields. Abundance and biomass of arthropods consumed by chicks were higher in glyphosate and glyphosate-interseeded strips with 1-, 2-, and 3-growing seasons post-treatment, but disking only provided this benefit for 1 growing season. Vacuum sampling provided a poor index of the availability of arthropods to bobwhite chicks, as measured by foraging of imprinted chicks. Vacuum sampling indicated arthropod abundance was greater in unmanaged than in managed fields ($P = 0.170$). Custom vacuums are not an appropriate tool for measuring the abundance of arthropods important to bobwhite chicks in tall fescue CRP. Fall strip disking is an inferior MCM practice to glyphosate-based treatments in tall fescue-dominated CRP.

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Key words: arthropod selection, brood habitat, *Colinus virginianus,* Conservation Reserve Program, disking, glyphosate, Illinois, mid-contract management, northern bobwhite, tall fescue, vacuum sampling

INTRODUCTION

Efforts are underway to restore northern bobwhite population densities to levels similar to those of the 1980s (NBTC 2011). The northern bobwhite is a culturally and economically important game bird species experiencing severe long-term population declines across most of its breeding range (Brennan 1991, Burger et al. 1999, Brennan 2002, Williams et al. 2004, Brennan and Kuvlesky 2005, NBTC 2011). Researchers suggest that availability of suitable nesting and brood-rearing habitat is limiting recovery of bobwhite populations range-wide (NBTC 2011). An extensive amount of Conservation Reserve Program (CRP) habitat for bobwhite has been lost in the Midwest and portions of the Southeast to the planting of tall fescue (*Schedonorus phoenix*). Tall fescue was popular among soil conservationists as a cover crop for CRP plantings during the early years of enrollment because of its ability to stabilize soil quickly, effectively control soil erosion, and relatively low cost (Burger et al. 2006). Tall fescue is a non-native, sod-forming, perennial grass with a dense and relatively short growth form (Barnes et al. 1995, Washburn et al. 2000). The percentage of bare ground rapidly decreases as the thatch layer density increases as tall fescue plantings age, and desirable seed-producing annual plants are out-competed (Ellis et al. 1969, Burger et al. 1990, David et al. 1995). This growth structure results in a monotypic stand of dominant grass that is impenetrable by bobwhite broods in search of arthropod prey (Fettinger et al. 2002).

Restoration efforts for northern bobwhite focus on improving nesting and brood-rearing habitat conditions

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within existing grassland-shrub communities (NBTC 2011). Emphasis in the Midwestern United States is on converting stands of introduced sod-forming pasture grasses, such as tall fescue, to mixed stands of native warm-season grasses and forbs (Ruffner and Barnes 2010). Tall fescue conversion is often limited by resource availability and is not a practice that private landowners will adopt without technical and financial assistance. Federally sponsored mid-contract management (MCM) provides CRP participants with technical and financial assistance to implement common farm practices (i.e., herbicide spraying, disking, and drill-seeding) to restore early successional plant communities in aging CRP fields for bobwhite and grassland-obligate birds. Limited information is available on the effects of specific MCM practices to improve foraging conditions for bobwhite chicks in tall fescue CRP fields.

Field experiments using human-imprinted gallinaceous chicks have been used with great success to assess habitat quality (Palmer et al 2001), wildlife-habitat interactions (Burke et al. 2008, Huwer et al. 2008), and nutrition (e.g., foraging rates, food availability, and selection of arthropod prey) (Smith and Burger 2005, Doxon and Carroll 2010). Researchers suggest that human imprinting techniques for evaluating foraging habitat quality and food availability may be superior to other standard sampling methods because imprinted chicks are more likely to sample and select arthropods that are truly available to wild chicks and will interact with environmental factors (e.g., vegetation structure) in ways similar to wild birds (Kimmel and Healy 1987, Palmer et al. 2001).

The objectives of our research were to compare the effects of 3 U.S. Department of Agriculture-approved MCM practices including: (1) fall strip disking, (2) fall glyphosate spraying, and (3) fall glyphosate spraying in combination with spring legume drill-seeding on foraging rates and arthropod prey selection of imprinted bobwhite chicks in tall fescue CRP fields in south-central Illinois.

STUDY AREA

We conducted our study in tall fescue-dominated CRP fields within Wayne, White, and Jefferson counties in south-central Illinois, USA (centered at 38° 22′ 49″ N, 88° 21′ 57″ W). The landscape was composed of 63.5% row-crop agriculture (i.e., corn, soybeans, sorghum, and winter wheat), 15.4% forested land (i.e., savanna uplands and coniferous), 12.6% agricultural grasslands (i.e., CRP grasses, hayfields, and pastures), and 8.5% wetlands, open water, and residential and commercial developments (USDA 2007a). Collectively, these counties encompassed nearly 9% (39,027 ha) of Illinois' total CRP enrollments with 5% (21,591 ha) in Wayne County alone (USDA 2007b). The majority of the CRP parcels enrolled in grassland-specific conservation practices in this region were planted to CP1 (non-native, cool-season grasses), and re-enrolled in CP10 (existing grasses and legumes) as contracts began to expire.

METHODS

Mid-contract Management

We selected 36 tall fescue-dominated CRP fields as paired plots ($n = 18$) based on similarities in vegetation structure, disturbance histories based on landowner records, and spatial proximity. We randomly assigned fields within paired plots as either treatment or control. Treatment fields were randomly assigned 1 of 3 MCM regimes. All MCM regimes were applied following USDA, Natural Resources Conservation Service (NRCS) Early Succession Habitat Development and Management Standards-647 (NRCS Standards-647; USDA 2000).

We managed 6 CRP fields with strip disking during October–November, 2005–2007 using multiple passes with an Athens 3-m wide wheel disk (Athens Plow Company, Athens, TN, USA) until 30–50% residual vegetation remained on the soil surface as required by NRCS Standards-647 (USDA 2000). We applied alternating disked strips to 33% of each treatment field annually for 3 consecutive years, and no portion of a field was managed more than once. Disked strips were 10-m wide and we left 20 m unmanaged between managed strips during the first treatment year. We disked 10-m wide strips adjacent to the managed strips during the second and third treatment years (i.e., 2007 and 2008).

We managed 12 fields with glyphosate during October–November, 2005–2007. Glyphosate was applied by 2 local agricultural service providers at a rate of 526.5 ml of Roundup Original® Max (Monsanto Company, St. Louis, MO, USA) and 476 g of ammonium sulfate/ha. We applied glyphosate in 17-m wide alternating strips and left 34 m unmanaged between managed strips. We used a 3-m wide no-till box drill (Great Plains, Salina, KS, USA) to interseed the glyphosate sprayed strips in 6 of the 12 fields annually for 3 consecutive years. We planted a legume seed mixture (Wyatt Seed Company Inc., Petersburg, IN, USA) consisting of 87.5% Korean lespedeza (*Lespedeza stipulacea maxim*) and 12.5% partridge pea (*Cassia fasciculata*) at a rate of 3.4 kg/ha.

Chick Care and Imprinting

We cared for and imprinted bobwhite chicks to humans following techniques described by Kimmel and Healy (1987), Palmer et al. (2001), and Smith and Burger (2005). All chick care, handling, imprinting, foraging trials, and crop dissection procedures followed the Southern Illinois University, Carbondale, Institutional Animal Care and Use Committee protocol (IACUC, protocol #06-011). We acquired bobwhite chicks from a licensed, commercial game bird breeder (Keith Deal Farms, Galatia, IL, USA) within hours of hatching and housed them in a 9-m^2 indoor brood-pen (1 m high). We maintained the temperature in the indoor brood-pen between 36 and 38° C using infra-red heat lamps positioned 30–60 cm above the floor of the pen. We minimized heat loss by covering the top of the pen with black roofing paper attached to a wood-framed panel. Collectively, 2 trainers spent at least 12 hrs/day in the indoor brood-pen with the chicks, handling and hand-feeding them live arthropods following Kimmel and Healy (1987), Palmer et al. (2001), and Smith and Burger (2005). We collected arthropods from nearby grasslands using sweep nets 2–3 times daily. We maintained a constant supply of water and commercial poultry food containing 28% crude protein in the indoor pen for optimum growth (Peoples et al. 1994).

We moved the chicks to a 21-m^2 outdoor brood-pen during daylight hours from 3 to 10 days of age and allowed them to forage in an area with mixed grasses and forbs. Trainers periodically walked through the outdoor brood-pen with the chicks, sounding a whistle call to expose the chicks to habitats and foraging conditions similar to the experimental foraging trials (Smith and Burger 2005). We returned the chicks to the indoor brood-pen overnight and provided them with supplemental poultry food and water. We removed all food items (i.e., live arthropods and commercial poultry food) from the indoor brood-pen 12 hrs prior to start of the experimental foraging trial to ensure passage of all undigested food items prior to the start of the trials.

Chick Foraging Trials

We conducted foraging trials during 5–8 June 2008 with chicks at 10–13 days of age in 6 fields per treatment and their paired control fields *(n* = 18 paired fields, 36 fields in total). We conducted foraging trials once per strip condition in managed fields (i.e., 1-yr, 2-yr, and 3-yr strips) and once in each paired control field. We conducted foraging trials between 0800 and 1200 hrs CST to avoid wet vegetation and cool ambient temperatures. Trainers released broods of 4 imprinted bobwhite chicks in a predetermined strip location and allowed chicks to forage for 30 min. The lead trainer traveled in front of the chicks when possible, sounding a whistle call periodically to encourage chicks to move through the vegetation patch as would an adult bobwhite with a young brood. The remaining trainers observed from 2–3 m behind or beside the chicks to minimize vegetation and arthropod disturbances and to prevent lateral movements into adjacent strips. The chicks were gathered after 30 min and euthanized by CO_2 asphyxiation, placed in zip tight freezer bags, and immediately placed on ice.

The esophagi and crops were removed from the base of the skull to the proventriculus in the laboratory, and stored in a 70% ethanol solution. Intact arthropods and body fragments were removed from these organs and identified to family taxa following Triplehorn and Johnson (2005; insects) and Kaston (1979; spiders). The individuals within a family were counted, dried at 19° C for 24 hrs, and weighed to the nearest 0.0001 g using a digital analytical balance (Thermo Fisher Scientific, Hampton, NH, USA).

Arthropod Vacuum Sampling

We used a modified, gasoline-powered yard vacuum (Echo model ES230 vacuum, Lake Zurich, IL, USA) to sample arthropods during 9–11 June 2008 at the same locations where the foraging trials were previously conducted on 5–8 June 2008. We altered 1,200 μm nylon mesh collection bags (WARD'S Natural Science, Rochester, NY, USA) to ensure a tight fit inside the intake tube of the yard vacuum (Steward and Wright 1995). We removed the manufacturer-installed shredder blade of the vacuum to prevent holes in the collection bag and subsequent loss of biological samples.

The vacuum operator walked a slow, constant pace along 2 consecutive, 5–m long linear transects at each sampling point. The operator ran the vacuum on full-power during sampling, and probed it repeatedly through the vegetation at < 60 cm above the ground surface. The contents of the nylon mesh collection bag (e.g., arthropods and grass debris) were stored in a zip tight freezer bag and frozen. We separated the arthropods from the grass debris in the laboratory, (1–4 weeks after sampling) and stored them in 70% ethanol. We identified arthropods to family, counted, dried at 19° C for 24 hrs, and weighed them to the nearest 0.0001 g.

Statistical Analyses

We used general linear mixed models (GLM) with block and nested effects to test for treatment and strip condition differences in relative abundance, dry-weight biomass, family richness, and diversity of arthropods consumed by imprinted chicks (PROC MIXED; SAS Institute, Cary, NC, USA). We included treatment and strip condition as fixed effects, and block and strip condition nested within treatment as random effects. We included the main effects and interaction terms in the model. Each brood of imprinted chicks was an experimental unit and dependent variables were averaged within broods. We tested dependent variables for normality and homogeneity of variances and applied logarithmic transformations to meet the assumptions of analysis of variance when appropriate. Significance level was set at $\alpha < 0.05$ for all analyses. *Post-hoc* pairwise comparisons with Tukey-Kramer adjustments were made among significantly different treatments and strip conditions.

We used the GLM to test for treatment and strip condition differences in relative abundance, dry-weight biomass, family richness, and diversity of arthropods collected using the vacuum sampling technique. We used a *post-hoc* Tukey-Kramer comparison when treatment differences were detected. We used compositional analysis (Aebischer et al. 1993) to test for differences between the proportion of arthropods consumed by imprinted chicks and the proportion of arthropods collected using vacuum sampling. We used BYCOMP.-SAS (Version 1.0; Ott and Hovey 1997) to perform compositional analysis. This program is designed to repeat 999 random simulations of the data, followed by a multivariate analysis of variance to calculate the significance of Wilks' lambda (Λ) from a ranked matrix of *t*-tests (Ott and Hovey 1997). We replaced missing values with 0.0001 for arthropods that were collected but not consumed by chicks.

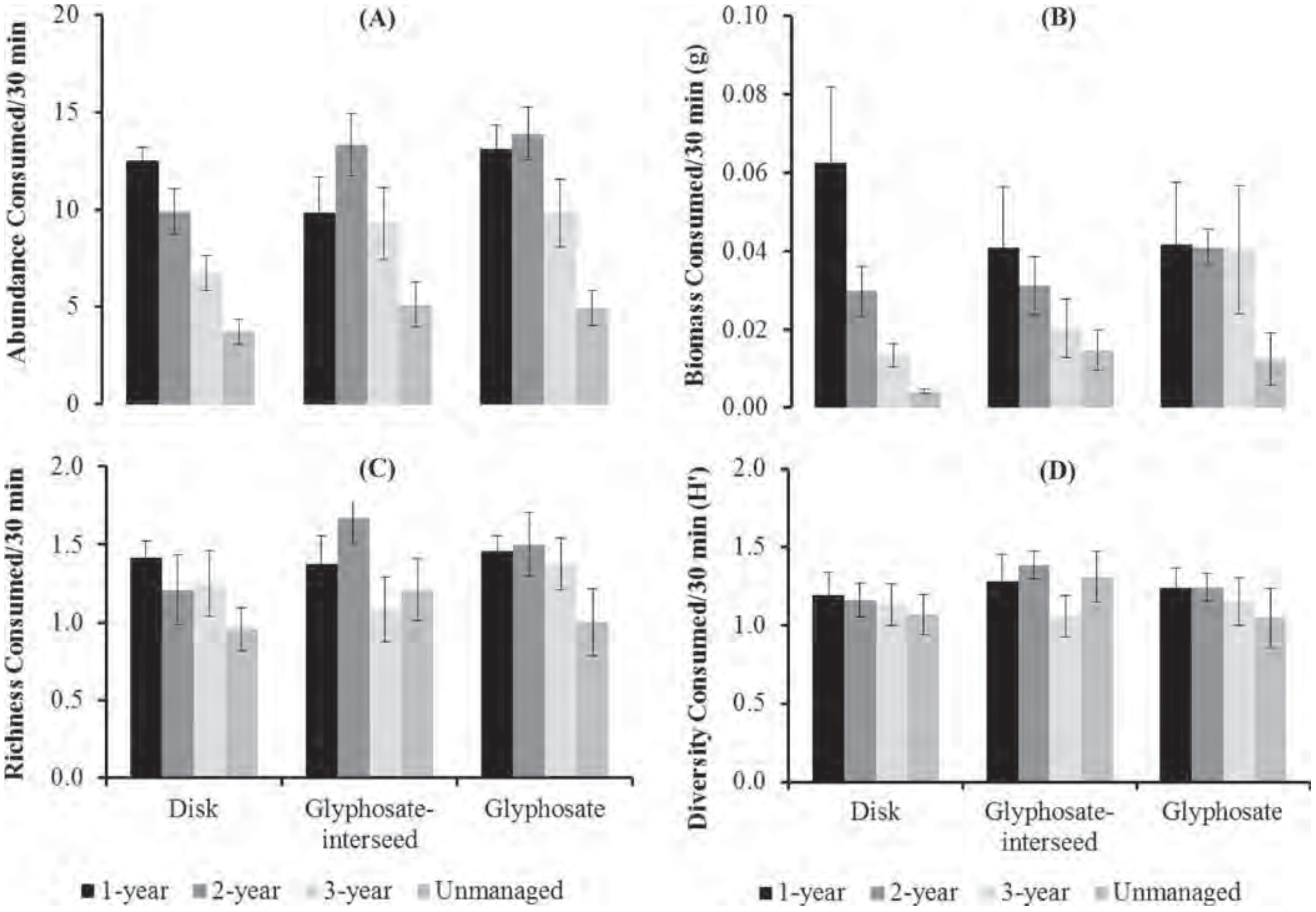

Fig. 1. Abundance, biomass, family richness, and diversity (mean ± SE) of arthropods consumed/30 min by northern bobwhite chicks during foraging trials in modified, tall fescue Conservation Reserve Program fields in south-central, Illinois, USA during 2008.

RESULTS

We conducted 72 foraging trials using 288 imprinted bobwhite chicks. Bobwhite chicks consumed 19 arthropod families. The 2 most common family taxa consumed were Formicidae (ants) and Armadillidiidae (pill bugs), followed by Oxyopidae (lynx spiders), Gnaphosidae (ground spiders), Chrysomelidae (leaf beetles), and Cicadellidae (leafhoppers).

Bobwhite chicks consumed more arthropods in managed than in unmanaged fields ($F_{3,14} = 16.02$, $P < 0.0001$). Chicks in disked fields consumed the greatest abundance of arthropods in 1-year strips, but abundance progressively decreased as the number of years post-treatment increased (Fig. 1A). Abundance of arthropods consumed by chicks in 3-year disked strips did not differ from unmanaged strips ($P = 0.4118$). Abundance of arthropods consumed in glyphosate and glyphosate-interseeded fields was greatest in 2-year strips compared to other years. Glyphosate-based treatments provided benefits for > 3 years, whereas disking provided benefits for only 2 years at most.

Biomass of arthropods consumed was greater in managed than in unmanaged fields ($F_{3,27} = 8.18$, $P = 0.0017$). Biomass did not differ among strip conditions ($F_{6,39} = 1.68$, $P = 0.1524$), but general trends indicate biomass decreased as the number of years post-treatment increased (Fig. 1B). Thus, biomass among 1-, 2-, and 3-yr glyphosate strips remained constant, and was greater compared to unmanaged strips. Family richness of arthropods consumed was greater in glyphosate and glyphosate-interseeded fields than in disked and unmanaged fields ($F_{3,14} = 3.22$, $P = 0.0286$; Fig. 1C). There were no differences in diversity of arthropods consumed among treatments ($F_{3,14} = 0.34$, $P = 0.7934$) or strip conditions ($F_{6,42} = 0.73$, $P = 0.6305$; Fig. 1D), indicating bobwhite chicks may obtain a search image or selected particular arthropod prey that are easier to capture. These data indicate chicks consumed more Formicidae than Armadillidiidae in glyphosate and glyphosate-interseeded fields, and more Armadillidiidae than Formicidae in disked fields (Fig. 2).

We collected 13,020 arthropods representing 13 Orders and 69 families from 144 vacuum samples. There was a greater abundance of arthropods in unmanaged strips than in managed strips ($F_{3,20} = 8.26$, $P = 0.0002$). Abundance of arthropods collected were marginally greater in unmanaged and disked strips than in glyphosate-based treatment strips ($F_{6,43} = 2.00$, $P = 0.0860$; Fig. 3A). Biomass was generally greater in unmanaged fields

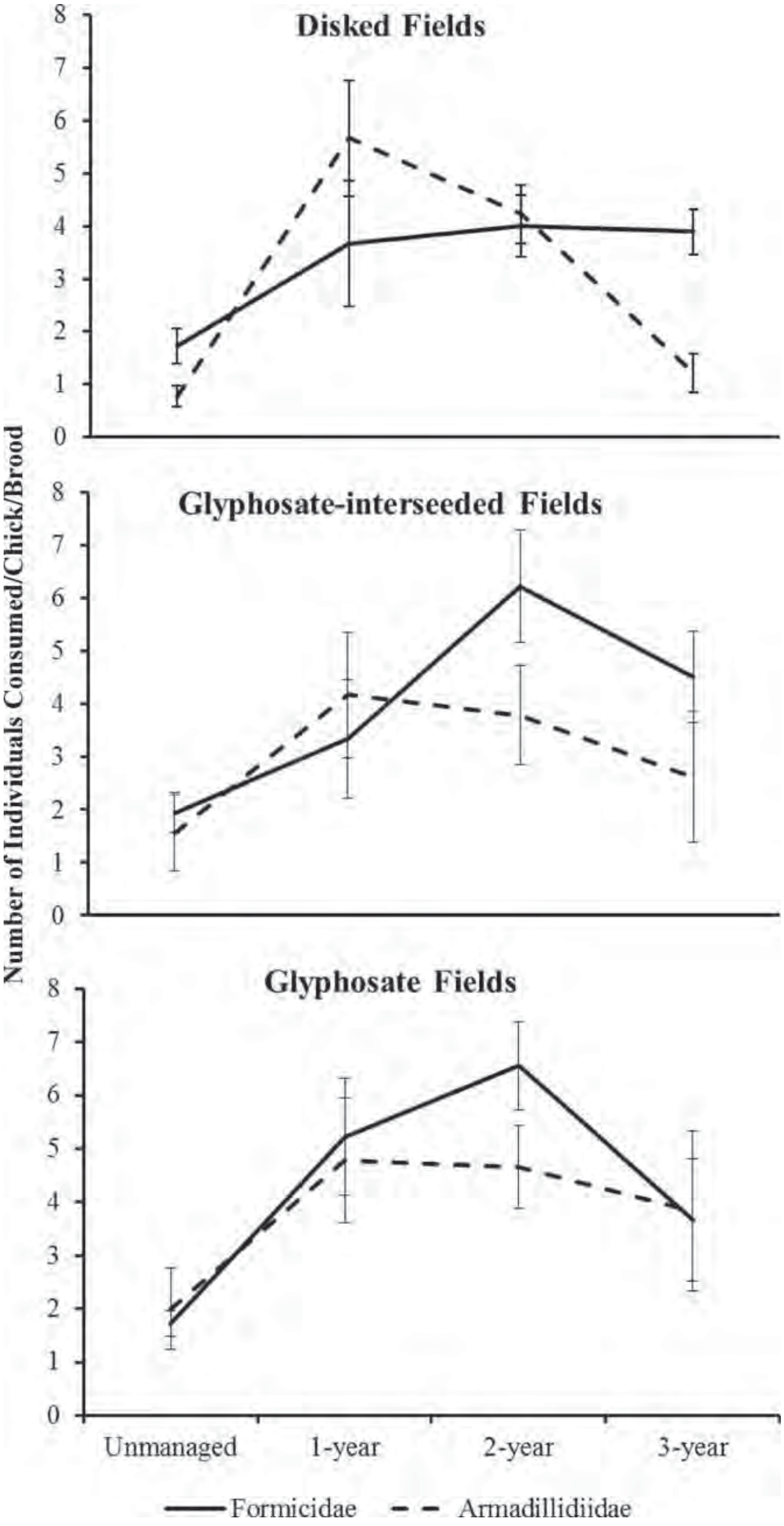

Fig. 2. Mean (± SE) abundance of Formicidae and Armadilliididae consumed by northern bobwhite chicks by treatment and years since treatment in modified, tall fescue Conservation Reserve Program fields in south-central, Illinois, USA during 2008.

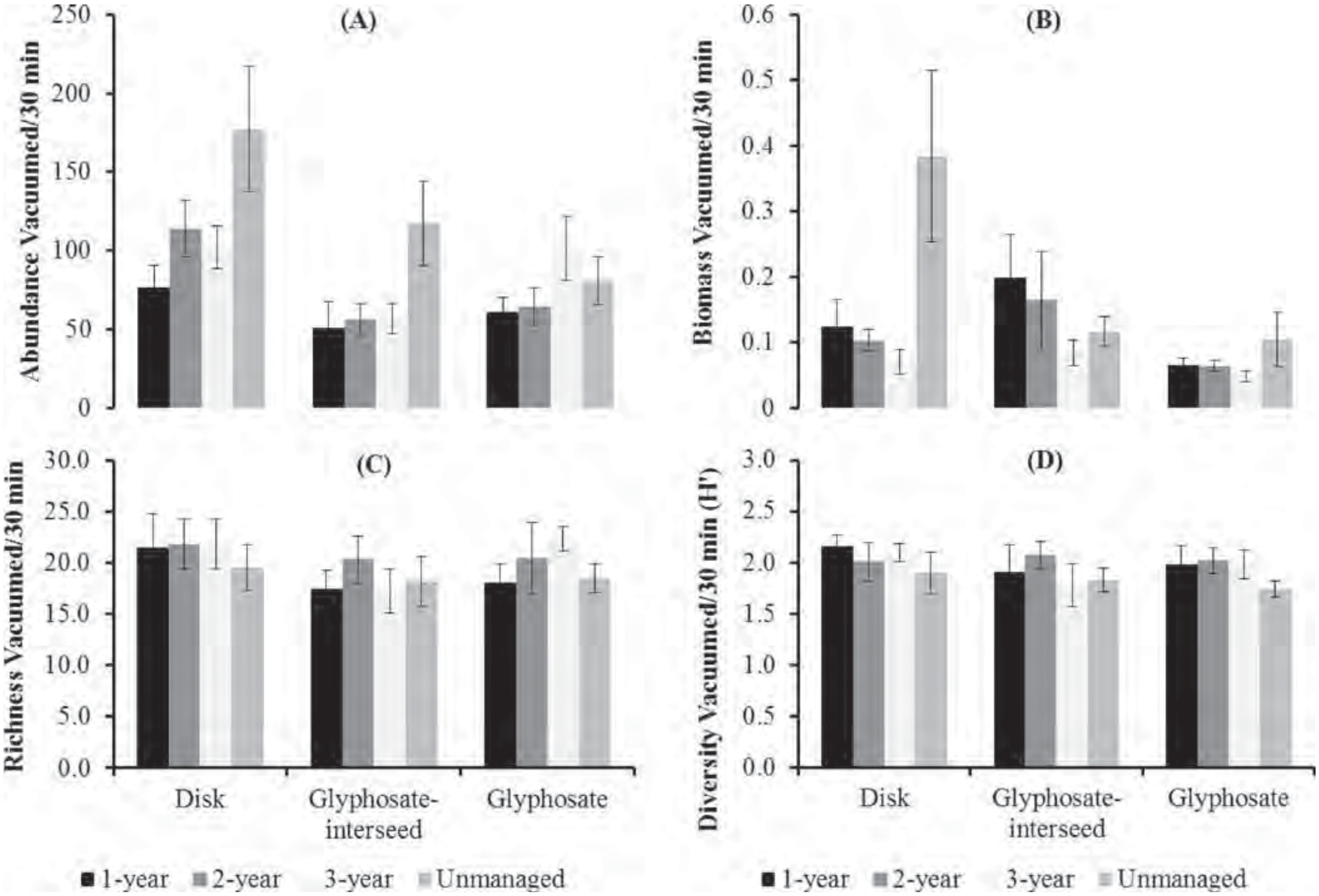

Fig. 3. Abundance, biomass, family richness, and diversity (mean ± SE) of arthropods collected/5-m transect by vacuum sampling in modified, tall fescue Conservation Reserve Program fields in south-central, Illinois, USA during 2008.

($F_{3,20} = 3.16$, $P = 0.0538$), but did not differ among strip conditions ($F_{6,43} = 1.68$, $P = 0.1729$; Fig. 3B). We found no treatment or strip condition effects on family richness or diversity of arthropods collected using vacuum sampling (Fig. 3).

Chicks consumed arthropods disproportionally to what was expected because vacuum sampling showed that arthropod abundance was greater in unmanaged fields compared to managed fields. Consequently, arthropod prey selection by bobwhite chicks foraging in tall fescue CRP fields occurred nonrandomly (Wilks' lamda $\Lambda = 0.13$, $F_{6,66} = 68.16$, Randomized $P < 0.0001$). Compositional analysis indicated chicks consumed a greater proportion of Hymenoptera, Isopoda, and Lepidoptera than were collected using vacuum sampling (Table 1).

DISCUSSION

Arthropods are the primary component of bobwhite chick diets during the first 2 weeks post-hatch (Handley 1931, Nestler 1940, Hurst 1972, Burger et al. 1993); thus, this essential food resource is a major factor influencing chick survival rates, recruitment, and population abundance (Rosene 1969, Hurst 1972). Lusk et al. (2005) noted the first 4 weeks post-hatch were the most critical for bobwhite chick survival, and that management of less suitable habitat could result in increased survival by increasing arthropod availability to chicks. Our study demonstrated bobwhite chicks consumed more arthropods in managed fields than in unmanaged fields, suggesting that MCM can be an effective tool for enhancing foraging

Table 1. Proportion and rank of used (consumed) arthropods by imprinted northern bobwhite chicks and arthropod availability in Conservation Reserve Program fields in south-central Illinois, USA, during 2008.

Order	Proportion consumed	Proportion collected	Rank
Hymenoptera	0.42	0.28	1[a]
Isopoda	0.33	0.08	2[a]
Lepidoptera[b]	0.03	0.01	3[a]
Araneae	0.07	0.11	4
Coleoptera	0.05	0.14	5
Other[c]	0.03	0.12	6
Hemiptera	0.07	0.26	7

[a] Rank numbers represent preferred food items that were consumed in larger proportion than were available.

[b] All Lepidoptera were larvae.

[c] Other includes Diptera, Orthoptera, and Opilione.

habitat quality for bobwhite broods in tall fescue-dominated CRP fields. The observed differences between managed and unmanaged CRP fields reinforce the importance to bobwhites of effective management of natural plant succession, vegetation structure, and plant species composition (Osborne 2010).

The foraging efficacy of bobwhite chicks in fields managed with fall strip disking, fall glyphosate spraying, and fall glyphosate-interseeding differed in regards to the MCM practice and time since disturbance. Benefits for foraging bobwhite chicks in glyphosate and glyphosate-interseeded fields persisted for at least 3 growing seasons post-treatment. Arthropod consumption rates in disked fields in contrast were greatest during the first growing season post-treatment with benefits diminishing as time since disturbance increased. We demonstrated benefits for foraging bobwhite chicks persist longer in glyphosate-based treatment strips than in disked and unmanaged strips.

Formicidae (ants) are an important arthropod prey for bobwhite chicks (Landers and Johnson 1976), and were the most abundant taxa consumed by imprinted chicks in our study. However, chicks in disked fields consumed less ants and more Armadillidiidae than in glyphosate-based treatment fields. Benson et al. (2007) noted that disking of the soil layer as a vegetation management tool alters the arthropod community composition due to an increased amount or decaying organic matter. We infer the observed differences in the diet of chicks likely resulted from differences in the physical properties of the soil and composition of the arthropod communities as described by Benson et al. (2007). We found little evidence in the literature of Armadillidiidae in the diet of bobwhite chicks (Landers and Johnson 1976). Additional research is needed to assess the nutritional value of this prey item compared to common arthropod prey. This information may have negative consequences on chick survival and population recruitment if Armadillidiidae are less digestible and do not provide adequate nutritional value for bobwhite chicks.

Barnes et al. (1995) suggested arthropod availability in tall fescue-dominated fields may be similar among grassland habitat types including native grasses, and foraging habitat quality for bobwhite chicks is limited by the vegetative structure. We demonstrated that bobwhite chicks consumed more arthropods in managed fields although arthropod availability was greater in unmanaged fields. We suggest that an increase in the percentage of bare ground and lower stem density in managed fields (Sparling and Osborne 2009, Osborne et al. 2012) allowed chicks to search more effectively for arthropod prey. We believe the observed differences in arthropod availability and composition among treatments may have resulted from differences in the vegetation structure and percentage of bare ground (Siemann et al. 1998, Symstad et al. 2000). Glyphosate and glyphosate-interseed treatments are more effective at suppressing tall fescue cover, and increasing the percentage of bare ground and annual forbs than disking (Barnes et al. 1995, Washburn et al. 2000, Greenfield et al. 2002, Ruffner and Barnes 2010, Osborne et al. 2012). We suspect the observed differences in arthropod consumption in these fields resulted from observed differences in the structure and compositional of the grassland habitat as demonstrated by Osborne et al. (2012).

Chicks foraging in managed fields were able to access bare ground and scratch and search for prey under the litter duff layer (Stoddard 1931, Rosene 1969, Roseberry and Klimistra 1984). The litter layer was mostly absent in glyphosate-interseeded fields during the first growing season post-treatment as the box-drill buried the dead and dying vegetation beneath the soil surface during planting. Thus, presence of the litter layer apparently provided a refuge for particular arthropod prey that were important for bobwhite chicks in our study. Mobility of chicks was not directly measured in our study, but our inferences support the conclusions of other researchers (Taylor et al. 1999, Doxon and Carroll 2010) and suggest insect prey consumption by chicks may be related to the percentage of bare ground cover and the chicks' ability to maneuver through the habitat. Chick movements and their ability to capture arthropod prey in unmanaged fields were highly restricted by dense stands of tall fescue.

Kimmel and Healy (1987) suggested human-imprinted chicks may be a superior technique to evaluate foraging habitat quality and food availability than other standard arthropod sampling methods including sweep nets and pitfall traps. Researchers suggest that imprinted chicks are more likely to sample and select arthropods that truly are available to wild chicks and would interact with environmental factors (e.g., vegetation structure) in ways similar to wild birds (Palmer et al. 2001). The vacuum samples in our study contained 23 arthropod families that were not present in the diet of bobwhite chicks. Many of the families unique to the vacuum samples were leaf-dwelling insects that inhabit the middle to upper strata of the vegetation column and are generally out of the reach of most bobwhite chicks. Similar to other researchers (Utz et al. 2001, Doxon and Carroll 2007), our study demonstrated that imprinted bobwhite chicks selected slow moving, ground-dwelling arthropods, primarily Formicidae, and that arthropod prey selection was nonrandom. Vacuum sampling provided a poor index of the availability of arthropods to bobwhite chicks, as measured by foraging by imprinted chicks. We conclude that vacuums are not an appropriate tool for measuring the abundance of arthropods important to bobwhite chicks in tall fescue CRP.

MANAGEMENT IMPLICATIONS

Our observation of differences between managed and unmanaged CRP fields reinforced the importance to bobwhite of effective management of natural plant succession, vegetation structure, and plant species composition (Osborne 2010).

Increased suitability of CRP for bobwhites could have a profound positive effect on abundance of the species with 14 million ha of tall fescue plantings in the Midwest and southeastern U.S. (Ball et al. 1993) and the predominate grass planted in CRP cool-season grass enrollments (Carmichael 1997).

We recommend that managers implement glyphosate-based MCM practices to improve brood-rearing habitat conditions for bobwhite chicks in tall fescue-dominated CRP fields. Glyphosate-based treatments suppress grass cover and create structurally diverse patches of habitat for longer periods than disking treatments. More open habitats should increase bobwhite brood foraging efficiency by facilitating chick movement through the habitat. A 3-year rotation of glyphosate-based MCM applied in alternating strips should provide a mosaic of nesting and brood-rearing habitat conditions with a diversity of early successional areas for foraging bobwhite broods.

Our study provides biologists and policy makers with information to facilitate science-based management decisions regarding management of tall fescue for bobwhite brood-rearing habitat.

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LITERATURE CITED

Aebischer, N. J., P. A. Robertson, and R. E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74:1313–1325.

Ball, D. M., J. F. Pedersen, and G. D. Lacefield. 1993. The tall-fescue endophyte. American Scientist 81: 370–379.

Barnes, T. G., L. A. Madison, J. D. Sole, and M. J. Lacki. 1995. An assessment of habitat quality for northern bobwhite in tall fescue-dominated fields. Wildlife Society Bulletin 23:231–237.

Benson, T. J., J. J. Dinsmore, and W. L. Hohman. 2007. Response of plants and arthropods to burning and disking of riparian habitats. Journal of Wildlife Management 71:1949–1957.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

Brennan, L. A. 2002. A decade of progress, a decade of frustration. Proceedings of the National Quail Symposium 5: 230–232.

Brennan, L. A., and W. P. Kuvlesky Jr. 2005. North American grassland birds: an unfolding conservation crisis? Journal of Wildlife Management 69:1–13.

Burger Jr., L. W., D. A. Miller, and R. I. Southwick. 1999. Economic impact of northern bobwhite hunting in the southeastern United States. Wildlife Society Bulletin 29:1010–1018.

Burger Jr., L. W., E. W. Kurzejeski, T. V. Dailey, and M. R. Ryan. 1990. Structural characteristics of vegetation on CRP fields in northern Missouri and their suitability as bobwhite habitat. Transactions of the North American Wildlife and Natural Resources Conference 55:74–83.

Burger Jr., L. W., E. W. Kurzejeski, T. V. Dailey, and M. R. Ryan. 1993. Relative invertebrate abundance and biomass in Conservation Reserve Program plantings in northern Missouri. Proceedings of the National Quail Symposium 3:102–108.

Burger Jr., L. W., D. McKenzie, R. Thackston, and S. J. DeMaso. 2006. The role of farm policy in achieving large-scale conservation: bobwhite and buffers. Wildlife Society Bulletin 34:986–993.

Burke, J. D., M. J. Chamberlain, and J. P. Geaghan. 2008. Effects of understory vegetation management on brood habitat for northern bobwhite. Journal of Wildlife Management 72:1361–1368.

Carmichael, D. B. 1997. The Conservation Reserve Program and wildlife habitat in the southeastern United States. Wildlife Society Bulletin 25: 773–775.

David, L. M., R. E. Warner, and J. L. Roseberry. 1995. Cover types planted on Illinois CP1 CRP fields. Illinois Department of Natural Resources, Springfield, USA.

Doxon, E. D., and J. P. Carroll. 2010. Feeding ecology of ring-necked pheasant and northern bobwhite chicks in Conservation Reserve Program fields. Journal of Wildlife Management 74:249–259.

Ellis, J. A., W. R. Edwards, and K. P. Thomas. 1969. Response of bobwhites to management in Illinois. Journal of Wildlife Management 33: 749–762.

Fettinger, J. L., C. A. Harper, and C. E. Doxon. 2002. Invertebrate availability for upland game birds in tall fescue and native warm-season grass fields. Journal of the Tennessee Academy of Science 77:83–87.

Greenfield, K. C., L. W. Burger Jr., M. J. Chamberlain, and E. W. Kurzejeski. 2002. Vegetation management practices on Conservation Reserve Program fields to improve northern bobwhite habitat quality. Wildlife Society Bulletin 30: 527–538.

Handley, C. O. 1931. Food of the young. Pages 159–165 *in* H. L. Stoddard, ed. The bobwhite quail: its habits, preservation, and increase. Third edition. Charles Scribner's Sons, New York, USA.

Hurst, G. A. 1972. Insects and bobwhite quail brood habitat management. Proceedings of the National Bobwhite Quail Symposium 1: 65–82.

Huwer, S. L., D. R. Anderson, T. E. Remington, and G. C. White. 2008. Using human-imprinted chicks to evaluate the importance of forbs to sage-grouse. Journal of Wildlife Management 72:1622–1627.

Kaston, B. J. 1979. How to know the spiders. Third edition. McGraw-Hill Science, Brown Company Publishers, New York, USA.

Kimmel, R. O., and W. M. Healy. 1987. Imprinting: a technique for wildlife research. Pages 39–52 *in* R. O. Kimmel, J. W. Schultz, and G. J. Mitchell, eds. Perdix IV: Gray Partridge Workshop. Minnesota Department of Natural Resources, Madelia, USA.

Krebs, C. J. 2001. Ecology: the experimental analysis of distribution and abundance. Fifth edition. Benjamin Cummings, San Francisco, California, USA.

Landers, J. L., and A. S. Johnson. 1976. Bobwhite quail food habits in the southeastern United States with a seed key of important foods. Miscellaneous Publication 4. Tall Timbers Research Station, Tallahassee, Florida, USA.

Lusk, J. J., F. S. Guthery, S. A. Cox, S. J. DeMaso, and A. D. Peoples. 2005. Survival and growth of northern bobwhite chicks in western Oklahoma. American Midland Naturalist 153:389–395.

National Bobwhite Technical Committee (NBTC). 2011. W. E. Palmer, T. M. Terhune, and D. F. McKenzie, eds. The National Bobwhite Conservation Initiative: a range-wide plan for recovering bobwhites. National Bobwhite Technical Committee Technical Publication. Version 2.0, Knoxville, Tennessee, USA.

Nestler, R. B. 1940. Feeding requirements of gallinaceous upland gamebirds. Pages 893–924 *in* Yearbook of Agriculture 1939. USDA, U.S. Government Printing Office, Washington, D.C., USA.

Osborne, D. C. 2010. Response of avian, arthropod, and vegetation communities to mid-contract management in Conservation Reserve Program tall fescue monocultures. Dissertation. Southern Illinois University, Carbondale, USA.

Osborne, D. C., D. W. Sparling, and R. L. Hopkins II. 2012. Influence of Conservation Reserve Program mid-contract management and landscape composition on northern bobwhite in tall fescue monocultures. Journal of Wildlife Management 76: 566–574.

Ott, P., and F. Hovey. 1997. BYCOMP.SAS. Clearinghouse for ecology software. Illinois Natural History Survey, Urbana, USA. nhsbig.inhs.uiuc.edu/wes/habitat.html

Palmer, W. E., M. W. Lane, and P. T. Bromley. 2001. Human-imprinted northern bobwhite chicks and indexing arthropod foods in habitat patches. Journal of Wildlife Management 65:861–870.

Peoples, A. D., R. L. Lochmiller, J. C. Boren, D. M. Leslie Jr., and D. M. Engle. 1994. Limitations of amino acids in diets of northern bobwhites (*Colinus virginianus*). American Midland Naturalist 132:104–116.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, USA.

Rosene Jr., W. 1969. The bobwhite quail, its life and management. Rutgers University Press, New Brunswick, New Jersey, USA.

Ruffner, M. E., and T. G. Barnes. 2010. Natural grassland response to herbicides and application timing of selective control of tall fescue, an invasive cool-season grass. Invasive Plant Science and Management 3: 219–228.

Siemann, E., D. Tilman, J. Haarstad, and M. Ritchie. 1998. Experimental tests of the dependence of arthropod diversity on plant diversity. American Naturalist 152:738–750.

Smith, M. D., and L. W. Burger. 2005. Use of imprinted northern bobwhite chicks to assess habitat-specific arthropod availability. Wildlife Society Bulletin 33:596–605.

Sparling, D. W., and D. C. Osborne. 2009. Response of bobwhite, vegetation, and invertebrates to three methods of renovating monotypic Conservation Reserve Program grasslands in south-central Illinois. Pages 117–127 *in* L. W. Burger Jr. and K. O. Evans, eds. Managing working lands for northern bobwhite. USDA, Natural Resource Conservation Service Bobwhite Restoration Project, Washington, D.C., USA.

Steward, A. J., and A. F. Wright. 1995. A new inexpensive suction apparatus for sampling arthropods in grasslands. Ecological Entomology 20:98–102.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner's Sons, New York, USA.

Symstad, A. J., E. Siemann, and J. Haarstad. 2000. An experimental test of the effects of plant functional group diversity on arthropod diversity. Oikos 89:243–253.

Taylor, J. S., K. E. Church, and D. H. Rusch. 1999. Microhabitat selection by nesting and brood-rearing northern bobwhite in Kansas. Journal of Wildlife Management 63:686–694.

Triplehorn, C. A., and N. F. Johnson. 2005. Borror and DeLong's Introduction to the study of insects. Seventh edition. Brooks/Cole, Belmont, California, USA.

U. S. Department of Agriculture (USDA). 2000. Conservation practice standards, early successional habitat development/management code 647. Technical Report. USDA, Natural Resources Conservation Service, Washington, D.C., USA.

U. S. Department of Agriculture (USDA). 2007a. Agricultural statistics for 2007. USDA, National Agricultural Statistics Service, General Printing Office, Washington, D.C., USA.

U. S. Department of Agriculture (USDA). 2007b. Cumulative Conservation Reserve Program enrollment by county, fiscal year 1986–2007. USDA, Washington, D.C., USA. www.fsa.usda.gov/Internet/FSA File/public.xls

Utz, K., J. P. Carroll, and S. J. Moreby. 2001. Comparison of northern bobwhite chick crop and fecal analyses. Proceedings of the National Quail Symposium 5: 225–228.

Washburn, B. E., T. G. Barnes, and J. D. Sole. 2000. Improving northern bobwhite habitat by converting tall fescue fields to native warm-season grasses. Wildlife Society Bulletin 28:97–104.

Williams, C. K., F. S. Guthery, R. D. Applegate, and M. J. Peterson. 2004. The northern bobwhite decline: scaling our management for the twenty-first century. Wildlife Society Bulletin 32:861–869.

INVERTEBRATE ABUNDANCE AT NORTHERN BOBWHITE BROOD LOCATIONS IN THE ROLLING PLAINS OF TEXAS

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ABSTRACT

Northern bobwhite (*Colinus virginianus*), a bird of significant ecological and economic importance throughout the Rolling Plains region of Texas, has experienced significant population declines. Bobwhites have been the focus of extensive research for decades but little is known about foraging ecology of adults and chicks during post-hatch. Invertebrates are a key summer diet component for chicks, and supply the necessary proteins and minerals needed to fuel rapid body development. We examined brood-foraging sites to investigate invertebrate abundance. We radiomarked 121 bobwhite hens during winter-spring 2008 and 2009 and subsequently monitored 14 broods post-hatch. We collected invertebrate samples from 34 brood points and random paired-locations using sweep nets. Samples were sorted by Order to ascertain abundance and diversity. There was no difference in total abundance, abundance of Coleoptera, Hemiptera, Orthoptera, and Order diversity between brood and random locations. Northern bobwhite hens do not appear to select foraging sites based upon invertebrate abundance in the Rolling Plains of Texas.

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Key words: broods, chicks, *Colinus virginianus*, feeding ecology, invertebrates, northern bobwhite, Rolling Plains, Texas

INTRODUCTION

Northern bobwhite populations are declining throughout their range (Brennan 1991, Church et al. 1993). Populations in Texas have been considered more stable but their long-term status is not assured. The USGS Breeding Bird Survey estimates a 3.68% decline per year of northern bobwhites between 1967 and 2009 in Texas (Sauer et al. 2011). Examination of the Texas Parks and Wildlife Department quail roadside count data (TPWD 2009) reveals steep declines in bobwhites in the Cross Timbers ecoregion with the 5-year average between 2004 and 2008 equaling 22% of the long-term mean since 1978. Northern bobwhite counts in the Rolling Plains are more stable around the long-term mean, but are trending downward. Populations in this ecoregion have only peaked significantly (at least 35% > than the long-term mean) once during the past 13 years. Significant peaks occurred almost every 5 years during the period between 1978 and 1994 with consecutive peak years not uncommon (TPWD 2009). These estimates reveal an east to west decline in bobwhite populations in the northern half of Texas.

This decline has emphasized the importance of understanding factors that influence northern bobwhite demographics. There is relatively little information available concerning bobwhite chick demographics although this metric has a major influence on population growth (Sandercock et al. 2008). Food availability, in the form of invertebrates, likely has a major influence on chick survival. Bobwhite chicks rely on invertebrates for an important source of protein during the first few weeks of life (Stoddard 1931, Nestler et al. 1942, Hurst 1972). We hypothesized brooding northern bobwhite hens would select foraging sites with the greatest invertebrate diversity and abundance to maximize opportunities for bobwhite chicks to acquire sufficient nutrition. Studies of black grouse (*Tetrao tetrix*), capercaillie (*T. urogallus*), and ruffed grouse (*Bonasa umbellus*) suggest hens select sites to take their broods where invertebrate abundance is greater than at random sites (Baines et al. 1996, Haulton et al. 2003, Wegge et al. 2005). In contrast, wild turkeys (*Meleagris gallopavo*) did not select sites with greater invertebrate abundance in Texas (Randel et al. 2007). Foraging studies using imprinted chicks have been conducted across the bobwhite's range (Palmer et al. 2001, Smith and Burger 2005, Doxson and Carroll 2010), but we do not know of attempts to quantify the relationship between invertebrate diversity and abundance and brooding northern bobwhite hen-feeding site selection in the Texas Rolling Plains nor using wild broods. Our objective was to investigate if brooding northern bobwhite

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Table 1. Invertebrate abundance and diversity at brood and random locations in the Texas Rolling Plains, 2008 and 2009, pooled.

Order	Brood ($n = 34$) $\bar{x} \pm$ SE	Random ($n = 34$) $\bar{x} \pm$ SE
Coleoptera	2.029 ± 0.541	1.97 ± 0.495
Hemiptera	1.558 ± 0.327	1.441 ± 0.280
Orthoptera	11.617 ± 1.537	12.176 ± 1.848
Total	15.647 ± 1.985	16.441 ± 2.188
Diversity	2.911 ± 0.232	3.205 ± 0.238

hens used feeding sites which contained greater invertebrate diversity and abundance than areas that were readily available but not selected.

STUDY AREA

Study sites were selected on private grazing lands within the Rolling Plains ecoregion in Gray County, in the eastern Texas Panhandle. The climate in this region is semi-arid with 84% of the 51.13 cm of average annual precipitation falling in the growing season of April–October (Williams and Welker 1966). Yearly precipitation varies widely and droughts are common with annual precipitation in Amarillo ranging from 24.28 to 100.97 cm (U.S. Department of Commerce 2010).

Soils encompassing the region are Likes-Springer-Tivoli and Miles-Springer (Williams and Welker 1966). Common grasses and shrubs include: big sandreed (*Calamovilfa gigantea*), eastern gamagrass (*Tripsacum dactyloides*), Indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparium*), sand bluestem (*Andropogon hallii*), sand lovegrass (*Eragrostis trichodes*), sideoats grama (*Bouteloua curtipendula*), switchgrass (*Panicum virgatum*), Chickasaw plum (*Prunus angustifolia*), Havard shinoak (*Quercus havardii*), sand sagebrush (*Artemisia filifolia*), sumac (*Rhus* spp.), and yucca (*Yucca glauca*) (Williams and Welker 1966, McMahon et al. 1984).

METHODS

We trapped bobwhite hens in February-April 2008 and 2009. Collapsible walk-in funnel traps (Stoddard 1931) were baited using a mixture of cracked corn and milo. Each hen was weighed, banded, and fitted with a 6-g necklace-style radio transmitter (American Wildlife Enterprises, Monticello, FL, USA). Hens were tracked ≥ 2 times weekly during the breeding season; nest and brood locations were recorded with a Global Positioning System (GPS) unit. Nest fate was ascertained upon nest termination, and hens were located during morning hours to avoid stress associated with high summer temperatures. Chicks ≤ 2 weeks of age were assumed to be foraging when the hen exhibited brooding behavior upon approach, flushed, or when chicks were directly observed due to difficulty in observing behavior in dense vegetation. Invertebrate samples were collected on the ensuing day where broods were observed.

Invertebrate samples were collected following Randel et al. (2007). Sample sites were sweep-netted along a 10-m transect with 25 sweeps (38-cm diam) (Sweep nets, Forestry Suppliers, Jackson, MS, USA) to encompass an area of 10-m^2 (Randel et al. 2006, 2007). Random site invertebrate collection was conducted at locations based on a random number generator for bearing (1°–360°) and distance (100–400 m) from the paired brood site. All samples collected were marked as brood or random, frozen, and stored in sealable plastic bags until sorted in the laboratory.

Samples were sorted by Order and counted to ascertain abundance and diversity between brood and random sites, and years. Diversity was calculated as the number of Orders present per sample. Shapiro-Wilks' test for normality indicated non-normal distribution of errors ($P > 0.05$) and a Wilcoxon signed-rank test was used to analyze the data. Statistical analyses were conducted using PASW 18 (SPSS Inc., Chicago, IL, USA).

RESULTS

Invertebrate samples were collected from 6 and 8 radio-marked females with broods in 2008 and 2009, respectively. Samples were pooled (Table 1) over both years for analysis due to limited quantity of brood locations ($n = 34$). Coleoptera, Hemiptera, and Orthoptera were selected for analysis from 14 collected orders because of high frequency of occurrence ($\lambda > 0.55$).

Total invertebrate abundance at brood locations did not differ from random locations ($P = 0.925$). Differences were not detected between random and brood sites for abundance of Coleoptera ($P = 0.990$), Hemiptera ($P = 0.888$), and Orthoptera ($P = 0.911$). No differences between invertebrate Order diversity ($P = 0.469$) were detected between random and brood sites.

DISCUSSION

Studies have shown invertebrates provide essential proteins and nutrients for chick muscle and feather development during their first 2 weeks of life (Hurst 1972, Savory 1989, Lusk et al. 2005). DeVos and Mueller (1993) found brooding adults used areas with higher invertebrate density, but our results do not support their finding. Rio Grande wild turkeys in the Edwards Plateau of Texas also did not select brood sites based on invertebrate abundance (Randel et. al 2007). In contrast, studies of black grouse, capercaillie, and ruffed grouse suggest hens select sites based upon invertebrate abundance (Baines et al. 1996, Haulton et al. 2003, Wegge et al. 2005).

Abundance of Coleoptera, Hemiptera, and Orthoptera in our study ranked highest among all Orders collected at both brood and random locations. DeVos and Mueller (1993) noted greater volumes of these Orders sampled at brood locations compared to random locations while Jackson et al. 1987) found Coleoptera, Hemiptera, and Hymenoptera ranking among the top three Orders selected by imprinted chicks. Similar results were reported among adult scaled quail (*Callipepla squamata*) based on fecal samples in the western Texas Panhandle with Orthoptera, Coleoptera, Hymenoptera, and Hemiptera comprising $\sim$ 50% of their summer diet (Ault and Stormer 1983). We found no difference in abundance or diversity between brood and random locations, but Coleoptera, Hemiptera, and Orthoptera, all important foods for chicks, comprised 97 and 95% of brood and random samples, respectively. The main components of $\leq$ 2 week old chick diets were well represented in our samples.

MANAGEMENT IMPLICATIONS

There was no detectable difference between hen-selected sites and random sites in invertebrate abundance or diversity. Thus, habitat management solely for the purpose of increased invertebrate abundance and diversity without regard to other living requirements may not necessarily benefit post-hatch brood survival and development. We suggest further examination of foraging behavior and resource selection of wild populations is needed.

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LITERATURE CITED

Ault, S. C., and F. A. Stormer. 1983. Seasonal food selection by scaled quail in northwest Texas. Journal of Wildlife Management 47:222–228.

Baines, D., I. A. Wilson, and G. Beeley. 1996. Timing of breeding in black grouse *Tetrao tetrix* and capercaillie *Tetrao urogallus* and distribution of insect food for the chicks. Ibis 138:181–187.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

Church, K. E., J. R. Sauer, and S. Droege. 1993. Population trends of quails in North America. Proceedings of the National Quail Syposium 3:44–54.

DeVos, T., and B. S. Mueller. 1993. Reproductive ecology of northern bobwhite in north Florida. Proceedings of the National Quail Symposium 4:83–90.

Doxon, E. D., and J. P. Carroll. 2010. Feeding ecology of ring-necked pheasant and northern bobwhite chicks in Conservation Reserve Program fields. Journal of Wildlife Management 74:249–256.

Haulton, G. S., D. F. Stauffer, and R. L. Kirkpatrick. 2003. Ruffed grouse (*Bonasa umbellus*) brood microhabitat selection in the southern Appalachians. American Midland Naturalist 150:95–103.

Hurst, G. A. 1972. Insects and bobwhite quail brood habitat management. Proceedings of the National Bobwhite Quail Symposium 1:65–82.

Jackson, J. R., G. A. Hurst, and E. A. Gluesing. 1987. Abundance and selection of invertebrates by northern bobwhite chicks. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 41:303–310.

Lusk, J. J., F. S. Guthery, S. A. Cox, S. J. DeMaso, and A. D. Peoples. 2005. Survival and growth of northern bobwhite chicks in western Oklahoma. American Midland Naturalist 153:389–395.

McMahon, C. A., R. G. Frye, and K. L. Brown. 1984. The vegetation types of Texas. Bulletin 7000-120. Texas Parks and Wildlife Department, Austin, USA.

Nestler, R. B., W. W. Bailey, and H. E. McClure. 1942. Protein requirements of bobwhite quail chicks for survival, growth, and efficiency of feed utilization. Journal of Wildlife Management 6:185–193.

Palmer, W. E., M. W. Lane II, and P. T. Bromley. 2001. Human-imprinted northern bobwhite chicks and indexing arthropod foods in habitat patches. Journal of Wildlife Management 65:861–870.

Randel, C. J., R. B. Aguirre, M. J. Peterson, and N. J. Silvy. 2006. Comparison of two techniques for assessing invertebrate availability for wild turkeys in Texas. Wildlife Society Bulletin 34:853–855.

Randel, C. J., R. B. Aguirre, M. J. Peterson, and N. J. Silvy. 2007. Invertebrate abundance at Rio Grande wild turkey brood locations. Journal of Wildlife Management 71:2417–2420.

Sandercock, B. A., W. E. Jensen, C. K. Williams, and R. D. Applegate. 2008. Demographic sensitivity of population change in northern bobwhite. Journal of Wildlife Management 72:970–982.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski Jr., and W. A. Link. 2011. The North American Breeding Bird Survey, results and analysis 1966–2009. Version 3.23.2011. USGS, Patuxent Wildlife Research Center, Laurel, Maryland, USA. www.pwrc.usgs.gov

Savory, C. J. 1989. The importance of invertebrate food to chicks of gallinaceous species. Proceedings of the Nutrition Society 48:113–133.

Smith, M. D., and L. W. Burger Jr. 2005. Use of imprinted northern bobwhite chicks to assess habitat-specific arthropod availability. Wildlife Society Bulletin 33:596–605.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. Third edition. Charles Scribner's Sons, New York, USA.

Texas Parks and Wildlife Department. 2009. Quail forecast 2008–2009; revised 25 September 2008. Austin, USA. www.tpwd.state.tx.us/huntwild/hunt/planning/quail_forecast/forecast/

U.S. Department of Commerce. 2010. Yearly precipitation for Amarillo, TX. National Oceanic and Atmospheric Administration, National Weather Service, Amarillo, Texas, USA. www.srh.noaa.gov/ama/?n=yearly_precip

Wegge, P., T. Olstad, H. Gegersen, O. Hjeljord, and A. Sivkov. 2005. Capercaillie broods in pristine boreal forest in northwestern Russia: the importance of insects and cover in habitat selection. Canadian Journal of Zoology 83:1547–1555.

Williams, J. C., and A. J. Welker. 1966. Soil Survey of Gray County, Texas. U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., USA.

DO BENEFICIAL INSECT HABITATS ALSO PROVIDE QUALITY BROOD HABITAT FOR NORTHERN BOBWHITE?

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ABSTRACT

Strips of fallow vegetation along cropland borders are an effective strategy for providing northern bobwhite (*Colinus virginianus)* habitat. However, a limitation of fallow borders is the lack of nectar-producing vegetation needed to sustain many beneficial insect populations. Planted borders that contain mixes of prairie flowers and grasses may harbor more diverse arthropod communities, but the relative value of these borders as bobwhite brood habitat compared to fallow borders is unknown. Vegetation composition likely has the largest influence on a field border's structural characteristics, which consequently may impact bobwhite foraging efficiency. Thus, actively planting field borders may not yield the vegetative composition and structure needed to provide quality brood habitat. We used groups of 6 human-imprinted bobwhite chicks as a bioassay for comparing 4 different field border treatments (planted native warm season grasses (NWSG) and prairie flowers, planted prairie flowers only, fallow vegetation, or mowed vegetation) as brood habitat from June to August 2009 and 2010. All field border treatments (0.33 ha each) were established around 9 organic crop fields. Groups of chicks were led through borders for 30-min foraging trials and immediately euthanized at the end of each trial. Their crops and gizzards were dissected in the laboratory, and eaten arthropods were measured, counted, and identified to taxonomic family. We used allometric equations to estimate the live weight of all arthropods consumed, and to calculate a mean foraging rate (grams of arthropods consumed/chick/30 min) for each field border treatment. We used a modified leaf blower-vacuum to sample arthropod prey availability and diversity in each field border treatment. Sampled arthropods were counted and identified to taxomomic family. We also calculated a Shannon-Weiner diversity index for each field border treatment. Foraging rate did not differ among border treatments in 2009 or 2010. Similarly, mean arthropod densities and diversity calculated from blower-vac samples did not differ among treatments in 2009 or 2010. Chick foraging rate was relatively high and arthropod prey was abundant even in mowed field borders. We suspect the amount of arthropod prey foods is likely not a limiting factor for bobwhite chicks in uncultivated habitats, rather, vegetative structure that facilitates movement, supports a suitable thermal micro-climate, and provides protection from predators is most important for bobwhite broods. Our results suggest that field borders planted for promoting beneficial insects provide bobwhite brood habitat equivalent to fallow borders. However, beneficial insect habitats are expensive, and require additional time and funding to insure successful establishment. The cost of establishing planted NWSG and prairie flowers and planted prairie flowers only borders in our study was ~ $1,928 and $1,773/ha, respectively. Fallow borders are likely the most cost-effective option for landowners/managers whose primary interest is providing bobwhite habitat.

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Key words: brood habitat, *Colinus virginianus,* field borders, insects, northern bobwhite

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IMPACTS OF BERMUDAGRASS ON NORTHERN BOBWHITE CHICKS: MOBILITY AND HEAT EXPOSURE

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ABSTRACT

Conservation programs to benefit northern bobwhites (*Colinus virginianus*) and other agriculturally-related wildlife species often target crop-field margins for management. The Bobwhite Quail Initiative in Georgia is a program where 3- to 18-m strips are disked and left fallow for 3-year cycles. However, several exotic grasses, such as bermudagrass (*Cynodon dactylon*), encroach in field margins, reducing their usefulness for avian species. We hypothesized that dense mats of bermudagrass would be a physical barrier to bobwhite chicks and also serve as a heat trap reducing habitat quality. We conducted two experiments to assess these factors. First, we used human-imprinted bobwhite chicks, 5 and 10 days of age, to assess mobility through vegetation with 3 levels (none, moderate, and high) of bermudagrass invasion. There was a significant impact of bermudagrass density on mobility of 5-day old chicks ($P = 0.002$), but no effect on 10-day old chicks ($P = 0.38$). Second, we placed temperature recorders at ground level in plots in field margins that had >75% cover of bermudagrass and those with >75% coverage of forbs. The mean temperature of bermudagrass plots was greater than in forb plots ($P = 0.03$). The percentage of time above the 40 °C critical threshold temperature for bobwhites was greatest in bermudagrass plots ($P = 0.03$) and ranged over 33–38% of daytime hours, but only 6-26% for forb plots. Our data suggests that bermudagrass degrades the quality of field margins and control of exotic invasive grasses is warranted to improve their efficacy.

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Key words: bermudagrass, *Colinus virginianus*, *Cynodon dactylon*, northern bobwhites

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EFFECT OF ABUNDANCE AND SURVEY PROTOCOL ON ESTIMATES OF OCCUPANCY AND DETECTION PROBABILITY FOR NORTHERN BOBWHITES

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ABSTRACT

We compared estimates of occupancy of northern bobwhite (*Colinus virginianus*) between areas with relatively low and high abundance using single-survey and multiple-survey protocols, with and without accounting for detection probability, and investigated how time during the breeding season affected detection probability in Oklahoma, USA, in 2009–2011. Estimates of occupancy and detection probability increased as the number of survey occasions increased. Detection probability was significantly higher in the area of high abundance ($P \leq 0.001$), and increased as the breeding season advanced from mid-May to late July. Accounting for detection probability increased occupancy estimates by 31% in the low-abundance area but only 1.9% in the high abundance area when using 3 survey occasions per year. Managers using occupancy to detect changes in bobwhite populations should use ≥ 4 survey occasions per year to ensure accurate estimates of both occupancy and detection probability.

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Key words: BBS, call counts, *Colinus virginianus*, detection probability, monitoring, occupancy, Oklahoma, PAO, population

INTRODUCTION

Many published reports of northern bobwhite population dynamics have relied on the number of calling males heard during spring and summer survey stops as their source of data (Cram et al. 2002, Lusk et al. 2002, Veech 2006, Twedt et al. 2007, Spinola and Gates 2008). This method, known as the call-count index, is an efficient way to index long-term trends in bobwhite populations over large areas (Church et al. 1993, Hansen and Guthery 2001), but may not be an accurate reflection of the state of the population in any given year or of short-term trends in abundance (Norton et al. 1961, Schwartz 1974, Hansen and Guthery 2001) due to a lack of a well-defined relationship between the number of calling males heard and bobwhite abundance. Additionally, many of these surveys are conducted only once per year and do not consider the probability of failing to detect bobwhites even when they are present (Veech 2006, Spinola and Gates 2008). The number of bobwhites heard during a given survey can vary substantially due to survey-specific factors such as time of year, time of day, cloud cover, temperature, and wind speed (Robel et al. 1969, Hansen and Guthery 2001), as well as simple random chance. Thus, given the deficiencies in using call counts as a short-term index of bobwhite abundance, it is useful to consider alternative variables in monitoring efforts directed at describing the current status and short-term trends in bobwhite populations. Proportion of area occupied, or occupancy, is commonly used in monitoring efforts for other species (Zielinski and Stauffer 1996, Trenham et al. 2003, Rhodes et al. 2006), and may offer an alternative.

Occupancy is defined as the proportion of the area or sample sites occupied by the species of interest (MacKenzie et al. 2006) and is often estimated from repeated or unrepeated presence-absence surveys. Traditional presence-absence surveys assume that when a species is not detected at a given site, it is absent from that site (MacKenzie and Royle 2005, MacKenzie et al. 2006) and the occupancy estimate is the proportion of sites where the species was detected. This method does not consider the possibility the species was present but not detected (a ‘false absence’) and, consequently, the occupancy estimate may be biased low if the species is rare and/or not easily detected (MacKenzie et al. 2002, MacKenzie et al. 2005). Theoretical advances over the last decade have addressed the issue of estimating occupancy when detection probabilities are < 1 (MacKenzie et al. 2002, MacKenzie 2005, MacKenzie et al. 2006). Methods that have been developed use repeat visits to survey sites to estimate the probability of detection of the target species with the goal of estimating the proportion of sites

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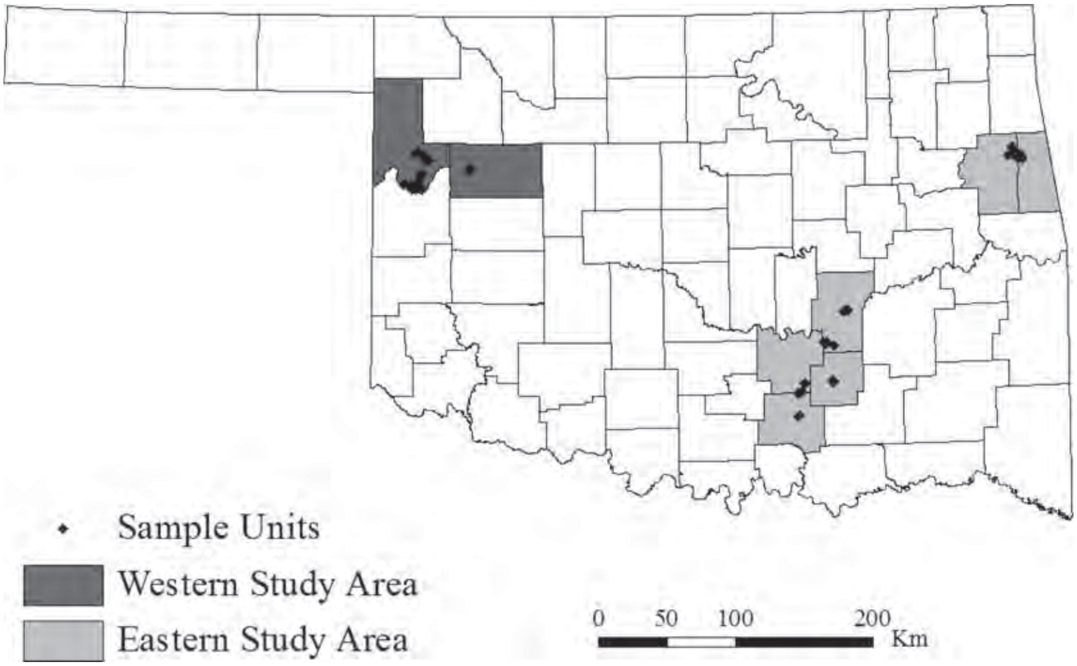

Fig. 1. Study areas and sample units where northern bobwhite surveys were conducted in Oklahoma, USA (2009–2011).

occupied knowing the species can be present yet not detected.

Estimates of bobwhite occupancy may change significantly based on the number of times survey sites are visited per season and whether or not detection probability is considered. Bobwhites, which are normally considered easy to detect, may also have significantly lower detection probabilities in areas where abundance is low as opposed to areas where it is high (Royle and Nichols 2003, Smith et al. 2007). Our objectives were to: (1) compare estimates of occupancy between areas with relatively low and high populations using single-survey and multiple-survey protocols, both with and without accounting for detection probability; and (2) investigate how time during the breeding season affects detection probability. We hypothesized that: (1) multiple surveys would result in significantly higher estimates of occupancy and detection probability than single surveys in both areas; (2) detection probability would be significantly higher in the high-population area; and (3) due to temporal differences in calling rates, a model that allowed detection probability to vary with time during the breeding season would perform better than a model where detection probability remained constant.

STUDY AREA

This study was conducted on properties enrolled in the Quail Habitat Restoration Initiative (QHRI) in Oklahoma, a program funded through the U. S. Department of Agriculture's Environmental Quality Incentives Program (EQIP) to provide cost-share incentives to private landowners for restoring or maintaining bobwhite habitat on their properties, and in control areas not enrolled in the program. We established 2 study areas for the purposes of this analysis that were analyzed separately: eastern and western. The eastern study area included portions of Adair, Cherokee, Hughes, Coal, Johnston, and Pontotoc counties in Oklahoma (Fig. 1). Properties consisted of 10 private ranches and 2 properties owned by The Nature Conservancy. These properties are characterized by a mosaic of tallgrass prairie and cross-timbers or central hardwoods forest. Dominant tree species are oaks (*Quercus* spp.) and hickories (*Carya* spp.), and the most prominent grasses include big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and Indiangrass (*Sorghastrum nutans*). Bobwhite populations within these properties and within the study area were relatively low with an average of 20 bobwhites heard per BBS route between 1966 and 2003 (Sauer et al. 2011) and little existing habitat on the private ranches under study.

The western study area included portions of Ellis and Dewey counties in Oklahoma (Fig. 1). Four private ranches and the Packsaddle State Wildlife Management Area, operated by the Oklahoma Department of Wildlife Conservation, were included in this study area. These properties are dominated by sand shinnery oak (*Quercus havardii*) and sand sage (*Artemisia filifolia*) plant communities. Dominant grasses are little bluestem and Indiangrass, and sand plum (*Prunus angustifolia*) is a common shrub. Bobwhite populations within these properties and in this study area were relatively more common than in the eastern study area with an average of 46 bobwhites heard per BBS route between 1966 and 2003 (Sauer et al. 2011), and large areas of habitat within the properties under study. We believe the differences in relative abundance as measured by the BBS were sufficient to test the impact abundance has on occupancy modeling while recognizing abundance varies greatly between years and the BBS is a coarse method of measuring absolute abundance.

METHODS

Bobwhite Surveys

We located 23 sample units in the eastern study area where habitat restoration was scheduled to occur and subjectively located 8 sample units in control areas, 2 that were closed-canopy forest and 6 that consisted of existing bobwhite habitat, for a total of 31 established sample units. This design was chosen as there was an ongoing bobwhite research project in the area that included treatments to create useable space for bobwhites. The necessity of specifically sampling restoration and maintenance areas precluded completely random placement of the sample units but, because our purpose was to census bobwhites within the sample units, rather than describe populations in the region, this was not considered detrimental to the analysis. We randomly located 1 to 4 sample units within pastures in the western study area where prescribed burning to maintain bobwhite habitat was scheduled to occur, for a total of 27 established sample units. We sampled 31 sample units in 2009 and 2010, and 29 sample units in 2011 in the eastern study area, and 27 sample units in 2009 and 2010, and 26 sample units in 2011 in the western study area. Differences in number of sample units between years were due to loss of access.

Each sample unit consisted of a 400-m radius circle where call counts were conducted from the center point (Stoddard 1931, Hansen and Guthery 2001). Center points of all sample units were $\geq$ 800 m apart, and sample units did not include agriculture or human development. We conducted call counts at each sample unit 3 times during the breeding season (mid-May–late Jul) at intervals of 2–3 weeks in 2009–2011, where all bobwhites seen or heard within 400 m of the sample unit center point during a 5-min period were recorded. We assumed the detection probability for bobwhites was ≥ 0.5, and used 3 surveys per season as recommended by MacKenzie and Royle (2005). Call counts were completed between 0.5 hr before and 4.5 hrs after sunrise; we did not sample when it was raining or when wind speeds exceeded 20 km/hr (Winter et al. 2005). We grouped sample units based on geographic proximity and surveyed one group per day, alternating the order in which both sample units and groups were surveyed to avoid detection bias due to time of day or time during the breeding season.

Occupancy Estimation and Survey-specific *p*

Our methods were similar to those used by Bailey et al. (2004) in an assessment of occupancy and detection probabilities for terrestrial salamanders in Great Smokey Mountains National Park, USA. We began with the assumption that probabilities of occupancy (ψ) and detection (p) were equal across times and sites, $\psi(.)$ $p(.)$. This constant model is not necessarily the most accurate representation of the system, but our objective was to compare the impacts of different sampling protocols on the parameters of interest; the inclusion of additional variables may have confounded our results (Bailey et al. 2004). Occupancy modeling is based on closed-population capture-recapture methods and assumes sample sites are closed to changes in occupancy status during the course of the surveys (MacKenzie et al. 2006). It is probable that individual bobwhites moved into or out of sample units during the sample period but, we assumed the limited breeding-season movements of bobwhites (Murphy and Baskett 1952, Fies et al. 2002, Townsend et al. 2003) would cause the occupancy status of sample units to remain constant during our survey periods despite some individual movements. The western study area represented a region where bobwhites were relatively common and the eastern study area represented a region where bobwhites were relatively uncommon for all statistical comparisons. We treated year as a random variable and combined data for all years.

We compared estimates of ψ and p using 3 different 'sampling protocols' reflecting different survey intensities (1-, 2-, or 3-surveys per season), and 2 different estimation procedures for ψ, separately for the eastern study area and the western study area. We randomly selected first 1 and then 2 of the survey occasions from each sampling unit in each year to represent the 1- and 2-survey protocols, respectively. All 3 sampling occasions combined were used to represent the 3-survey protocol. We first calculated the proportion of sample units where the species was observed, ψ(obs), which is a naïve estimate of occupancy that does not account for detection probability, using 1-, 2-, and 3-sampling occasions per year. We then estimated $\psi(.)$ and $p(.)$ from occupancy models accounting for detection probability using both 2 and 3 sampling occasions. Our estimate of the precision of $\psi(.)$ and $p(.)$ was the standard error of the estimate divided by the estimate, and precision was considered good if the result was < 0.3 (Bailey et al. 2004). We compared ψ(obs) between each protocol using McNemar's Chi-square test for paired samples (Conover 1999), and compared $p(.)$ between the 2 study areas using a Chi-square test on proportions. We considered all inferential tests with $P < 0.05$ to be significant.

The literature indicates calling rates change throughout the breeding season (Rosene 1957, Robel et al. 1969, Hansen and Guthery 2001); thus, we tested the hypothesis that a model that allowed detection probability to vary with time during the breeding season would perform better than a model where detection probability remained constant by modeling detection probability as a function of Julian day, $\psi(.)$ p(day), and comparing it to the model where detection probability was constant, $\psi(.)$ $p(.)$, using Akaike's Information Criterion (Anderson 2008). We interpreted a change in the AIC score (ΔAIC) of > 4 to indicate the first-ranked model was significantly better than the second-ranked model (Anderson 2008). Estimation of ψ and p, as well as AIC model selection, was done using Program PRESENCE (Version 4.0, http://www.mbr-pwrc.usgs.gov/software/presence.html). We conduct-

Table 1. Observed occupancy rates [ψ(obs)], estimates of occupancy [ψ(.)], and detection probability [p(.)] and their associated standard errors from occupancy models accounting for detection probability, using 1-, 2-, and 3-survey occasions per year for northern bobwhites in an area where populations were relatively low (Eastern) and an area where they were relatively high (Western) in Oklahoma, USA (2009–2011).

						Precision[b]		
	Area	ψ(obs)	ψ(.)	SE	p(.)	SE	ψ(.)	p(.)
One survey[a]	Eastern	0.075						
	Western	0.711						
Two surveys	Eastern	0.194	0.970	0.870	0.105	0.097	0.897	0.924
	Western	0.901	0.997	0.046	0.708	0.047	0.046	0.066
Three surveys	Eastern	0.226	0.296	0.066	0.396	0.082	0.223	0.207
	Western	0.938	0.956	0.028	0.732	0.032	0.029	0.044

[a] p cannot be estimated from only 1-survey occasion and only the (obs) values were calculated.

[b] Precision = [$SE_{estimate}$/estimate].

ed all other statistical analyses using Program R (R Version 2.13.1, http://cran.r-project.org).

RESULTS

We detected bobwhites on 96 of 174 sampling occasions at 58 individual sample units in 2009–2011. Twenty-one detections occurred in the eastern study area and 75 occurred in the western study area. The standard presence-absence analysis showed that ψ(obs) increased as survey intensity increased (Table 1). The McNemar's test showed statistically significant increases between 1-survey and 2- or 3-survey protocols, but not between 2- and 3-survey protocols for both areas. Bobwhites were less common in the eastern study area and ψ(obs) increased 201% between the 1- and 3-survey protocols ($P \leq 0.001$) but only increased 16.5% between the 2- and 3-survey protocols ($P = 0.248$). Bobwhites were more common in the western study area and there was an increase in ψ(obs) of 32% between the 1- and 3-survey protocols ($P \leq 0.001$), and an increase of 4% between the 2- and 3-survey protocols ($P = 0.480$).

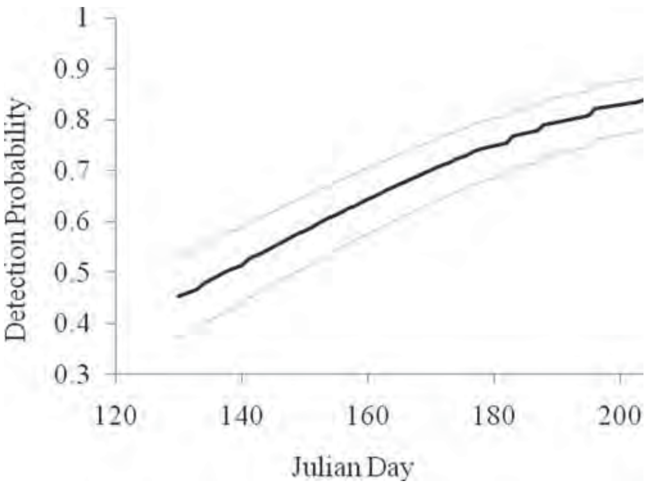

Fig. 2. Predicted detection probabilities (solid line) and standard errors (dotted lines) for northern bobwhite call-count surveys as a function of Julian day in Oklahoma, USA (2009–2011).

Our estimate of ψ(.), when using the 3-survey protocol, was 31% higher than ψ(obs) in the eastern study area and 1.9% higher in the western study area. Estimates of p were significantly higher in the western than in the eastern study area ($P \leq 0.001$). The 2-survey protocols in the eastern study area had an estimated p of 0.105, resulting in an estimate of ψ that was extremely high relative to the 3-survey protocol with high standard error and low precision (Table 1). A slightly lower detection probability in the western study area using the 2-survey protocol resulted in a slightly higher estimate of ψ than when using the 3-survey protocol. Precision of the model estimates of both ψ and p were considered good with the $SE_{estimate}$/estimate ≤ 0.223, except in the case of the 2-survey protocol in the eastern study area ($SE_{estimate}$/estimate $= 0.897$).

Model comparison showed significant support for the model using Julian day as a survey-specific variable, $\psi(.)$ p(day), over the constant model, $\psi(.)$ $p(.)$, (ΔAIC $= 11.17$). The plot of Julian day versus p increased in detection probability as the breeding season advanced (Fig. 2).

DISCUSSION

Survey protocols requiring > 1 sampling occasion per season are crucial to obtaining accurate estimates of bobwhite occupancy; estimates may be biased low if detection probability is not considered. Our results show estimates of occupancy and detection probability can change substantially based on bobwhite abundance and survey protocol, and indicate when surveys are done only once per year unreliable estimates of the state of the population can be expected in any given year. Accounting for detection probability in the analysis of occupancy data for bobwhites is particularly important in areas where abundance is relatively low, as in our eastern study area. As abundance and/or detection probability decreases, the number of sample sites or survey occasions required to obtain accurate estimates of occupancy increases (MacKenzie and Royle 2005).

The number of survey occasions per season can have a substantial influence on estimates of occupancy and detection probability (Bailey et al. 2004, MacKenzie and Royle 2005, Royle 2006). Our results suggest values of ψ(obs) based on only 1-survey occasion per season will significantly underestimate occupancy, and $<$ 3-survey occasions may not be adequate in areas where bobwhite abundance is relatively low even when detection probability is considered. The 2-survey protocol in our eastern study area had such a low detection probability that it resulted in an unrealistically high occupancy estimate. This is consistent with the findings of MacKenzie et al. (2002) and Bailey et al. (2004) who showed that detection probabilities < 0.15 can yield unreasonable estimates of occupancy.

Our results support the conclusions of Royle and Nichols (2003) and Smith et al. (2007) that local abundance may be the most important source of variation in detection probability between sample sites, study areas, or years. This is because the probability of detecting a single individual increases as local density increases (Bailey et al. 2004). Methods have been developed to estimate abundance from repeated presence/absence surveys by formalizing the relationship between detection probability and abundance (Royle and Nichols 2003), but the relationship between calling male bobwhites and breeding season abundance is still unknown. Thus, it is not possible at this time to relate detection probability to actual abundance. However, the significantly higher detection probability that we found in the western study area, where bobwhite abundance was higher, shows that estimates of detection probability may be good predictors of relative abundance.

Improving detection probability is important in increasing the reliability and utility of occupancy models (Royle 2006). Maximizing detection probability through survey design will maximize the variation between sample sites and provide the most information about differences between sites (Hansen and Guthery 2001). It is possible to increase the precision of estimates of detection probability through increasing the complexity of the models, but Royle (2006) showed it is better to address this issue with design-based approaches. Sampling during daily and seasonal peaks in calling activity as well as using an appropriate number of sampling occasions per year is most efficient when using summer call-counts for bobwhites (Robel et al. 1969, Hansen and Guthery 2001). Our goal was not to establish parameter estimates for maximizing detection probabilities, but our results agree with Hansen and Guthery (2001) in that detection probability increases throughout June and into late July and should be considered when designing studies. Our assumption that detection probability for bobwhites would be ≥ 0.5 was incorrect for the eastern study area. According to MacKenzie and Royle (2005), if detection probability is < 5, then >3 sampling occasions would be required to obtain accurate estimates of occupancy. Thus, sampling designs requiring ≥ 4 sampling occasions per season should be considered to ensure accurate estimates of occupancy as the status of abundance may be unknown and highly variable between years (i.e., abundance can fall quickly even in areas of suitable habitat due to climatic variation).

Our estimates of occupancy and detection probability between the eastern and western study areas are reflective of the relative differences in abundance between the 2 areas, but they can only be interpreted in terms of the collection of sample units in each area and should not be generalized to the regional level. It is possible, given the time interval between sampling occasions (2–3 weeks), the model assumption that sample units were closed to changes in occupancy over the course of the season was violated. It is certainly possible for individual bobwhites to move into and out of a 400-m sample unit, but our definition of occupancy reflected ongoing use by bobwhites. Thus, while it was likely the number of individuals changed during our sampling, it is unlikely occupancy status would change. Dispersing bobwhites could have colonized unoccupied sample units after sampling was begun, which would have affected our results by biasing our estimate of detection probability low (MacKenzie et al. 2006). This effect can be mitigated by allowing detection probability to vary with survey occasion (MacKenzie et al. 2006).

MANAGEMENT IMPLICATIONS

Monitoring programs that seek to establish the status of a population and detect spatial or temporal changes can use either of 3 variables: (1) abundance, (2) an index of abundance, and (3) occupancy (Hansen and Guthery 2001, Manley et al. 2004, MacKenzie et al. 2006, Johnson 2008). The choice of which variable to use depends on the system under study, specific objectives of the program, and resources available (Bailey et al. 2004, MacKenzie and Royle 2005, MacKenzie et al. 2006). Methods have been developed to obtain density estimates for bobwhites from autumn covey-call counts (DeMaso et al. 1992, Wellendorf et al. 2004, Riddle et al. 2008); however, these methods require considerably more time and expense than summer call-count surveys. The call-count index has been useful for monitoring long-term trends in abundance over large areas (Church et al. 1993, Twedt et al. 2007, Spinola and Gates 2008, Sauer et al. 2011), but violations of assumptions necessary for inference about annual trends in abundance make its reliability for short-term studies questionable (Hansen and Guthery 2001), and there is still disagreement as to what male call counts actually measure (Terhune et al. 2006). Occupancy is not a measure of abundance, but an estimate of the proportion of area occupied by the species of interest. It can be considered to be a crude surrogate for abundance (Bailey et al. 2004, MacKenzie et al. 2006), but it is a fundamentally different variable. The advantages of using occupancy modeling are that occupancy estimates are generally much less costly to obtain than abundance estimates (Manley et al. 2004), and occupancy is less sensitive to variability in detection probability than abundance estimates or indices of abundance (Bailey et al. 2004). The main disadvantages are that models are not reliable when detection probability is extremely low

(MacKenzie et al. 2002) nor are they useful when occupancy is ~1 (Perry et al. 2011).

Occupancy modeling offers a viable alternative to the call-count index for detecting changes in bobwhite populations both spatially and temporally, and may be particularly appropriate for detecting annual changes in areas where populations are low to moderate. That estimates of occupancy are less sensitive than abundance indices to factors affecting detection probability may make it a more stable variable when monitoring population changes over short time periods. When occupancy is ~1, as in our western study area, differences in detection probability may act as a surrogate for relative abundance although this possibility has not, to our knowledge, been explored and should be approached with caution because abundance is only one of the factors that affect detection probability (Anderson 2001). Sampling protocols must ensure that detection probabilities will be > 0.15 to provide accurate estimates of bobwhite occupancy when abundance is extremely low (Bailey et al. 2004).

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LITERATURE CITED

Anderson, D. R. 2001. The need to get the basics right in wildlife field studies. Wildlife Society Bulletin 29:1294–1297.

Anderson, D. R. 2008. Model based inference in the life sciences: a primer on evidence. Springer, New York, USA.

Bailey, L. L., T. R. Simons, and K. H. Pollock. 2004. Estimating site occupancy and species detection probability parameters for terrestrial salamanders. Ecological Applications 14:692–702.

Church, K. E., J. R. Sauer, and S. Droege. 1993. Population trends of quails in North America. Proceedings of the National Quail Symposium 3:44–54.

Conover, W. J. 1999. Practical nonparametric statistics. John Wiley and Sons Inc., New York, USA.

Cram, D. S., R. E. Masters, F. S. Guthery, D. M. Engle, and W. G. Montague. 2002. Northern bobwhite population and habitat response to pine-grassland restoration. Journal of Wildlife Management 66:1031–1039.

DeMaso, S. J., F. S. Guthery, G. S. Spears, and S. M. Rice. 1992. Morning covey calls as an index of northern bobwhite density. Wildlife Society Bulletin 20:94–101.

Fies, M. L., K. M. Puckett, and B. Larson-Brogdon. 2002. Breeding season movements and dispersal of northern bobwhites in fragmented habitats of Virginia. Proceedings of the National Quail Symposium 5:173–179.

Hansen, H. M., and F. S. Guthery. 2001. Calling behavior of bobwhite males and the call-count index. Wildlife Society Bulletin 29:145–152.

Johnson, D. H. 2008. In defense of indices: the case of bird surveys. Journal of Wildlife Management 72:857–868.

Lusk, J. J., F. S. Guthery, R. R. George, M. J. Peterson, and S. J. DeMaso. 2002. Relative abundance of bobwhites in relation to weather and land use. Journal of Wildlife Management 66:1040–1051.

MacKenzie, D. I. 2005. Was it there? Dealing with imperfect detection for species presence/absence data. Australian and New Zealand Journal of Statistics 47:65–74.

MacKenzie, D. I., and J. A. Royle. 2005. Designing occupancy studies: general advice and allocating survey effort. Journal of Applied Ecology 42:1105–1114.

MacKenzie, D. I., J. D. Nichols, N. Sutton, K. Kawanishi, and L. L. Bailey. 2005. Improving inferences in population studies of rare species that are detected imperfectly. Ecology 86:1101–1113.

MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royle, and C. A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248–2255.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Elsevier, San Diego, California, USA.

Manley, P. N., W. J. Zielinski, M. D. Schlesinger, and S. R. Mori. 2004. Evaluation of a multiple-species approach to monitoring species at the ecoregional scale. Ecological Applications 14:296–310.

Murphy, D. A., and T. S. Baskett. 1952. Bobwhite mobility in central Missouri. Journal of Wildlife Management 16:498–510.

Norton, H. W., T. G. Scott, W. R. Hanson, and W. D. Klimstra. 1961. Whistling-cock indices and bobwhite populations in autumn. Journal of Wildlife Management 25:398–403.

Perry, R. W., T. B. Wigley, M. A. Melchiors, R. E. Thill, P. A. Tappe, and D. A. Miller. 2011. Width of riparian buffer and structure of adjacent plantations influence occupancy of conservation priority birds. Biodiversity and Conservation 20:625–642.

Rhodes, J. R., A. J. Tyre, N. Jonzen, C. A. McAlpine, and H. P. Possingham. 2006. Optimizing presence-absence surveys for detecting population trends. Journal of Wildlife Management 70:8–18.

Riddle, J. D., C. E. Moorman, and K. H. Pollock. 2008. A comparison of methods for estimating northern bobwhite covey detection probabilities. Journal of Wildlife Management 72:1437–1442.

Robel, R. J., D. J. Dick, and G. F. Krause. 1969. Regression coefficients used to adjust bobwhite quail whistle count data. Journal of Wildlife Management 33:662–668.

Rosene Jr., W. 1957. A summer whistling cock count of bobwhite quail as an index to wintering populations. Journal of Wildlife Management 21:153–158.

Royle, J. A. 2006. Site occupancy models with heterogeneous detection probabilities. Biometrics 62:97–102.

Royle, J. A., and J. D. Nichols. 2003. Estimating abundance from repeated presence-absence data or point counts. Ecology 84:777–790.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, and D. J. Ziolkowski Jr. 2011. The North American Breeding Bird Survey, results and analysis 1966–2009. Version 3.23.2011. USGS, Patuxent Wildlife Research Center, Laurel, Maryland, USA. www.mbr-pwrc.usgs.gov/bbs/bbs.html

Schwartz, C. C. 1974. Analysis of survey data collected on bobwhite in Iowa. Journal of Wildlife Management 38:674–678.

Smith, J. B., J. A. Jenks, and R. W. Klaver. 2007. Evaluating detection probabilities for American marten in the Black Hills, South Dakota. Journal of Wildlife Management 71:2412–2416.

Spinola, R. M., and R. Gates. 2008. Population status and trends of northern bobwhite (*Colinus virginianus*) in Ohio: 1984–2004. Ohio Journal of Science 108:26–30.

Stoddard, H. L. 1931. The bobwhite quail: it's habits, preservation, and increase. Charles Scribner's Sons, New York, USA.

Terhune, T. M., R. G. Hamrick, D. C. Sisson, and H. L. Stribling. 2006. Summer male call index relative to nesting chronology and autumn density of northern bobwhite. Gamebird 2006: Quail VI and Perdix XII:54–64.

Townsend, D. E., D. M. Leslie Jr., R. L. Lochmiller, S. J. DeMaso, S. A. Cox, and A. D. Peoples. 2003. Fitness costs and benefits associated with dispersal in northern bobwhites (*Colinus virginianus*). American Midland Naturalist 150:73–82.

Trenham, P. C., W. D. Koenig, M. J. Mossman, S. L. Stark, and L. A. Jagger. 2003. Regional dynamics of wetland-breeding frogs and toads: turnover and synchrony. Ecological Applications 13:1522–1532.

Twedt, D. J., R. R. Wilson, and A. S. Keister. 2007. Spatial models of northern bobwhite populations for conservation planning. Journal of Wildlife Management 71:1808–1818.

Veech, J. A. 2006. Increasing and declining populations of northern bobwhites inhabit different types of landscapes. Journal of Wildlife Management 70:922–930.

Wellendorf, S. D., W. E. Palmer, and P. T. Bromley. 2004. Estimating calling rates of northern bobwhite coveys and measuring abundance. Journal of Wildlife Management 68:672–682.

Winter, M., D. H. Johnson, and J. A. Shaffer. 2005. Variability in vegetation effects on density and nesting success of grassland birds. Journal of Wildlife Management 69:185–197.

Zielinski, W. J., and H. B. Stauffer. 1996. Monitoring *Martes* populations in California: survey design and power analysis. Ecological Applications 6:1254–1267.

EXPANDING PREDICTIVE ASSESSMENT OF NORTHERN BOBWHITE COVEY CALLING RATES TO INCORPORATE REGIONAL EFFECTS

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ABSTRACT

Many surveys based on discrete vocalizations make the invalid assumption that individuals present in the survey area are always available for detection (e.g., calling) during the survey period. Northern bobwhites (*Colinus virginianus*) are known to exhibit variable calling rates, particularly during autumn covey surveys. Adjustment of density and abundance estimates to account for calling rate may increase reliability of population metrics, and may increase our ability to effectively assess conservation management. Two previous independent studies across 4 regions used logistic regression to evaluate effects of weather, time, and density covariates on calling rates of radio-marked autumn bobwhite coveys. Results from these studies varied and there is uncertainty regarding application without further investigation into regional differences in calling rates. We combined these data sets comprising known calling rates of 279 bobwhite coveys in 4 regions (Florida, Missouri, North Carolina, and Tennessee) from 1998 to 2000. Observed calling rates averaged 69% over all sites, and ranged from 56 to 80% in the Florida and Missouri regions, respectively. We used binomial logistic regression to evaluate effects of region, adjacent calling coveys, weekly period, change in barometric pressure, percent cloud cover, temperature, and wind speed on covey calling rates. The top ranking model suggested strong effects of region and number of adjacent coveys on calling probability ($P < 0.0001$) with 42% model weight relative to other candidate models. Two competing models suggested inclusion of the 6-hr change in barometric pressure (0100 – 0700 hrs) (18% model weight) or weekly period (17% model weight) might also be appropriate. Validation using the best approximating model (region + adjacent coveys) suggested calling probability estimates were within 6% of the observed calling rate in one region. This suggests the predictive model may provide a valid estimator of calling rate when applied to covey survey data in the appropriate region. However, there is uncertainty regarding application of region-specific model coefficients to survey data outside of these regions. If effects of region are important predictors of calling rate, managers must be cognizant of these prior to adjusting parameter estimates. Further, there is a research need concerning utility and ubiquity of calling rate predictors, particularly for regions that lack known calling rate data.

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Key words: calling rates, *Colinus virginianus*, Florida, Missouri, North Carolina, northern bobwhites, Tennessee

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MONITORING NORTHERN BOBWHITE BREEDING POPULATIONS IN THE CENTRAL HARDWOODS BIRD CONSERVATION REGION

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ABSTRACT

Monitoring northern bobwhite (*Colinus virginianus*) breeding populations is an important component of the National Bobwhite Conservation Initiative as a means of evaluating success of achieving population goals. Northern bobwhite populations declined by 3.8% from 1980 to 2006 in the Central Hardwoods Bird Conservation Region (CHBCR). Northern bobwhite research in the CHBCR is limited and population trend estimates are based on North American Breeding Bird Survey (BBS) data. Monitoring northern bobwhite populations and developing accurate population estimates by incorporating detection functions and occupancy estimates are important components of the conservation initiative in this region. We documented northern bobwhite abundance throughout the CHBCR via a roadside-based removal and distance sampling survey method, and assessed differences in detection with respect to observer, northern bobwhite relative abundance, and land cover. We also addressed the potential for a roadside survey bias to ascertain if there was a seasonal, or site effect on northern bobwhite detection and occupancy through repeated surveys. Finally, we measured northern bobwhite calling rates by time of day and day of the breeding season to assess bobwhite availability for detection with radiotelemetry data. The spatially-balanced, roadside, monitoring strategy used counties as basic sampling units within bobwhite focal areas in the CHBCR ($n = 37$ counties). We randomly located 5, 15-km monitoring routes in each focal county along secondary roads. We conducted 5-min unlimited distance point counts along each route (30 counts/route) from May through July, 2008–2011. We conducted off-road and radiotelemetry surveys on Peabody Wildlife Management Area (PWMA), and additional off-road surveys on Fort Campbell Military Base, Tennessee-Kentucky and on private lands in Livingston County, Kentucky from May through July, 2010–2011.We detected 6,440 individual northern bobwhite on roadside survey routes; >95% of the survey routes had at least 1 northern bobwhite detection. We developed a suite of 17 *a priori* removal models in Program MARK to estimate roadside survey detection probabilities. The best model included differences in time interval detection, observer, and 3 covariates: distance from the observer, number of individuals aurally detected, and percent forested habitat within a 100-m radius of the point count. Detection probabilities were greatest during the first minute of detection, and then decreased. Detection probabilities (± SD) decreased as distance from the observer ($\beta = -0.0020 \pm 0.0005$, $n = 6{,}440$) increased, but increased as the number of individuals detected at a point ($\beta = 0.15 \pm 0.04$, $n = 6{,}440$) increased. We used the most parsimonious model and mean covariate values to generate overall parameter estimates, which differed

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between observers and time intervals. We detected 637 individual northern bobwhite on 90 off-road transects across 4 sites from 2010 to 2011. We developed a suite of 10 *a priori* occupancy models in Program MARK to estimate off-road survey detection probabilities and site occupancy. Detection probabilities were greater ($>$26%) during the second point count visit ($\rho = 0.69 \pm 0.03$) versus first ($\rho = 0.51 \pm 0.04$) and third ($\rho = 0.47 \pm 0.04$) visits ($n = 270$). Detection probability increased as relative abundance increased ($\beta = 2.90 \pm 0.22$, $n = 270$). Occupancy was held constant and was not affected by any covariates evaluated. Peak northern bobwhite detection probabilities occurred from 1 to 25 June, an important consideration for population models that use breeding season survey data. Distance from road was not a significant grouping variable in any of the models, suggesting that roadside bias may not be an important consideration in designing bobwhite monitoring strategies. We located 295 radio-marked male bobwhites from 2010 to 2011. Marked males called on 115 of 295 points (39.0%). The furthest distance a radio-marked male moved during the survey period was 60 m, and movement distances were generally small ($\bar{x} = 4.2 \pm 10.3$ m, $n = 295$). We compared 8 *a priori* time-of-detection models in Program MARK to estimate radiotelemetry survey detection probabilities. We grouped surveys based on year and included time-of-day, and day-of-year as additional temporal covariates. Detection probability was inversely related to time of day ($\beta = -0.04 \pm 0.10$, $n = 105$), but positively related to day of year ($\beta = 0.010 \pm 0.008$, $n = 105$); β estimates overlapped 0 suggested weak relationships. Our results documented the first attempt to explicitly model differences in northern bobwhite detection related to spatial (potential roadside biases, habitat parameters, northern bobwhite distances), temporal (seasonality, annual fluctuations), and behavioral (observer, northern bobwhite relative abundance) variables. We used a combination of 3 methodologies to estimate detection parameters and will adjust indices of relative abundance and density estimates across a broad spatial extent. Our spatially-balanced roadside survey can be effectively used to monitor northern bobwhite populations across broad spatial extents and incorporates the components of detection to improve estimates of northern bobwhite relative abundance.

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Key words: breeding, *Colinus virginianus,* Kentucky, monitoring, northern bobwhite, Tennessee

CALLING RATES OF MALE BOBWHITES DURING SUMMER IN NORTH FLORIDA

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ABSTRACT

The summer call-count survey is a common method used as an index of abundance for male northern bobwhites (*Colinus virginianus*). Typically, abundance estimates have limited use and transference to other analyses because they lack estimates of detection and availability. Incorporating availability into abundance estimates has not been common because of the difficulty in attaining an availability estimate. We monitored the calling rates of radio-marked northern bobwhites, April–July, to ascertain the proportion of males available for detection within biweekly periods to attain a direct measure of availability. We measured daily and seasonal peaks in calling rates and investigated potential parameters that may influence the calling rate. We used a 5-min survey period and observed a mean calling rate of 0.40, which increased to 0.493 when a 10-min survey period was used. The biweekly calling rates were similar during May and June, but were significantly lower in April and July. Daily call rates within the 4-hr survey time period were consistent for May and June, but were more variable in July. Incorporating availability estimates into standard distance sampling procedures allowed us to produce more robust estimates of summer bobwhite density. Little is known about the variability of male bobwhite calling rates regionally or at different densities and we encourage other researchers to attain availability estimates from other landscapes and population densities.

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Key words: call-counts, calling rates, *Colinus virginianus*, Florida, northern bobwhites

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THE TEXAS QUAIL INDEX: EVALUATING PREDICTORS OF NORTHERN BOBWHITE PRODUCTIVITY AND ABUNDANCE USING CITIZEN SCIENCE

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ABSTRACT

Annual abundance of northern bobwhites (*Colinus virginianus*) fluctuates drastically in semi-arid environments (e.g., Texas), which complicates the ability of wildlife biologists and quail managers to predict annual bobwhite productivity and relative abundance for the ensuing hunting season. The Texas Quail Index (TQI) was a 5-year citizen science project that evaluated several indices as predictors of bobwhite productivity and abundance during the subsequent fall. Indices included spring cock-call counts, forb species richness, simulated-nest fate, potential nest-site density, scent station visitation rates, roadside counts, fall covey call counts, and harvest data. Spring cock-call counts explained only 41% of the variation in fall bobwhite abundance across all study sites in years 1–4; yet explained 89% of the variation in year 5. The percentage of juveniles in the fall population (an index of bobwhite productivity) was significantly lower in year 5. All study sites experienced drought conditions throughout year 5 based on the Palmer Drought Severity Index (PDSI). Thus, drought conditions in semi-arid environments result in reduced productivity compared to non-drought years. Our results suggest low recruitment during drought years makes fall bobwhite abundance more predictable than during non-drought years. Wildlife biologists and quail managers should have a better ability to predict bobwhite productivity and fall abundance in drought years by recording spring cock-call counts.

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Key words: call counts, citizen science, *Colinus virginianus*, density estimate, northern bobwhite, population dynamics, predators, quail abundance, reproduction, Texas

INTRODUCTION

Annual abundance of northern bobwhites fluctuates drastically in Texas (Lehmann 1984:124, Peterson 2001), particularly in semiarid regions (Bridges et al. 2001, Lusk et al. 2005). The exact mechanism(s) governing these fluctuations is still unclear (Hernández and Peterson 2007), although weather accounts for much of this variation in bobwhite populations (Bridges et al. 2001, Lusk et al. 2005). Quail managers in these regions lease trespass-rights to quail hunters dependent upon quail abundance. Drastic population fluctuations complicate forecasting, scheduling, and overall harvest management. Thus, quail managers need a practical and reliable method to forecast quail abundance on their property well before (≥ 6 months) the hunting season.

The Texas Quail Index (TQI) was a 5-year (2002–2006) citizen science project that assessed the relationship between indices of quail abundance, habitat conditions, and bobwhite abundance during the following quail hunting season. Indices included spring cock-call counts, forb species richness, simulated-nest fate, potential nest-site density, scent station visitation rates, roadside counts, fall covey call counts, and harvest data.

Previous studies evaluated the forecasting efficacy of a variety of indices of quail abundance, including spring cock-call counts (Bennitt 1951, Reeves 1954, Rosene 1957, Brown et al. 1978), roadside counts (Peterson and Perez 2000), and fall covey-call counts (Roseberry and Klimstra 1984, Guthery 1986:138–141, DeMaso et al. 1992). Spring cock-call counts are an inexpensive way to index quail populations over an extensive area and are good indicators of breeding potential (Hansen and Guthery 2001, Rollins et al. 2005), but results differ as to whether spring cock-call counts are effective predictors of quail abundance for the following hunting season (Rosene 1957, Norton et al. 1961, Ellis et al. 1972, Snyder 1984). Fall covey-calls of bobwhites are thought to

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primarily function to announce a covey's location to neighboring coveys (Wellendorf and Palmer 2004). Stoddard (1931), Roseberry and Klimstra (1984), and DeMaso et al. (1992) used fall covey-call counts to index fall quail abundance and spatial distribution. These indices have been criticized as measures of abundance (Norton et al. 1961, Anderson 2001), but may enable detection of relative differences in populations among areas or years (Guthery 2000:103, Engeman 2003).

Forb species richness indicates the diversity of forbs that produce seeds and host insects that are consumed by quail (Stoddard 1931), and which are vital for chick survival (Guthery 2000). Bobwhites typically nest in a bunchgrass about 0.4 m in diameter (e.g., little bluestem [*Schizachyrium scoparium*]), or a clump of prickly pear (*Opuntia* spp.) about 1.0 m in diameter (Hernández et al. 2001, Slater et al. 2001), and we recorded the density of potential nesting sites.

Reliable estimates of the abundance of most carnivores, due to their elusiveness, are difficult and expensive to obtain (Sargeant et al. 2003). Thus, biologists may rely on indices of relative abundance (i.e., scent-station visitation rates; Travaini et al. 1996, Warrick and Harris 2001) with varying success (Conner et al. 1983, Minser 1984, Nottingham et al. 1989, Diefenbach et al. 1994, Sargeant et al. 2003). Simulated quail-nest fate also provides an index of actual bobwhite nest success (% nests intact) relative to habitat condition and predator activity (Hernández et al. 2001, Slater et al. 2001, Buntyn 2004).

The ratio of juveniles to adults in the fall harvest is often used as an index of production (Stoddard 1931, Pollock et. al 1989, Roseberry and Klimstra 1992, Flanders-Wanner et al. 2004). However, age ratios can be misleading as they reflect relative survival of adults, as well as their productivity (Guthery 2000), and the differential vulnerability of adults and juveniles to harvest (Pollock et. al. 1989, Shupe et al. 1990, Roseberry and Klimstra 1992). As a result, Guthery (2000) recommended using an index of quail population density (e.g., hunting success rates) in conjunction with age ratios.

The TQI used citizen scientists (i.e., trained volunteers) to record all indices for 3 reasons: (1) citizen science is practical and affordable in projects where collection of data is large-scale, time-sensitive, and funding is limited (Altizer et al. 2004); (2) it has been used increasingly for survey and monitoring animal populations (Lepczyk 2005); and (3) it is a tool to educate the public about science while collecting useful data (Brossard et al. 2005). Our objectives were to: (1) identify which (if any) indices were good predictors of fall abundance of bobwhites, and (2) inform landowners, ranch managers, and local land support personnel (i.e., state biologists or county extension agents) on ways to assess their quail populations, while collecting useful data.

STUDY AREA

Study sites were in 59 Texas counties (Fig. 1), including 65 private ranches and 6 Wildlife Management Areas, in 5 ecological regions of Texas (Gould 1975). Twenty-three counties were in the Rolling Plains, 13 in the Edwards Plateau, 11 in the Cross Timbers and Prairies, 10 in the South Texas Plains, and 2 in the Trans-Pecos ecoregions.

METHODS

Cooperator Recruitment and Training

We mailed invitations to participate in the TQI to county Texas AgriLife Extension agents, agency biologists (e.g., Texas Parks and Wildlife Department), and private landowners in Texas. New cooperators attended a 2-day training session in April each year. This included classroom instruction, field training, and testing to ensure cooperators were capable of conducting each survey on their respective sites. Each cooperator also received a packet including detailed instructions and materials necessary to follow TQI protocols. A web site (teamquail.tamu.edu) provided appropriate literature and data sheets for cooperators including contact information for the TQI coordinator—the primary point of contact.

Establishing Permanent Transects

Each cooperator established a 16-km, road-based permanent transect on their property with data collection points (i.e., numbered signs attached to steel t-posts) established at 1.6-km intervals (Bennitt 1951, Brown et al. 1978). Transects along existing ranch roads, at times, were not straight, but were chosen to minimize overlap of the presumed 600-m radius of audibility for bobwhites (Rollins et al. 2005) between data collection point locations. Cooperators selected a transect location sufficiently removed from heavily-traveled roads that was representative of the habitat types on the property. Each cooperator recorded their transect on a map for approval by the TQI coordinator.

Potential Indices of Bobwhite Abundance

We selected 5 indices of bobwhite abundance to be monitored by cooperators: spring cock-call counts, forb species richness, simulated-nest fate, potential nest-site density, and scent station visitation rates.

Spring Cock-call Counts.—Cooperators counted the number of calling males heard at each data collection point ($n = 11$) and recorded the approximate location (distance and direction from the collection point) of each male detected (Guthery 1986, Rollins et al. 2005) during a 5-min span (Reeves 1954, Rosene 1957, Hansen and Guthery 2001), at, or just prior to official sunrise (Bennitt 1951, Norton et al. 1961, Hansen and Guthery 2001). All counts were to be completed within $\sim$ 1.5 hrs. Counts were replicated 3 or 4 times (Smith and Gallizioli 1965) between 1 May and 1 June, and were not conducted during rain or when winds exceeded 16 km/hr. Cooperators reported the average number of calling bobwhites/stop as the spring cock-call index.

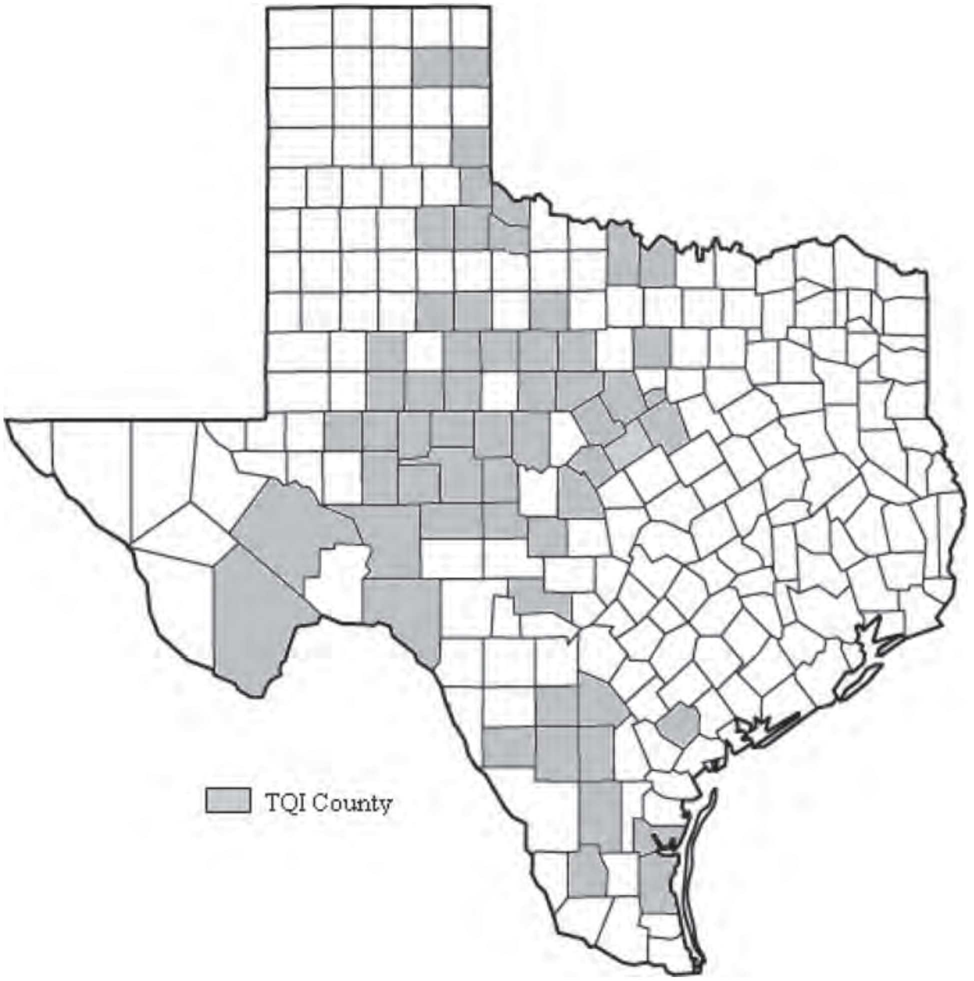

Fig. 1. Distribution of Texas Quail Index study sites by county, 2002–2006.

Forb-species Richness.—Cooperators recorded forb species richness by tossing a 1-m diameter circular quadrat over their shoulder at each collection point. The ultimate location of the circular quadrat served as a random sampling point. Cooperators recorded the number of different forb species rooted within the quadrat, and recorded the average for all points as the forb diversity index.

Simulated-nest Fate.—A 300-m nesting transect was established perpendicular to the permanent transect at 6 randomly selected data collection points. Cooperators established a simulated nest at 50-m intervals in a suitable nesting substrate, typically a bunchgrass about 0.5 m in diameter (e.g., little bluestem), or a clump of prickly pear about 1.0 m in diameter (Hernández et al. 2001, Slater et al. 2001). Cooperators recorded the coordinates of the nest for ease of relocation. Cooperators placed 3 domestic chicken eggs and a steel washer (2.0-cm diameter) in each nest. The steel washer increased the probability of finding the nest bowl when eggs were missing. Cooperators replaced eggs in non-disturbed nests after 14 days and wore latex gloves while handling eggs to reduce human scent (Whelan et al. 1994). Cooperators recorded fate of simulated nests as intact or depredated at 14 and 28 days after establishment (spanning the 23-day incubation period of bobwhites; Stoddard 1931). Nests were considered depredated if ≥ 1 egg was rolled out of the nest bowl or destroyed. The percentage of nests intact after 14 days of exposure was the simulated-nest index.

Potential Nest Sites.—Cooperators, after establishing simulated-nests, walked back to the data collection point (300 m from the last simulated-nest) holding their arms out straight at shoulder height, perpendicular to their body and recorded the number of potential nests sites (i.e., suitable nesting substrates) rooted within their arms' span ($\sim$ 2 m for a person 2 m in height; Rollins et al. 2005). The density of potential nest sites was reported as the potential nest site index.

Scent-station Visitations.—The TQI scent-station protocol followed Linhart and Knowlton's (1975) general methodology and incorporated Roughton and Sweeny's (1982) recommended modifications. Cooperators removed all vegetation and debris from a circular area 1-m in diameter and covered the area with a smooth layer of tracking substrate (i.e., flour), at each data collection point in May. Flour enabled detection of visitation to a scent lure (fatty acid scent tablet; Pocatello Supply Depot, Pocatello, ID, USA) placed in the center of the station.

Table 1. Stepwise multiple regression data for the Texas Quail Index. Transformed fall covey-call counts ($FC_t = \ln$ [fall covey-call counts + 1]) were used as the dependent variable.

Independent variable	Standardized coefficient	Significance
Spring cock-call counts	0.675	<0.001
Habitat photo points	0.157	0.301
Forb species richness	−0.200	0.187
Simulated-nest fate	0.147	0.338
Predator scent-stations	0.085	0.586
Potential nest sites	−0.004	0.981

The following morning, cooperators recorded the presence or absence of tracks of individual carnivore species. Cooperators repeated the process for 2 consecutive nights replenishing flour and lure as needed for day 2. The average of the 2 nights comprised the predator scent-station index (mean number of visits/100 scent-station nights [SSN]). Precipitation, wind, or non-target animals (e.g., livestock) occasionally obliterated stations; these occurrences were censored in the analysis.

Measures of Bobwhite Abundance

We selected 3 indices of bobwhite abundance during the fall to be recorded by cooperators: (1) roadside counts, (2) fall covey-call counts, and (3) harvest data.

Roadside Counts.—Cooperators recorded the number of bobwhites visually observed as they drove transects at $\leq$ 33.3 km/hr within 1.5 hrs of either dawn or dusk on 3 different days during the first 2 weeks of September (Peterson and Perez 2000). The direction of travel along transects alternated between successive counts. The average of all counts comprised the roadside count index.

Fall Covey-call Counts.—Fall covey-call counts were conducted at 1 data collection point per morning because fall covey-calls are elicited for $<$ 20 min during the early morning. Counts began $\sim$ 40 min before official sunrise (typical covey calling time; Rosene 1957). Cooperators recorded the number of coveys calling and the approximate location (distance and direction from the data collection point) of each covey calling. Call counts were not conducted during rain or when winds exceeded 16 km/hr. Cooperators repeated fall covey-call counts at 2 to 4 randomly selected data collection points between 1 October and 15 November (Wellendorf and Palmer 2004). The average of all counts was the fall covey-call index (number of coveys calling/stop).

Harvest Data.—Cooperators recorded 2 harvest variables during quail hunts from November to February: (1) number of coveys flushed per hour of hunting effort (an index of density), and (2) percentage of juveniles in the hunter's bag. Cooperators recorded age of bobwhites from an examination of the primary coverts (Stoddard 1931, Guthery 2000).

Statistical Analyses

We used the Statistical Package for the Social Sciences (SPSS; Chicago, IL, USA) Version 15.0 to analyze data from each study site. An observation consisted of 1 year of data per study site. We evaluated 6 spring and summer indices as predictors of hunting-season bobwhite abundance using multiple regression analysis with stepwise inclusion of variables (Ott and Longnecker 2001).

The candidate independent variables were spring cock-call counts (SC), forb species-richness (FD), simulated-nest fate (SN), predator scent-stations (PS), and potential nest sites (PN). Dependent variables were the number of coveys flushed/hour of hunting effort (CF), roadside counts (RC), and fall-covey counts (FC). We used fall-covey counts as the dependent variable for our analysis due to the variation of roadside counts (coefficient of variation = 1.30) and the low sample size of cooperators that recorded the number of coveys flushed per hour of hunting effort ($n = 5$). Fall-covey counts were strongly correlated with coveys flushed per hour of hunting effort on sites where recorded ($r = 0.81$).

We transformed fall covey counts to achieve normality ($P = 0.2$) as ($FC_t = \ln [FC + 1]$). A Breusch-Pagan (1979) test indicated that FC_t met constant variance assumptions ($P = 0.29$, α-level = 0.01). All tests used an *alpha*-level of 0.05 to denote statistical significance unless otherwise stated. We used FC_t as the dependent variable for an initial regression equation of

$$FC_t = \beta_0 + \beta_1(SC) + \beta_2(FD) + \beta_3(SN) + \beta_4(PS) + \beta_5(PN) + \varepsilon,$$

where β_o is the intercept, β_1–β_6 are slopes of the corresponding indices, and ε is error. An *alpha*-level of 0.05 was used for inclusion of variables and 0.10 for removal of variables. We used analysis of covariance (Ott and Longnecker 2001) to test for variation among years and ecological regions. The test equation was

$$FC_t = \beta_{0i} + \beta_{1i}(SC) + \varepsilon,$$

where $i = 1$–5 for years 2002–2006 respectively, or $i = 1$–4 for ecoregions (1 = Rolling Plains, 2 = Edwards Plateau, 3 = Cross Timbers, 4 = South Texas Plains). We used a Fisher's least significant difference (LSD) procedure (Ott and Longnecker 2001) to examine which year(s) explained more of the variation in FC_t.

RESULTS

Data Collection

Seventy-six cooperators returned 165 data sets over the 5 years of data collection. Only 7.8% of the data sets were complete and 86% were missing covey flushes per hour of hunting effort, our only fall density index. However, 68% contained at least one index of fall abundance (68% contained roadside counts, and 51% fall covey-call counts). Thus, we had 84 data sets suitable for analysis.

Data Evaluation

A multiple regression analysis with stepwise inclusion of variables removed all variables except spring

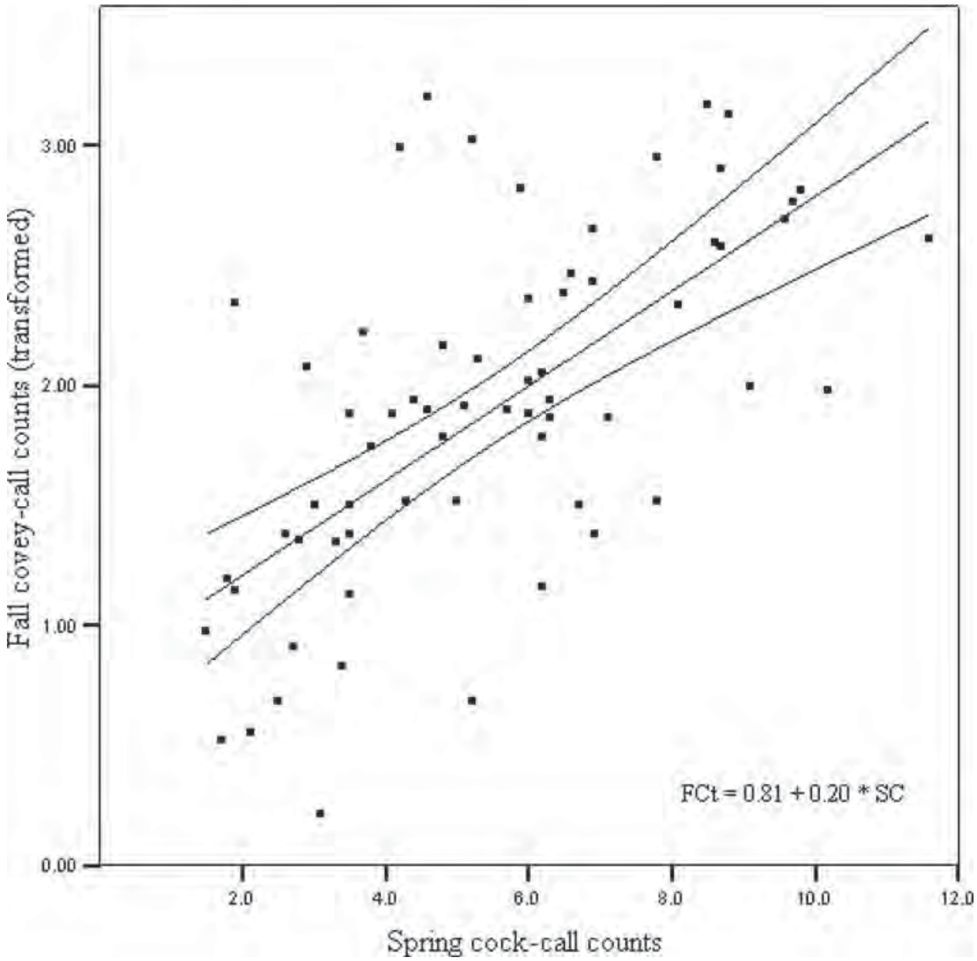

Fig. 2. Fall covey-call counts (transformed; $FC_t = \ln$ [fall covey-call counts + 1]) plotted versus spring cock-call counts for years 1–4 of the Texas Quail Index (2002–2005). Predicted line and 95% confidence intervals around the line are given ($P < 0.01$, $R^2 = 0.41$).

cock-calls from the regression model (Table 1; $P < 0.0001$, $R^2 = 0.440$) indicating spring cock-calls explained 44% of the variation in fall covey-calls for all study sites across all years. An ANCOVA showed variation in predictability among years, ($P = 0.004$, $R^2 = 0.389$), and no correction factor was needed for ecological region ($P = 0.244$). A Fisher's LSD procedure indicated the equation for year 5 was different from all other years ($P = 0.008$) resulting in 2 distinct prediction models. The equation for years 1–4 was $FC_t = 0.81 + 0.20*SC$ ($P < 0.01$, $R^2 = 0.41$; Fig. 2), and the equation for year 5 was $FC_t = -0.04 + 0.51*SC$ ($P < 0.01$, $R^2 = 0.89$; Fig. 3). Individual index results are available in Reyna (2008)

DISCUSSION

We sought to develop a practical and reliable predictor of fall bobwhite abundance that quail managers could use to assess their bobwhite population. The 5-year regression model showed spring cock-calls were significant predictors of FC_t but the R^2 value indicated that only 41% of the variation in FC_t was explained by spring cock-call counts (not a reliable predictor). There was a difference in the relationship between spring cock-call counts and FC_t among years; the equations for years 1–4 did not differ significantly but year 5 yielded an entirely different equation with less variability and more predictability. We were curious if weather variables (e.g., drought conditions) explained any variation in FC_t since other studies have demonstrated correlations between quail abundance and weather (Bridges et al. 2001, Guthery et al. 2001).

We examined the monthly Palmer Drought Severity Index (PDSI) (Palmer 1965) for 2002–2006 and found 2006 (year 5) to be a drought year for the TQI ecological regions and the state of Texas (NOAA 2008). The PDSI is the monthly value (meteorological drought index) generated to indicate the severity of a wet or dry period by measuring the departure from the normal regional moisture supply (Palmer 1965). It is based on the principles of a balance between moisture supply and vegetation demand (Palmer 1965). Bridges et al. (2001) found the PDSI was a better indicator of changes in northern bobwhite abundance than raw precipitation alone, especially in dry ecological regions. Our data support the findings of Bridges et al. (2001) and further show that spring cock-call counts were better indicators of

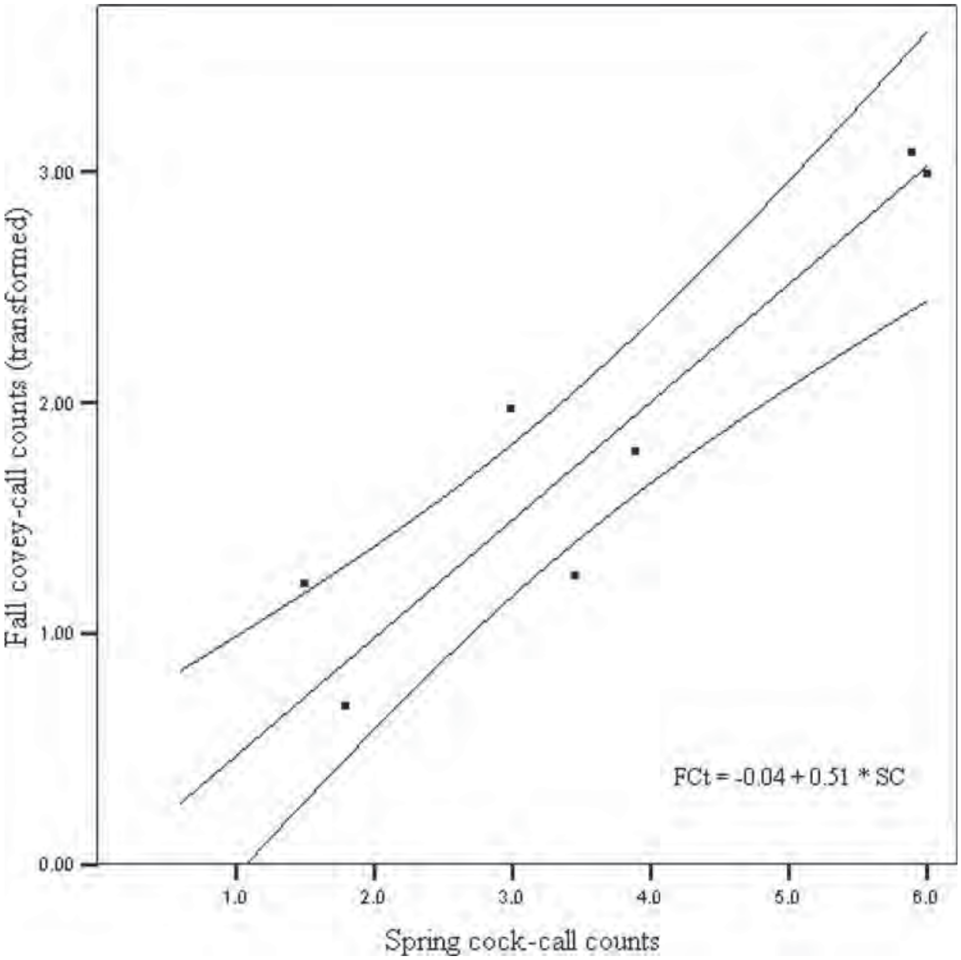

Fig. 3. Fall covey-call counts (transformed; $FC_t = \ln$ [fall covey-call counts + 1]) plotted versus spring cock-call counts for year 5 of the Texas Quail Index (2006). Predicted line and 95% confidence intervals around the line are given ($P < 0.01$, $R^2 = 0.89$).

hunting-season bobwhite abundance during drought years than during non-drought years.

Low breeding success due to heat (Guthery et al. 2001), or drought (Bridges et al. 2001) may be the reason that spring cock-call counts explained 89% of FC_t in the drought year which had a significantly lower percentage of juveniles than in other years (Fig. 4; Reyna 2008). Guthery et al. (2001) recorded temperatures during the nesting season that were sufficient (>39°C) to suppress bobwhite production (by killing bobwhite embryos, chicks, and adults); accelerate the onset of incubation (disrupting synchronous hatching); reduce the length of the laying season (inhibiting renesting and multiple-brooding); and reduce the number of males and females in reproductive condition. These are likely repercussions of the drought year and may explain the variation in breeding success between 'boom' and 'bust' years.

Debate continues regarding the reliability of data collected by citizen scientists (Irwin 1995, Fore et al. 2001, McCaffrey 2005). The large variation in the fall data might be attributed to: (1) inexperience of citizen scientists (Irwin 1995, Fore et al. 2001); (2) inherent variability in discerning unique coveys calling (DeMaso et al. 1992, Irwin 1995); or (3) inconsistent data collection at a site among years, as well as the low rate of return of complete data sets which reduced the sample size and affected the results of the data analysis (Reyna 2008).

Irwin (1995) and Fore et al. (2001) suggested that inexperienced citizen scientists can contribute to inflated variation in data. It can be assumed that as cooperators became more familiar with the protocols, they became better at collecting the data, thus reducing variation in later years. The TQI had additional sources of observer inexperience where untrained family members or friends would collect data when needed, although the occurrence was rare. DeMaso et al. (1992) found variation among observers in the number of coveys identified during morning covey-call surveys, and suggested that identifying unique calls would especially be a concern where fall populations were large (e.g., > 7 coveys/stop; Ellis et al. 1972). This may explain why more variation in the data was observed during non-drought years (when bobwhite population numbers were higher) than in the drought year. The initial cooperator dropped out of the program on 66% of the sites and had to be replaced (Reyna 2008). The new cooperator attended training in each case, but an observer effect may have contributed to errors as a result of different skill levels and hearing abilities of the new cooperator.

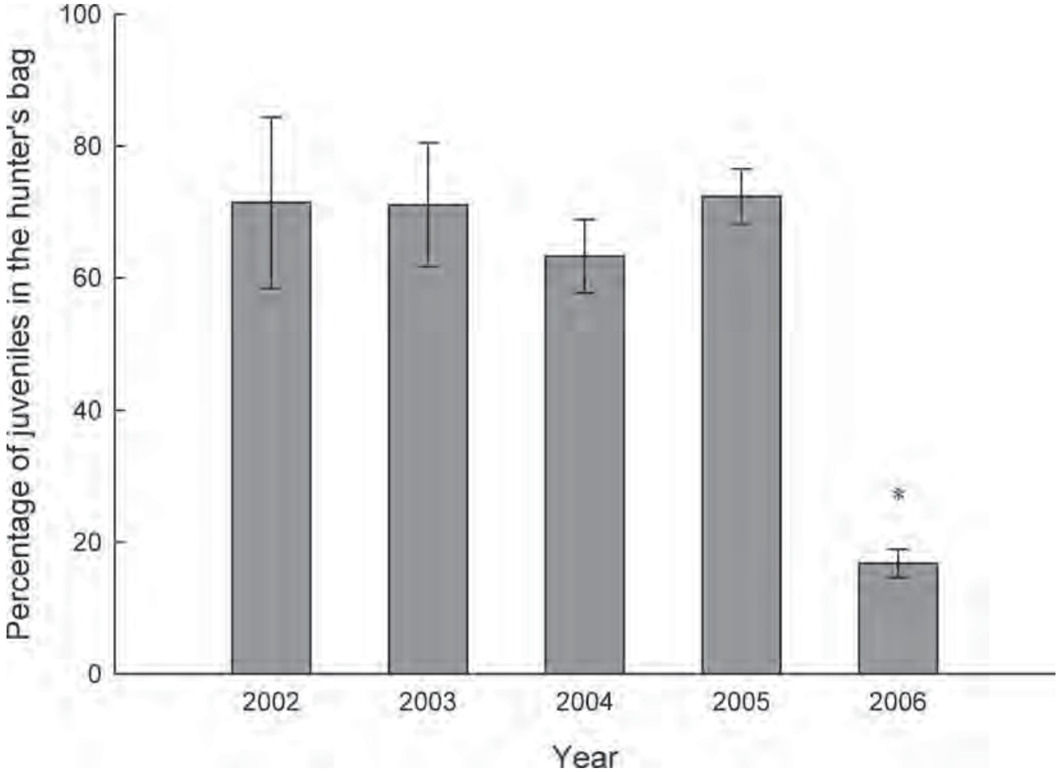

Fig. 4. Mean (± SE) percentage of juveniles in the hunter's bag at 7 Texas Quail Index study sites from 2002 to 2006 (modified from Reyna 2008). Severe drought conditions were experienced across all study sites in 2006, which was significantly* different from all other years ($P = 0.008$).

TQI cooperators were trained and tested on their ability to implement TQI protocols, but were only trained once (at the onset of their participation) and were subsequently responsible for adhering to TQI protocols (Reyna 2008). Some minor protocol violations were made (e.g., inconsistent data collection methods at a site among years) that could have affected our results. Moreover, a few major violations were reported, such as inflating roadside count numbers to attract hunters or missing peak calling times (Reyna 2008). These records were censored before analysis, but the inconsistencies and errors suggest inadequate scientific rigor (Irwin 1995), which should urge caution when evaluating research involving citizen science projects. We believe citizen science is a useful tool to teach citizens about science, conservation, or land stewardship (McCaffrey 2005) and to monitor general trends in bird populations (e.g., Christmas Bird Counts; Lepczyk 2005) but not for scientific data collection in projects that have minimal supervision and do not require annual training.

MANAGEMENT IMPLICATIONS

Spring cock-call counts were better indicators of FC_t in drought years, possibly because of a lower percentage of juveniles in the fall population, or fewer total birds overall. Observer accuracy was more likely to improve with fewer calling birds (Ellis et al. 1972) resulting in less overall variability in the data. A rigorous scientific method was not established but we believe, on a local level, that wildlife managers will find recording spring cock-call counts in conjunction with the Palmer drought indices useful, This should provide a better indication of the trend in their bobwhite abundance as well as an increased ability to predict the declines of their fall bobwhite population abundance in drought years. Seasons with low bobwhite reproduction are the most critical to sustaining a hunting operation because landowners may need to supplement their income with other sources. Our results may be economically and ecologically expedient by providing a 5-month forewarning of a poor upcoming season.

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LITERATURE CITED

Altizer, S., W. M. Hochachka, and A. A. Dhondt. 2004. Seasonal dynamics of mycoplasmal conjunctivitis in eastern North

American house finches. Journal of Animal Ecology 73: 309–322.

Anderson, D. R. 2001. In my opinion: the need to get the basics right in wildlife field studies. Wildlife Society Bulletin 29: 1294–1297.

Bennitt, R. 1951. Some aspects of Missouri quail and quail hunting 1938–1948. Technical Bulletin 2. Missouri Conservation Commission, Jefferson City, USA.

Breusch, T. S., and A. R. Pagan. 1979. A simple test for heteroscedasticity and random coefficient variation. Econometrica 47: 1287–1294.

Bridges A. S., M. J. Peterson, N. J. Silvy, F. E. Smeins, and B. Wu. 2001. Differential influence of weather on regional quail abundance in Texas. Journal of Wildlife Management 65: 10–18.

Brossard, D., B. Lewenstein, and R. Bonney. 2005. Scientific knowledge and attitude change: the impact of a citizen science project. International Journal of Science Education 27: 1099–1121.

Brown, D. E., C. L. Cochran, and T. E. Waddell. 1978. Using call-counts to predict hunting success for scaled quail. Journal of Wildlife Management 42: 281–287.

Buntyn, R. J. 2004. Reproductive ecology and survival of scaled quail in the Trans-Pecos region of Texas. Thesis. Angelo State University, San Angelo, Texas, USA.

Conner, M. C., R. F. Labisky, and D. R. Progulske Jr. 1983. Scent-station indices as measures of population abundance for bobcats, raccoons, gray foxes and opossums. Wildlife Society Bulletin 1: 146–152.

Diefenbach, D. R., M. J. Conroy, R. J. Warren, W. E. James, L. A. Baker, and T. Hon. 1994. A test of scent-station survey technique for bobcats. Journal of Wildlife Management 58: 10–17.

DeMaso, S. J., F. S. Guthery, G. S. Spears, and S. M. Rice. 1992. Morning covey calls as an index of northern bobwhite density. Wildlife Society Bulletin 20: 94–101.

Ellis, J. A., K. P. Thomas, and P. Moore. 1972. Bobwhite whistling activity and population density on two public hunting areas in Illinois. Proceedings of the National Quail Symposium 1: 282–288.

Engeman, R. M. 2003. More on the need to get the basics right: population indices. Wildlife Society Bulletin 31: 286–287.

Flanders-Wanner, B. L., G. C. White, and L. L. McDaniel. 2004. Validity of prairie grouse harvest-age ratios as production indices. Journal of Wildlife Management 68: 1088–1094.

Fore, L. S., K. Paulsen, and K. O'Laughlin. 2001. Assessing the performance of volunteers in monitoring streams. Journal of Freshwater Biology 46: 109–123.

Gould, F. W. 1975. Texas plants: a checklist and ecological summary. Miscellaneous Publication 585. Texas Agricultural Experiment Station, College Station, USA.

Guthery, F. S. 1986. Beef, brush and bobwhites. Caesar Kleberg Wildlife Research Institute, Kingsville, Texas, USA.

Guthery, F. S. 2000. On bobwhites. Texas A&M University Press, College Station, USA.

Guthery, F. S., C. L. Land, and B. W. Hall. 2001. Heat loads on reproducing bobwhites in the semiarid subtropics. Journal of Wildlife Management 65:111–117.

Hansen, H. M., and F. S. Guthery. 2001. Calling behavior of bobwhite males and the call-count index. Wildlife Society Bulletin 29: 145–152.

Hernández, F., and M. J. Peterson. 2007. Northern Bobwhite ecology and life history. Pages 40–64 *in* L. A. Brennan, ed. Texas quails: ecology and management Texas A&M University Press, College Station, USA.

Hernández, F., S. Henke, N. Silvy, and D. Rollins. 2001. Comparison of success between actual northern bobwhite and wild turkey nests and simulated nests. Wildlife Society Bulletin 29: 1212–1218.

Irwin, A. 1995. Citizen science: a study of people, expertise and sustainable development. Routledge, London, England.

Lehman, V. W. 1984. Bobwhites in the Rio Grande Plain of Texas. Texas A&M Press, College Station, USA.

Lepczyk, C. A. 2005. Integrating published data and citizen science to describe bird diversity across a landscape. Journal of Applied Ecology 42: 672–677.

Linhart, S. B., and F. F. Knowlton. 1975. Determining the relative abundance of coyotes by scent station lines. Wildlife Society Bulletin 3: 119–124.

Lusk, J. J., F. S. Guthery, M. J. Peterson, and S. J. DeMaso. 2005. Evidence for regionally synchronized cycles in Texas quail population dynamics. Journal of Wildlife Management 71: 837–843.

McCaffrey, R. E. 2005. Using citizen science in urban bird studies. Urban Habitats 3 (1). www.urbanhabitats.org/v03n01/citizenscience_full.html

Minser III, W. G. 1984. Comment on scent-station method for monitoring furbearers. Wildlife Society Bulletin 12: 328.

National Oceanic and Atmospheric Administration (NOAA). 2008. National Climatic Data Center database of the Palmer Drought Severity Index for the United States 1895–2008. U.S. Department of Commerce, National Climatic Data Center-NOAA, Asheville, North Carolina, USA. ftp.ncdc.noaa.gov/pub/data/cirs/

Norton, H. W., T. G. Scott, W. R. Hanson, and W. D. Klimstra. 1961. Whistling-cock indices and bobwhite populations in autumn. Journal of Wildlife Management 25: 398–403.

Nottingham Jr., B. G., K. G. Johnson, and M. R. Pelton. 1989. Evaluation of scent-station surveys to monitor raccoon density. Wildlife Society Bulletin 171: 29–35.

Ott, R. L., and M. Longnecker. 2001. An introduction to statistical methods and data analysis. Fifth edition. Duxbury, Pacific Grove, California, USA.

Palmer, W. C. 1965. Meteorological drought. Weather Bureau Research Paper Number 45. U. S. Department of Commerce, Washington, D.C., USA.

Peterson, M. J. 2001. Northern bobwhite and scaled quail abundance and hunting regulation: a Texas example. Journal of Wildlife Management 65: 828–837.

Peterson, M. J., and R. M. Perez. 2000. Is quail hunting self regulatory? Northern bobwhite and scaled quail abundance and quail hunting in Texas. Proceedings of the National Quail Symposium 4: 85–91.

Pollock, K. H., C. T. Moore, W. R. Davidson, F. E. Kellogg, and G. L. Doster. 1989. Survival rates of bobwhite quail based on band recovery analysis. Journal of Wildlife Management 53: 1–6.

Reeves, M. C. 1954. Bobwhite quail investigation. Indiana Department of Conservation, Division of Fish and Game, Indianapolis, USA.

Reyna, K. S. 2008. The Texas Quail Index: evaluating predictors of quail abundance using citizen science. Thesis. Texas A&M University, College Station, USA.

Rollins, D., J. Brooks, N. Wilkins, and D. Ransom Jr. 2005. Counting quail. Texas AgriLife Extension Bulletin 6173. College Station, USA.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, USA.

Roseberry, J. L., and W. D. Klimstra. 1992. Further evidence of differential harvest rates among bobwhite sex-age groups. Wildlife Society Bulletin 20: 91–94.

Rosene Jr., W. 1957. A summer whistling-cock count of bobwhite quail as an index to wintering populations. Journal of Wildlife Management 21: 153–158.

Roughton, R. D., and M. W. Sweeney. 1982. Refinement in scent-station methodology for assessing trends in carnivore populations. Journal of Wildlife Management 46: 217–229.

Sargeant, G. A., D. H. Johnson, and W. E. Berg. 2003. Sampling designs for carnivore scent-station surveys. Journal of Wildlife Management 67: 289–298.

Shupe, T. E., F. S. Guthery, and R. L. Bingham. 1990. Vulnerability of bobwhite sex and age classes to harvest. Wildlife Society Bulletin 18: 24–26.

Slater, S. C., D. Rollins, and R. L. Dowler. 2001. *Opuntia*: a "prickly paradigm" for quail management in west Texas. Wildlife Society Bulletin 29: 713–719.

Smith, R., and S. Gallizioli. 1965. Predicting hunter success by means of a spring call count of Gambel's quail. Journal of Wildlife Management 29: 806–813.

Snyder, W. D. 1984. Management procedures for northern bobwhites in eastern Colorado. Special Report 56. Colorado Division of Wildlife, Fort Collins, USA.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. Charles Scribner's Sons, New York, USA.

Travaini, A., R. Laffitte, and M. Delibes. 1996. Determining the relative abundance of European red foxes by scent-station methodology. Wildlife Society Bulletin 24: 500–504.

Warrick, G. D., and C. E. Harris. 2001. Evaluation of spotlight and scent-station surveys to monitor kit fox abundance. Wildlife Society Bulletin 29: 827–832.

Wellendorf, S. D., and W. E. Palmer. 2004. Conducting early morning covey call point counts standard operating procedure. Tall Timbers Research Station, Tallahassee, Florida, USA. www.talltimbers.org/research/images/coveysurveyguidelines9-21-04.pdf

Whelan, C. J., M. L. Dilger, D. Robson, N. Hallyn, and S. Dilger. 1994. Effects of olfactory cues on artificial-nest experiments. Auk 111: 945–952.

SUMMER WHISTLE COUNTS, ROADSIDE COUNTS, AND FALL ABUNDANCE OF NORTHERN BOBWHITE

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ABSTRACT

Reliable information on fall abundance of northern bobwhite (*Colinus virginianus*) is important for proper harvest management. Aerial surveys can provide reliable estimates of abundance, but can be expensive. Alternatively, whistle counts and roadside counts are indices of abundance that are relatively inexpensive, simple, and commonly used by biologists. We compared whistle and roadside counts conducted during summer to fall relative abundance (coveys/km) estimates obtained using helicopter surveys. All data were collected at the pasture scale (mean = 1,716–2,762 ha) on the King Ranch (334,000 ha), which is comprised of 4 divisions across South Texas. Average survey effort was 245 km/year (1999–2001) and 1,194 km/year (1999–2007) for whistle and roadside counts, respectively, and 48 km/pasture/year (1999–2009) for fall helicopter surveys. Preliminary analyses demonstrate a moderate correlation between whistling bobwhite males and fall relative abundance ($r = 0.68$). We collected age-based (i.e., chicks, juveniles, and adults) and population structure-based (i.e., singles, pairs, or coveys) data for roadside counts. Correlations between roadside counts and fall relative abundance varied by age and population structure. We found moderate correlation between total juveniles and fall relative abundance ($r = 0.49$); all other correlations were low ($r = <0.36$). We explore the feasibility of using summer whistle and roadside counts as a surrogate for fall relative abundance and discuss optimum timing to conduct surveys.

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Key words: *Colinus virginianus*, count methodology, northern bobwhite, South Texas

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DO RESIDENT AND NON-RESIDENT NORTHERN BOBWHITE HUNTERS SELF-REGULATE HARVEST BASED ON POPULATION SIZE?

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ABSTRACT

A variety of factors influence the relative strength of additive and compensatory mortality of harvest on northern bobwhite (*Colinus virginianus*) including covey dynamics, habitat fragmentation, and timing of harvest. State wildlife agencies have long believed regulations could be liberal because hunters will self-regulate effort when populations decrease. A confounding observation is that with lower population abundances, hunter skill and harvest rate increases because the more novice hunters do not participate. This raises the question whether non-resident small game hunters could have a larger impact at lower population levels if they have (1) more money to dedicate to out of state licenses and travel/lodging, and (2) time to dedicate to the hunting experience? We examined long-term bobwhite population and harvest data from Kansas (1966–1999) to learn if self-regulation differed between resident and non-resident small game hunters. The number of resident and non-resident small game hunters was related to their respective harvest of northern bobwhites. Decreasing October population index was associated with a decline in the number of resident bobwhite hunter days and harvest. Conversely, increasing numbers of non-resident hunters participated in the hunting season with higher hunter efficiency and a larger harvest at lower October population index levels. Total relative harvest decreased overwinter (Oct–Jan) survival. The Kansas resident bobwhite harvest is probably self-regulatory but non-resident harvest is not. Future harvest regulations should consider the impact of non-resident harvest.

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Key words: *Colinus virginianus*, hunting, nonresident, northern bobwhite, resident, self-regulation

INTRODUCTION

The effect of harvest on northern bobwhite populations has been of interest to wildlife professionals because of their economic, recreational, and ecological values (Burger et al. 1994). Thus, state wildlife agencies have long had interest in designing harvest regulations to maximize recreational potential while remaining consistent with sustaining bobwhite populations. The relationship between harvest and natural mortality has been described between 2 opposing models: additive and compensatory (Anderson and Burnham 1976, Caughley 1983). We define compensatory mortality as occurring when harvest is ameliorated by reduced natural mortality or increased density-dependent reproduction. Additive mortality occurs when natural mortality or reproductive responses are unaffected by increased harvest pressure. Early empirical evidence supported a compensation hypothesis where natural mortality decreases and reproduction increases to compensate for increased hunting mortality for multiple quail species (Baumgartner 1944, Glading and Saarni 1944, Parmalee 1953, Swank and Gallizioli 1954, Campbell et al. 1973). However, reanalysis of older (Guthery 2002:101) and recent research indicates harvest mortality tends to be additive to winter natural mortality (discounting for a reproductive response) for bobwhites during the fall–winter (Roseberry and Klimstra 1984:142, Pollock et al. 1989, Robinette and Doerr 1993, Dixon et al. 1996, Williams et al. 2004a, Rolland et al. 2011). A variety of factors influence the relative strength of additive and compensatory mortality including covey dynamics (Williams et al. 2003b), habitat fragmentation (Roseberry and Klimstra 1984:147–148, Ellison 1991, Guthery et al. 2000), and late season harvest (Roseberry 1982, Kokko 2001).

A common observation is that hunter numbers tend to fluctuate with quail abundance and state wildlife agencies have additionally believed self-regulation occurs in bobwhite harvest (i.e., hunting effort and resulting harvest will decrease with decreasing population; Peterson and Perez 2000). For example, when bobwhite numbers are low, hunter effort is low and fewer quail are harvested than when quail numbers are high (Latham and Studholme 1952, Gallizioli 1965, Guthery 1986, Peterson and Perez 2000, Guthery et al. 2004). Agencies often do not have robust and cost-effective quail population indices to guide season decisions that are made months or a year in advance. Therefore, agencies rely on faith in self-

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regulation to set socially acceptable regulations on a standard opening date with standard bag limits, possession limits, and season lengths (Peterson and Perez 2000).

Hunter effort and total harvest decline with lower population abundance, and Guthery et al. (2004) found hunter skill and resulting harvest rate increase as populations decline. Self-regulation is brought into question because hunters that continue to hunt when populations are low are more avid than those that quit. Peterson and Perez (2000) and Guthery et al. (2004) made strong inroads into understanding self regulation, but neither addressed the impact of non-resident hunters in these relationships.

Kansas is a popular destination for quail hunters from throughout the United States with an estimated 20,000 non-resident small game hunters (of a total 72,900 hunters) during the 2009–2010 season. Thus, understanding self-regulation for this group has implications for establishing regulations. We tested the hypothesis that as bobwhite populations decline, the number of hunters and harvest would decline (as predicted by Guthery et al. 2004) using long-term bobwhite population and harvest data from Kansas (1966–1999). We extend the hypothesis that self-regulation patterns do not differ between resident and non-resident hunters.

METHODS

Population indices for northern bobwhite (quail/km/observer) were obtained from annual roadside surveys conducted by rural mail carriers (RMCS) during the second week of October and January throughout all counties in the state of Kansas (Robinson et al. 2000, Williams et al. 2003a). Wells and Sexson (1982) found the October survey gave the best predictor of subsequent bobwhite hunter harvest. Counts were taken by carriers while making deliveries on their regular mail routes. This survey involves 550 mail carriers that drive 400,000 km during the 2 weeks (Wells and Sexson 1982). Data were recorded on prepaid postage cards supplied by the Kansas Department of Wildlife, Parks, and Tourism (KDWPT).

KDWPT obtained annual northern bobwhite resident harvest numbers from a mail questionnaire sent to a random sample of 5–10% (yearly mean ± SE = 8,689 ± 1,867) of the previous year's resident small game license holders between 1966 and 1999 (following Turner 1970). We sent an introductory mailing to each selected cooperator before opening of the small game season. The introductory mailing consisted of a letter explaining the survey and a report card to record hunting activity and harvests. We mailed the questionnaire to the selected group after the close of the small game season. We also mailed a follow-up questionnaire to account for non-respondents (Turner 1970, Yu and Cooper 1983). This resulted in an average return rate of 27.8 ± 2.5% of usable questionnaires. We acknowledge potential non-response bias, which might have yielded overestimates of hunter-days and harvest (Peterson 2001). We expanded questionnaire results (Sondrini 1950, Landwehr 1982) to estimate annual northern bobwhite harvest.

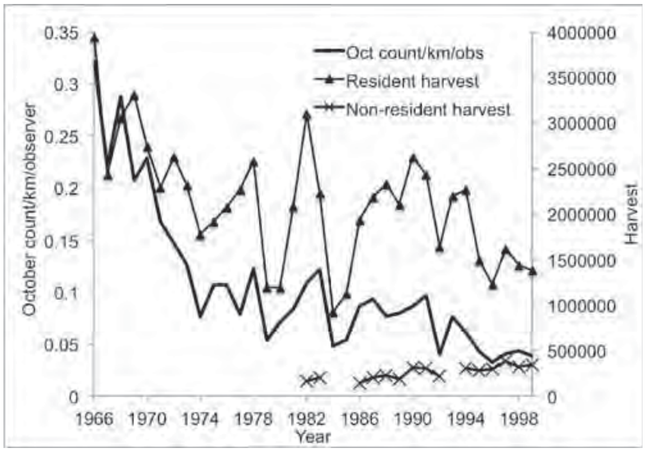

Fig. 1. Trends in the October northern bobwhite population index and estimated resident and non-resident harvest in Kansas, 1966–1999.

Non-resident harvest was estimated by mailing a questionnaire, identical to that mailed to the resident sample, to all non-residents purchasing licenses from KDWPT Licensing Section in Pratt. This sampling frame was used because all non-resident license applications sent to the Licensing Section were computerized whereas all licenses sold through other KDWPT offices or vendors were not. We mailed an average of 974 ± 512 questionnaires annually and obtained a 45 ± 8% response rate. We expanded questionnaire results in an identical fashion to that of resident questionnaire results. We used all available non-resident data collected in 1982–83, 1986–92, 1994–1999 ($n = 15$ years).

We modeled the relationship of both resident and non-resident harvest with bobwhite abundance; our assumption was that October population index (I) was an approximately linear, zero-intercept function of population abundance. This relationship is reasonable because harvest is linear to both local and regional population abundance indices (Brown et al. 1978, Guthery 1986:149, Peterson and Perez 2000, DeMaso et al. 2002, Palmer et al. 2002, Guthery et al. 2004) indicating a linear correlation between population indices and true abundance. We predicted that resident and non-resident hunting pressure (P, hunter days) was a linear function of abundance (Peterson and Perez 2000):

$$P = f(I).$$

We calculated relative pressure (P_R; pressure/index bird) from that equation as:

$$P_R = \frac{P}{I}$$

and the total annual harvest (H) as:

$$H = g(P) = g\Big(f(I)\Big)$$

because harvest pressure is a function of the population

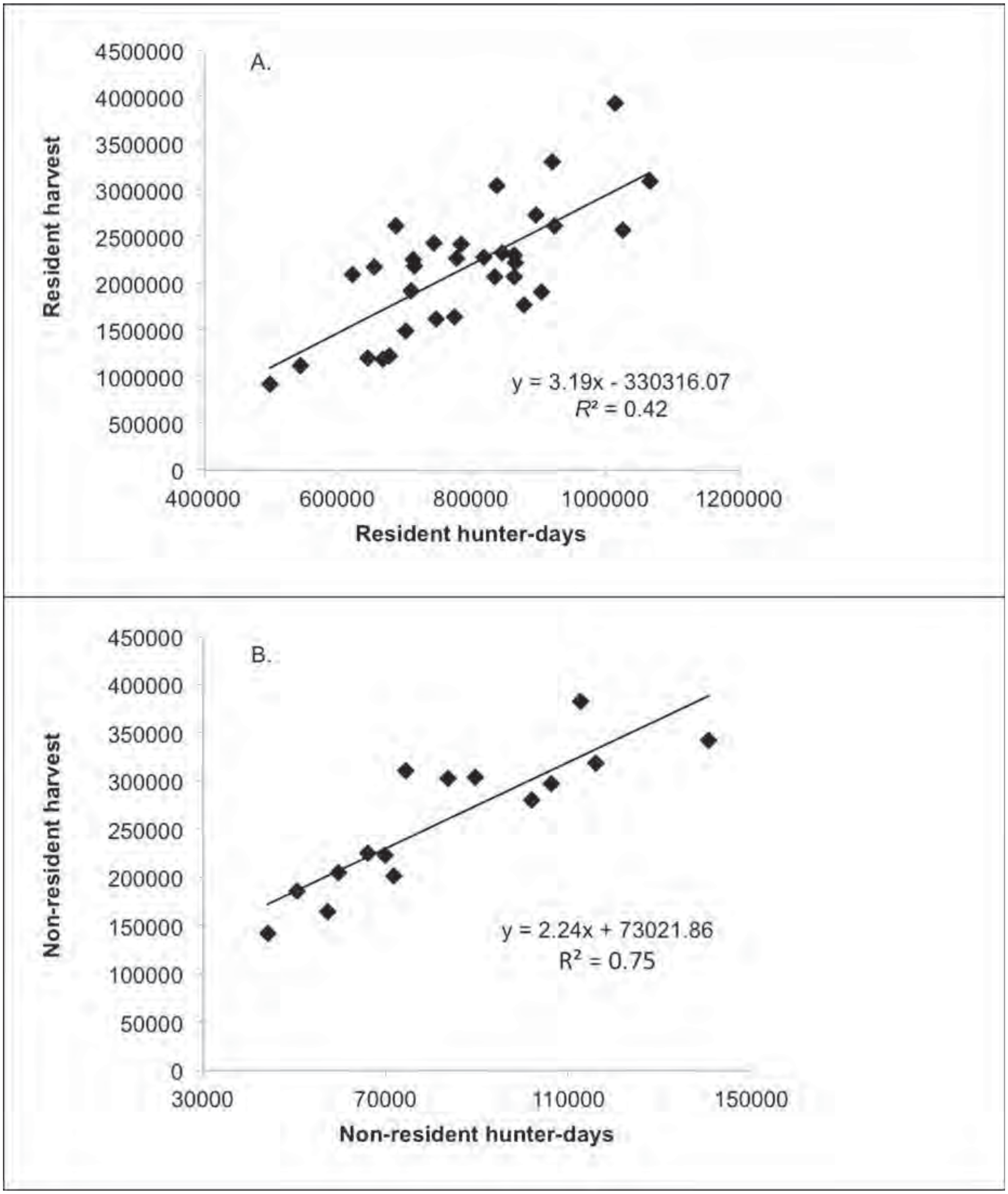

Fig. 2. Relationship between total number of resident and non-resident hunters and respective northern bobwhite harvest in Kansas, 1966–1999.

index. We defined hunter efficiency (S) as ‘harvest/hunter-day/index bird’ or ‘harvest/index-bird exposure-day’:

$$S = \frac{\frac{H}{P}}{I} = \frac{\frac{H}{I}}{P} = \frac{H}{PI}.$$

We define relative harvest rate (R; harvest/index bird) as:

$$R = \frac{H}{I}$$

where the relative harvest is a product of pressure and efficiency, and is a scaled version of the absolute harvest rate (percent of population harvested). We related the relative harvest to an index of overwinter mortality (M) defined as:

$$\hat{M} = 1 - \frac{I_{Jan}}{I_{Oct}}.$$

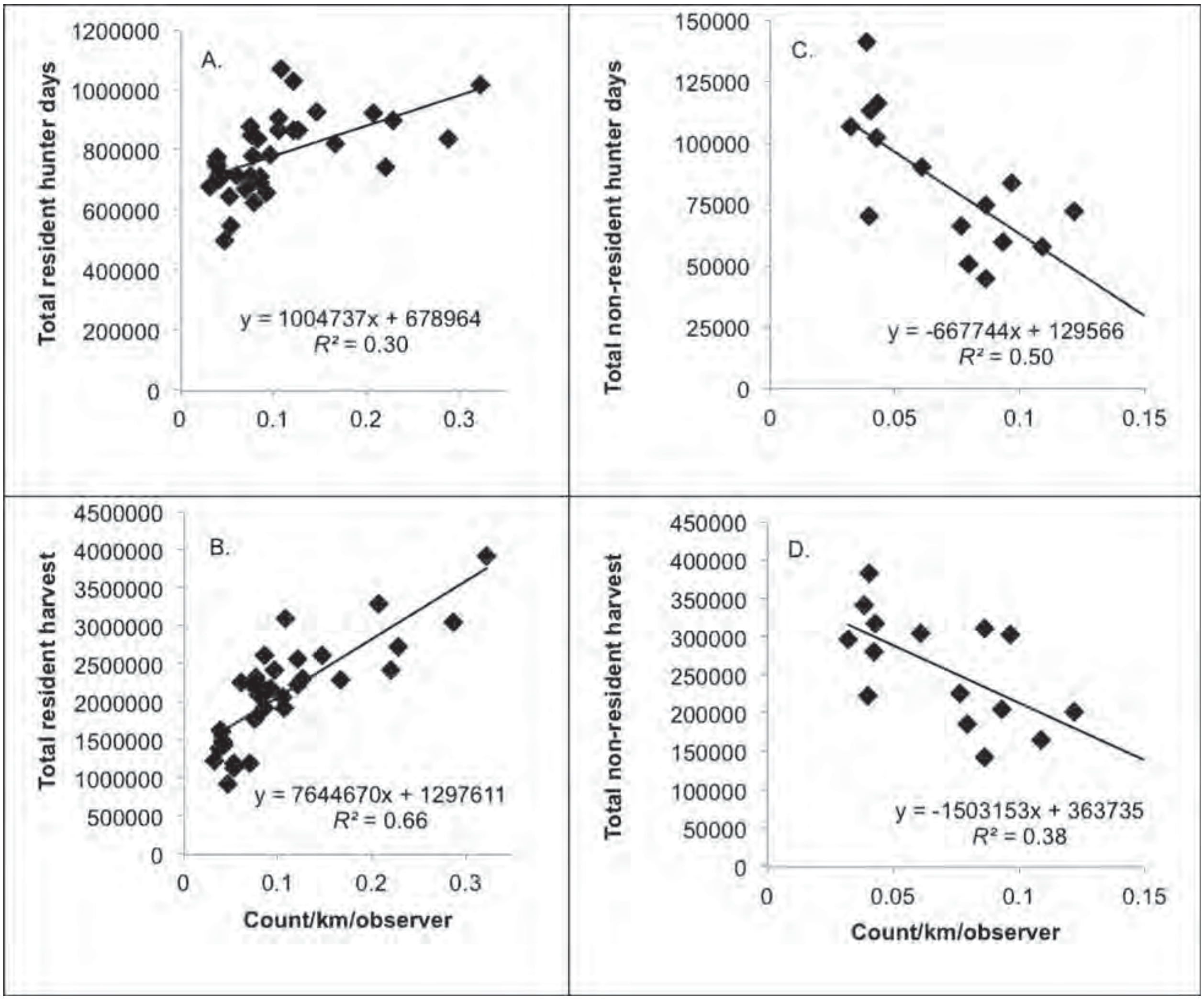

Fig. 3. Relationship between October northern bobwhite population index and resident hunters (A), resident harvest (B), non-resident hunters (C), and non-resident harvest (D) in Kansas, 1966–1999.

We used simple linear regression ($P \leq 0.05$) to examine: (1) the number of resident and non-resident hunters and harvest; (2) the relationship between October population index and the number of resident and non-resident bobwhite hunters, harvest, and hunter efficiency; and (3) the relationship between total relative harvest of both resident and non-resident hunters and estimated overwinter mortality.

RESULTS

There was a steady decline in the October population index between 1966 and 1999 (Fig. 1). Estimated resident harvest also declined and generally tracked natural increases and decreases in the population (Fig. 1). Non-resident harvest was substantially lower but generally increased despite the declining population (Fig. 1). Numbers of resident and non-resident hunters were correlated to resident and non-resident northern bobwhite harvest (respectively: $F_{1,35} = 25.49$, $P < 0.01$; $F_{1,13} = 39.71$, $P < 0.01$; Fig. 2). Decreasing October population index decreased the number of resident bobwhite hunter days and harvest ($F_{1,32} = 13.87$, $P < 0.01$; $F_{1,32} = 60.95$, $P < 0.01$; Fig. 3A, C). The existence of non-zero intercepts suggested hunting pressure and harvest declined more slowly than quail abundance indicating the ratio of hunters to quail numbers increased as the quail population declined. Conversely, numbers of non-resident hunters participating in the hunting season increased at lower October population index levels and a larger number of birds were harvested (respectively: $F_{1,13} = 12.88$, $P < 0.01$; $F_{1,13} = 7.93$, $P = 0.02$; Figs. 3B, D). Models for hunter efficiency (harvest/hunter day/index bird) were curvilinear decreasing functions of quail abundance for both resident and non-resident hunters (Fig. 4) indicating the average hunter at low quail abundance was more efficient than the average hunter at high quail abundance.

We calculated the total relative harvest examining the 15 years when both resident and non-resident harvests were known. Non-resident harvest comprised only ~5% of total harvest when populations were at moderate levels (~0.15

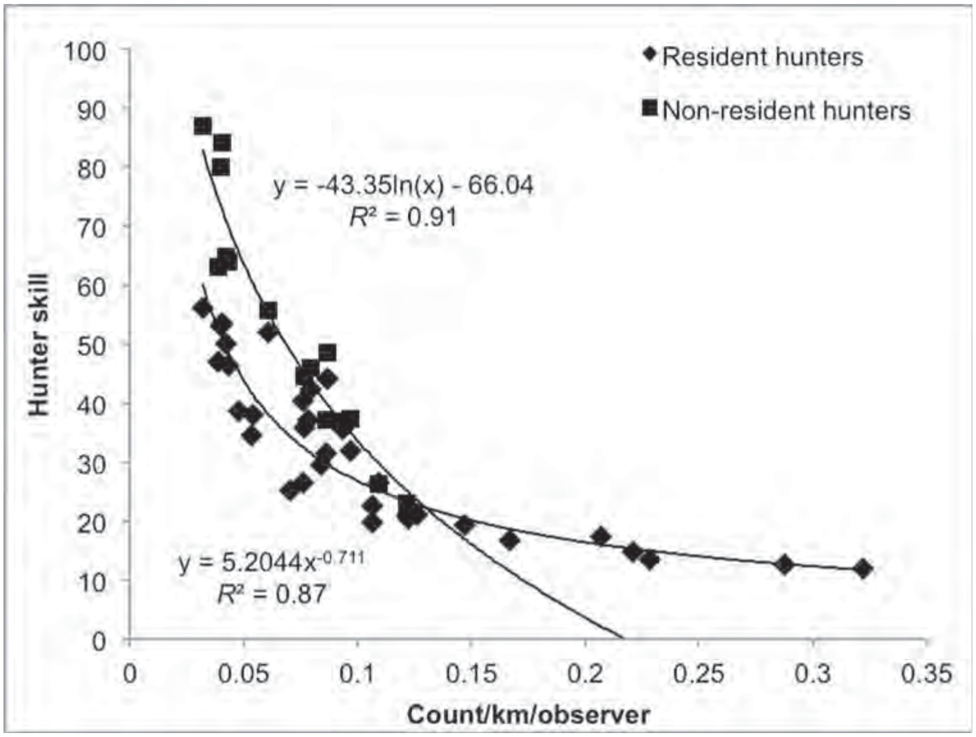

Fig. 4. Hunter efficiency as a function of northern bobwhite abundance for both resident and non-resident hunters in Kansas, 1966–1999.

index birds). However, non-resident harvest comprised ~20% of total harvest when populations were at low densities (~0.05 index birds) and harvest rates increased. We also examined how relative harvest rate during those years affected estimated mortality in the population between October and January indices. The increased relative harvest rate (when populations were moderate to low) increased overwinter mortality ($F_{1,13} = 4.80$, $P = 0.05$) indicating a more additive effect to harvest mortality (Fig. 5).

DISCUSSION

The concept of self-regulation stems from early work with ring-necked pheasants (*Phasianus colchicus*) (Allen

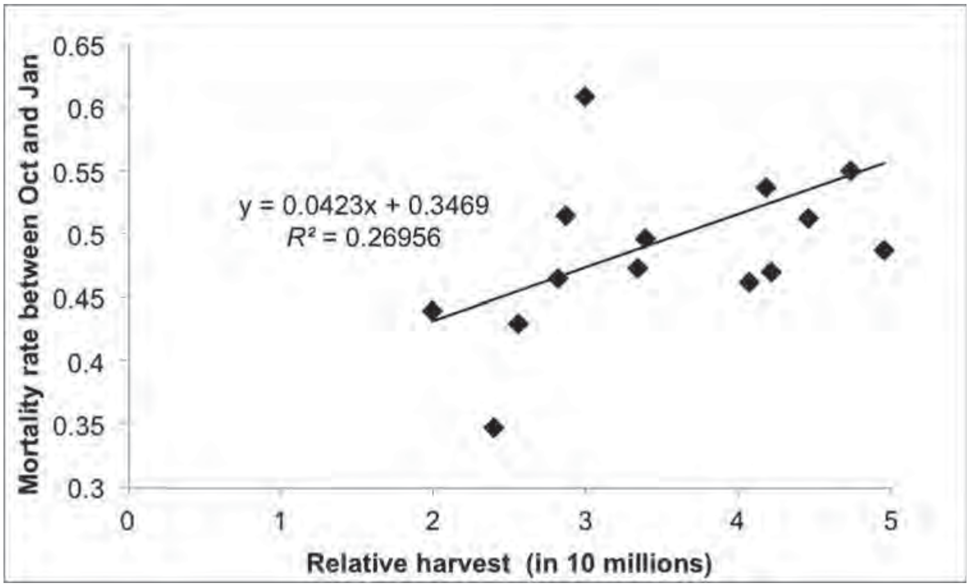

Fig. 5. Relationship between total northern bobwhite relative harvest and estimated mortality between October and January population indices during years both resident and non-resident data were collected in Kansas (1982–83, 1986–92, 1994–1999; $n = 15$ years).

1942, 1947; Lauckhart 1946; Schick 1952) and indirectly with Errington's (1945) theory of 'threshold of security'. Self-regulation can be both passive, where hunters do not go hunting because they hear it was a poor reproductive year, or active when a private landowner closes their land. Passive self-regulation of northern bobwhite harvest has been assumed, but rarely tested. Vance and Ellis (1972) suggested this relationship, but failed to demonstrate it on two wildlife management areas in Illinois. Schwartz (1974), Wells and Sexson (1982), and Peterson and Perez (2000) reported bobwhite abundance could predict harvest in Iowa, Kansas, and Texas, respectively.

Policies associated with the concept of self-regulation continue to be promoted (Kabat and Thompson 1963, MDC 1986, Madson 2000). The relative harvest rate (harvest/index bird) tended to increase with lower bobwhite abundance following Guthery et al.'s (2004) observations in 6 states (including the resident data from Kansas). This observation was attributed to increased hunter efficiency despite the lower hunting pressure. Kansas, among the 6 states, had the most profound effect and the other 5 states had a more subdued increasing trend in relative harvest rate as a function of decreasing abundance. However, the non-resident relative harvest rate in Kansas increased over 3 times that of resident harvest rate at low population levels. Thus, not only did the ratio of hunters to quail increase as the quail populations declined, but also the efficiency of the average hunter increased. However, the magnitude of this effect was substantially higher for non-resident hunters as a function of their continued and skilled hunting pressure even when bobwhites were at low densities.

Our results indicate resident northern bobwhite hunting in Kansas is self-regulatory. However, our results may indicate lack of passive self-regulation for non-resident hunters. This is likely driven by non-resident hunters increasingly coming to Kansas where populations were more robust than in their home states in recent years, as bobwhite populations have decreased throughout the region,. Non-residents (1) have a greater investment in transportation, lodging, food, and license costs, (2) must plan in advance to make trips to hunt, and (3) likely are avid hunters with high hunting skill (Hurst and Warren 1982, Guthery et al. 2004). This suggests harvest rate is higher and passive regulation will be lower even under low population levels (Guthery et al. 2004). This trend cannot biologically continue despite the linearly increasing participation and harvest by non-resident hunters and eventually would become curvilinear and drop to zero as the bobwhite population declines to zero. Informal surveys conducted by KDWPT (Jim Pitman, personal communication) have found in recent years that 92% of non-resident bobwhite hunters consider themselves to be 'mixed bag' hunters and exhibit more passive self-regulation by switching to pheasants. However, we cannot predict at what threshold this might occur. Future researchers may wish to examine the relationships documented in this paper between Central/Western counties (where bobwhites are scarce and pheasants are more abundant; Williams et al. 2003a) and Eastern counties in Kansas (where bobwhites are more common and pheasants are more scarce) to identify the spatial dynamics of non-resident passive self-regulation.

MANAGEMENT IMPLICATIONS

Kansas resident bobwhite harvest seems to be self-regulatory but non-resident harvest does not and harvest regulations should consider the increased additivity from non-resident hunters in future regulations. We question the assumption of northern bobwhite passive self-regulation if non-resident hunters increasingly make up a larger percentage of the total hunting population. We believe, as did Errington and Hamerstrom (1936), that hunting of bobwhites should be regulated with care. Hunters and agencies, in part, have wanted liberalization (Roseberry and Klimstra 1993), but the tendency over the past 30 years to liberalize bobwhite hunting seasons despite continued habitat deterioration and loss should be questioned (Williams et al. 2004b). Managers may want to consider closing the bobwhite season on or before the closing of the season in neighboring states that provide high numbers of non-resident hunters.

ACKNOWLEDGMENTS

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LITERATURE CITED

Allen, D. L. 1942. That season limit. Michigan Conservation 11 (2):4–5.

Allen, D. L. 1947. Hunting as a limitation to Michigan pheasants. Journal of Wildlife Management 11:232–243.

Anderson, D. R., and K. P. Burnham. 1976. Population ecology of the mallard. VI. The effect of exploitation on survival. USDI, Fish and Wildlife Service Resource Publication 128.

Baumgartner, F. M. 1944. Bobwhite quail populations on hunted vs. protected areas. Journal of Wildlife Management 8:259–260.

Brown, D. E., C. L. Cochran, and T. E. Waddell. 1978. Using call-counts to predict hunting success for scaled quail. Journal of Wildlife Management 42:281–287.

Burger, Jr., L. W., E. W. Kurzejeski, L. D. Vangilder, T. V. Dailey, and J. H. Schultz. 1994. Effects of harvest on population dynamics of upland game birds: are bobwhite the model? Transactions of the North American Wildlife and Natural Resources Conference 59:466–476.

Campbell, H., D. K. Martin, P. E. Ferkovich, and B. K. Harris. 1973. Effects of hunting and some other environmental factors on scaled quail in New Mexico. Wildlife Monographs 34.

Caughley, G. 1983. Harvesting of wildlife: past, present, and future. Pages 3–14 *in* S. L. Beasom and S. F. Roberson, eds. Game harvest management. Caesar Kleberg Wildlife Research Institute, Kingsville, Texas, USA.

DeMaso, S. J., M. J. Peterson, J. R. Purvis, N. J. Silvy, and J. L. Cooke. 2002. A comparison of two quail abundance indices and their relationship to quail harvest in Texas. Proceedings of the National Quail Symposium 5:206–212.

Dixon, K. R., M. A. Horner, S. R. Anderson, W. D. Henriques, D. Durham, and R. J. Kendall. 1996. Northern bobwhite habitat use and survival on a South Carolina plantation during winter. Wildlife Society Bulletin 24:627–635.

Ellison, L. N. 1991. Under what conditions can shooting of declining species of tetraonids be justified in France? Gibier Faune Sauvage 8:353–365.

Errington, P. L. 1945. Some contributions of a fifteen-year local study of the northern bobwhite to a knowledge of population phenomena. Ecological Monographs 15:1–34.

Errington, P. L., and F. N. Hamerstrom Jr. 1936. The northern bobwhite's winter territory. Iowa State College Agricultural Experiment Station Research Bulletin 201.

Gallizioli, S. 1965. Quail research in Arizona. Arizona Game and Fish Department, Phoenix, USA.

Glading, B., and R. W. Saarni. 1944. Effect of hunting on a valley quail population. California Fish and Game 30:71–79.

Guthery, F. S. 1986. Beef, brush, and bobwhites: quail management in cattle country. Caesar Kleberg Wildlife Research Institute Press, Kingsville, Texas, USA.

Guthery, F. S. 2002. The technology of bobwhite management: the theory behind the practice. Iowa State University Press, Ames, USA.

Guthery, F. S., M. J. Peterson, and R. R. George. 2000. Viability of northern bobwhite populations. Journal of Wildlife Management 64:646–662.

Guthery, F. S., M. J. Peterson, J. J. Lusk, M. J. Rabe, S. J. DeMaso, M. Sams, R. D, Applegate, and T. V. Dailey. 2004. Multistate analysis of fixed, liberal regulations in quail harvest management. Journal of Wildlife Management 68:1104–1113.

Hurst, G. A., and R. C. Warren. 1982. Harvest rates and efforts of avid quail hunters in east central Mississippi. Proceedings of the National Quail Symposium 2:48–50.

Kabat, C., and D. R. Thompson. 1963. Wisconsin quail 1834–1962: population dynamics and habitat management. Technical Bulletin 30. Wisconsin Department of Conservation, Madison, USA.

Kokko, H. 2001. Optimal and suboptimal use of compensatory responses to harvesting: timing of hunting as an example. Wildlife Biology 7:141–150.

Landwehr, T. J. 1982. A comparison of trapping harvest estimates determined from trapper report cards and mail surveys, 1976–79. Minnesota Wildlife Research Quarterly 42:25–47.

Latham, R. M., and C. R. Studholme. 1952. The bobwhite quail in Pennsylvania. Pennsylvania Game News Special Issue 4.

Lauckhart, J. B. 1946. Habitat areas and their relation to pheasant management. Proceedings of the Western Association of State Game and Fish Commissioners 26:120–123.

Madson, C. 2000. To gun or not to gun? Wing and Shot 14 (6):28–29.

Missouri Department of Conservation (MDC). 1986. Small game regulations: can they save quail? Wildlife Information 2. Missouri Department of Conservation, Jefferson City, USA.

Palmer, W. E., S. D. Wellendorf, L. A. Brennan, W. R. Davidson, and F. E. Kellogg. 2002. Hunting success and northern bobwhite density on Tall Timbers Research Station: 1970–2001. Proceedings of the National Quail Symposium 5:213–216.

Parmalee, P. W. 1953. Hunting pressure and its effect on bobwhite quail populations in east-central Texas. Journal of Wildlife Management 17:341–345.

Peterson, M. J. 2001. Northern bobwhite and scaled quail abundance and hunting regulation: a Texas example. Journal of Wildlife Management 65:828–837.

Peterson, M. J., and R. M. Perez. 2000. Is quail hunting self-regulatory? Northern bobwhite and scaled quail abundance and quail hunting in Texas. Proceedings of the National Quail Symposium 4:85–91.

Pollock, K. H., C. T. Moore, W. R. Davidson, F. E. Kellogg, and G. L. Doster. 1989. Survival rates of bobwhite quail based on band recovery analysis. Journal of Wildlife Management 53:1–6.

Robinette, C. F., and P. D. Doerr. 1993. Survival of northern bobwhite on hunted and nonhunted study areas in the North Carolina Sandhills. Proceedings of the National Quail Symposium 3:74–78.

Robinson Jr., D. A., W. E. Jensen, and R. D. Applegate. 2000. Observer effect on a Rural Mail Carrier survey population index. Wildlife Society Bulletin 28:330–332.

Rolland, V., J. A. Hostetler, T. C. Hines, F. A. Johnson, H. F. Percival, and M. K. Oli. 2011. Effects of harvest and climate on population dynamics of northern bobwhites in south Florida. Wildlife Research 38:396–407.

Roseberry, J. L. 1982. Sustained harvest of bobwhite populations. Proceedings of the National Bobwhite Symposium 2:51–56.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, USA.

Roseberry, J. L., and W. D. Klimstra. 1993. Attitudes of a select group of Illinois quail hunters. Proceedings of the National Quail Symposium 3:34–42.

Schick, C. 1952. A study of pheasants on the 9,000 acre Prairie Farm, Saginaw County, Michigan. Michigan Department of Conservation, Lansing, USA.

Schwartz, C. C. 1974. Analysis of survey data collected on bobwhite in Iowa. Journal of Wildlife Management 38:674–678.

Sondrini, W. J. 1950. Estimating game from licensee reports. Connecticut Board of Fisheries and Game, Pittman-Robertson Bulletin 3.

Swank, W. G., and S. Gallizioli. 1954. The influence of hunting and rainfall upon Gambel's quail populations. Transactions of the North American Wildlife Conference 19:283–297.

Turner, D. W. 1970. Mail surveys of hunting-precision and sample size. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 24:292–303.

Vance, D. R., and J. A. Ellis. 1972. Bobwhite populations and hunting on Illinois public hunting areas. Proceedings of the National Quail Symposium 1:165–174.

Wells, R., and K. Sexson. 1982. Evaluation of bobwhite quail surveys in Kansas. Proceedings of the National Quail Symposium 2:19–30.

Williams, C. K., A. R. Ives, and R. D. Applegate. 2003a. Population dynamics across geographical ranges: time-series analysis of three small game species. Ecology 84:2654–2667.

Williams, C. K., R. S. Lutz, and R. D. Applegate. 2003b. Optimal group size in northern bobwhite coveys. Animal Behaviour 66:377–387.

Williams, C. K., R. S. Lutz, and R. D. Applegate. 2004a. Winter survival and additive harvest in northern bobwhite coveys in Kansas. Journal of Wildlife Management 68:94–100.

Williams, C. K., F. S. Guthery, R. D. Applegate, and M. J. Peterson. 2004b. The northern bobwhite decline: scaling our management for the twenty-first century. Wildlife Society Bulletin 32:861–869.

Yu, J., and H. Cooper. 1983. A quantitative review of research design effects on response rates to questionnaires. Journal of Marketing Research 20:36–44.

FACTORS INFLUENCING NORTHERN BOBWHITE HUNTING SUCCESS ON TWO SOUTH GEORGIA PLANTATIONS

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ABSTRACT

Success of wild northern bobwhite (*Colinus virginianus*) management programs on private lands is most often measured by the rate of coveys pointed during the hunting season. Thus, managers of these properties are keenly interested in factors that influence hunting success. We examined how coveys pointed/hour, a measure of hunting success, was influenced by time of hunting season, time of day, weather parameters, and supplemental feeding on 2 intensively-managed plantations over 4 years. There were significant annual differences in the number of coveys pointed/hour among the 4 study years, but hunting success did not vary during the hunting season. Afternoon hunts had consistently higher success rates than morning hunts; however, the effect size was variable from year to year. The selected weather model indicated an interaction between 12-hr barometric pressure change and starting air pressure; hunting success increased with a rapid pressure increase that resulted in a high pressure value at the start of the hunt. A secondary weather model documented a negative relationship between starting air temperature and hunting success. The number of days since supplemental feed was spread had no significant effect on hunting success in 5 of 6 years for the 2 plantations over 3 years. Knowledge of how these variables influence hunting success should improve hunting and provide realistic expectations of hunt success for a given set of circumstances.

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Key words: *Colinus virginianus*, coveys pointed/hour, Georgia, hunting success, northern bobwhite, season, supplemental feeding, weather

INTRODUCTION

Plantations that intensively manage for wild northern bobwhite hunting often use the number of coveys pointed during a hunt as a primary measure of success. Landowners and managers of these properties, expend extensive time and monetary effort to maintain high bobwhite population levels to maximize hunting success. Hunting success is often the only variable used to evaluate management success or to generate an index of population size (Palmer et al. 2002). Thus, there is tangible interest from plantation staff to better understand the potential factors that influence hunting success to better assess population levels and land management impacts.

Southeastern plantations support bobwhite populations that are sufficiently large to observe coveys on essentially every hunt and provide an opportunity to measure potential factors that impact hunting success (Stribling and Sisson 2009). There is often adequate variation in daily hunting success to assess the effect of independent variables at multiple time scales. Bobwhite populations do not fluctuate as dramatically annually compared to other portions of the species range, which allows for data to be pooled among years with a reduced year effect (Brennan et al. 2000, Palmer et al. 2002). Plantations conduct hunts regardless of weather rather than picking the best days to hunt, which provide a breadth of hunting weather conditions. They also hunt based on tradition and routine, and record covey observations following specific rules, which has allowed for hunts and data collection to be relatively standardized (Rosene 1969). This level of hunting consistency and sample size allows for a more detailed analysis of some of the factors influencing hunting success. There has been limited previous research that has quantified the influence and interaction of temporal hunting variability and weather variables on hunting success. Previous analyses have been based on general observations (Rosene 1969) or from quantified observations (Sisson and Stribling 2009) with no specific attempt to document effect size.

Use of supplemental feed spread along dedicated trails consistently every 2 to 3 weeks throughout the year has become a standard practice on southeastern plantations (Stribling and Sisson 2009). Sisson et al. (2000b) documented that use of supplemental feeding initially reduced hunting success when compared to

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hunting results in areas without food supplementation. This result was also correlated with decreased winter home range size and increased over-winter survival (Sisson et al. 2000a). Presumably, high food availability associated with supplemental food areas reduced the susceptibility of bobwhites to harvest. However, it has been recognized that availability of supplemental feed decreases during the time between spreading of feed (Miller 2011). There is potential for hunting success to change as food availability changes between feedings.

Our study objectives were to: (1) quantify the changes to hunting success relative to daily and seasonal timing, (2) investigate the potential impacts of weather variables on hunting success, and (3) investigate the relationship between the days post supplemental feeding and plantation hunting success.

STUDY AREAS

We conducted this study on 2 private plantations in southern Grady County (Grady Plantation) and Baker County, Georgia (Baker Plantation). The primary management objective of these plantations is to maintain high density bobwhite populations (> 3.7 bobwhites/ha) with other game species management and timber production as secondary objectives. Grady Plantation (2,266 ha) contained upland pine (*Pinus* spp.) (70%), hardwood drainages (22%), scattered 0.8–2 ha annually-disked fields (4%), and other minor land cover types and property improvements (4%). Upland pine habitat consisted of planted loblolly pine (*P. taeda*) stands ranging from 10 to 50 years of age. All pine stands had been thinned over a 5-year period to timber densities with a range of basal areas (4.4 and 9.1 m^2/ha), which resulted in open canopies that allowed growth of contiguous groundcover suitable for bobwhites. The Baker Plantation (4,490 ha) was composed of natural openly-spaced mature pine (4.4 and 9.1 m^2/ha) woodlands with scattered live oaks (*Quercus virginiana*) (78% of study area). Upland timber was managed to have a low density of trees with an open canopy to promote a contiguous growth of groundcover favored by bobwhites. Scattered throughout the uplands were fields (1–2 ha) (17%), which were annually disked in January to promote annual weed growth.

Management in the uplands on both study areas included use of low intensity biennial prescribed fires, roller drum chopping, and mowing to produce groundcover conditions favorable for bobwhites. Other management activities included year-round supplemental feeding with milo and corn, and mesomammal predator trapping. Supplemental feed was scattered throughout the uplands along a dedicated trail using a tractor and feed wagon. Feed trail density varied, but averaged 2.9 km of feed trail for every 40.5 ha of upland habitat. Feed was spread on a course approximately every 14 days, but feed times ranged from 12 to 25 days. The amount of feed used on both study areas was ~ 174 to 261 L/ha/yr.

METHODS

Hunting Data

Bobwhite hunting on both plantations was conducted consistently throughout the Georgia bobwhite hunting season, mid November-late February. Hunting parties consisted of the hunt manager who coordinated all activities during the hunt, 1 or 2 scouts that kept track of the hunting dogs, a wagon driver, the hunting supply wagon, and 1 to 4 hunters. All hunts were conducted on horseback and from the hunting wagon. Hunting dogs, primarily English pointers, were used in braces with 2 to 4 braces used throughout the hunt. The amount of land covered during a hunt ranged from 81 to 162 ha, which was the typical size of a hunting course. Hunting courses were hunted between 1 and 6 times within a hunting season. The typical hunt was ~ 3 hrs in length, but ranged from 1.5 to 3.5 hrs. Hunts were classified as morning (0900 and 1200 hrs), or afternoon (1500 and 1800 hrs). Start times and length of hunting had minimal variation during the study. Records for each hunt were recorded by the hunt manager. Records included the location of the hunting course, start and end times, number of participants, general weather, days since supplemental feed was spread on the hunt course, number of coveys seen, number of coveys pointed, single bobwhites pointed, and number of bobwhites harvested. Coveys seen was the total number of coveys seen during the hunt including wild flushes and pointed coveys. Pointed coveys were those that were pointed by a steady dog and included those that were shot into and those that flew before the hunt party could arrive. Single bird flushes, both pointed and wild flushes, were recorded separately and not used in the analysis. A covey was defined as a group of $\geq$ 6 bobwhites.

Weather Data

We collected detailed weather information from a Georgia automated environmental monitoring network weather station at Wight Nurseries (4.3 km west of Cairo, GA, USA), 16 km northwest of Grady Plantation and 48 km south of Baker Plantation. We selected this weather station because it was between both study areas and data were collected hourly with minimal interruptions, and were archived. Hourly weather data collected from the station were air pressure (kilopascal), air temperature (°C), relative humidity (%), wind speed (m/sec), wind direction (degrees), and precipitation (mm).

Data Analysis

The analysis focus was the effect of various weather parameters on the number of coveys pointed during a hunt. The exact time that each covey was pointed was not known and only the total number of coveys pointed during the hunt was known. Thus, the rate of coveys pointed/hour (pointed/hr) and the total coveys pointed divided by length of hunt was used as the dependent variable. Weather variables were summarized for each hunt and analyzed. Hunt start times were rounded down and end times up to maximize the number of weather observations

Table 1. Annual hunting success differences (mean ± CI) by time of day and time of season for 2 plantations in southern Georgia, 2006-07 to 2009-10.

	Hunting season	n	Pointed coveys/ hour	Time of day		Time of season	
				AM	PM	Early	Late
Grady Plantation	2006-07	40	3.10 ± 0.28	3.08 ± 0.44	3.03 ± 0.36	2.91 ± 0.41	3.16 ± 0.37
	2007-08	41	2.80 ± 0.28	2.28 ± 0.44	2.94 ± 0.37	2.89 ± 0.51	2.75 ± 0.34
	2008-09	44	3.23 ± 0.33	2.54 ± 0.32	3.76 ± 0.42	3.37 ± 0.58	3.12 ± 0.38
	2009-10	50	4.22 ± 0.22	4.12 ± 0.32	4.37 ± 0.28	4.37 ± 0.36	4.13 ± 0.27
Baker Plantation	2006-07	127	4.70 ± 0.32	4.62 ± 0.49	4.78 ± 0.41	4.60 ± 0.43	4.80 ± 0.48
	2007-08	100	4.10 ± 0.30	3.59 ± 0.40	4.63 ± 0.41	4.39 ± 0.61	3.97 ± 0.34
	2008-09	105	4.98 ± 0.30	4.59 ± 0.40	5.40 ± 0.43	4.77 ± 0.5	5.08 ± 0.38
	2009-10	100	5.26 ± 0.30	4.70 ± 0.39	5.72 ± 0.41	5.69 ± 0.59	5.09 ± 0.35

for each hunt. Each hunt had between 3 to 5 weather observations for analysis. Correlation matrixes were analyzed to assess multicolinearity among the data, which could decrease the precision of individual estimated coefficients by inflating variance (Burnham and Anderson 1998). A pairwise comparison of weather variable regression coefficients was used and correlated variables of $r < -0.40$ or $r > 0.40$ were considered similar and only one was selected for further analysis. It resulted in a truncated list of weather variables to use as independent variables in the model analysis. Variables included in the model were air pressure at the start of the hunt (AIRPRES), the 12-hr change in air pressure prior to the start of the hunt (PRESCHANGE), average air temperature during the hunt (TEMP), average relative humidity during the hunt (RH), average wind speed during the hunt (WIND), average wind direction during the hunt (WINDDIR), and the amount of precipitation 3 days before the hunt (PRECIP). The categorized variables time of day and time of season were used as independent variables. Time of day was categorized as morning (0900–1200 hrs) or afternoon (1300–1800 hrs) and time of season was classified as early (Nov–Dec) and late (Jan–Feb).

We used an Akaike Information Criterion (AIC) modeling approach for data analysis and inference related to weather parameters. A list of 23 biologically plausible models was generated using a combination of weather variables, time of day variables, and relevant 2-way interactions prior to analysis. The global model included all variables including all possible 2-way interactions and was preliminarily analyzed to test for model convergence and significance. We generated AIC for small sample sizes (AIC_c) for each model and estimated variable parameters using generalized linear modeling (GLM) procedures for both fixed and random variables (PROC MIXED; SAS Institute Inc. 2008). Hunt year was not included in any of the model statements in the weather analysis due to model over parameterization.

GLM procedures were used (PROC GLM; SAS Institute Inc. 2008) for analysis of the supplemental feeding data. Hunting records for each study site were analyzed separately. Hunting success data were blocked on year and days since feeding was treated as a covariate and the interaction between these variables was analyzed.

RESULTS

We reviewed 175 hunting records on Grady Plantation that were collected during 4 hunting seasons (2006-07 to 2009-10). Number of hunts per year ranged from 40 to 50 and the average number of coveys pointed/hr was 3.4 ± 0.16 (95% CI) (Table 1). Hunting success varied among hunting seasons with 2007-08 having below average coveys pointed/hr and the 2009-10 hunting season having above average coveys pointed/hr (Table 1). We observed minimal differences in coveys pointed/hour between the early (mean = 3.44 ± 0.27, $n = 71$) and late hunting seasons (mean = 3.33 ± 0.20, $n = 104$) with this pattern being similar across years (Table 1). Coveys pointed/hr were slightly higher for afternoon hunts (mean = 3.51 ± 0.21, $n = 94$) compared to morning hunts (mean = 3.21 ± 0.24, $n = 81$). Higher afternoon hunting success was documented for 3 of 4 years with the 2008-09 hunting season having significantly more coveys pointed/hr in the afternoon (Table 1).

Grady Plantation hunting records were also used in the weather variable analysis. The selected best model ($AIC_c = 465.8$; $\Delta AIC_c = 0.0$; $w_i = 0.73$) from the 23 models included the explanatory variables time of day, AIRPRES, PRESCHANGE, and AIRPRES x PRESCHANGE interaction. Variable parameter estimates (± 95% CI) for the selected best model were 7.03 ± 39.5 for intercept, –0.6221 ± 0.280 for time of day (AM), –0.033 ± 0.240 for AIRPRES, –127.44 ± 75.8 for PRESCHANGE, and 1.256 ± 0.744 for the AIRPRES x PRESCHANGE interaction. Variable parameter estimates where the 95% CI did not incorporate zero included time of day (AM), PRESCHANGE, and AIRPRES x PRESCHANGE. There were significant differences in the predicted slopes of PRESCHANGE between low and high starting AIRPRES (Fig. 1). We observed model convergence with good model fit and a significant predicted slope for all but 1 explanatory variable, but the overall coefficient of determination was low ($R^2 = 0.12$). The second best model ($AIC_c = 468.0$; $\Delta AIC_c = 2.2$; $w_i = 0.24$) was the same as the selected best model with the addition of TEMP (–0.0368 ± 0.0358). This indicated a decrease in coveys pointed/hr as the temperature increased.

There were 135 observations on Grady Plantation from 3 hunting seasons, 2007-08, 2008-09, and 2009-10, used for analysis on the impacts of days since supple-

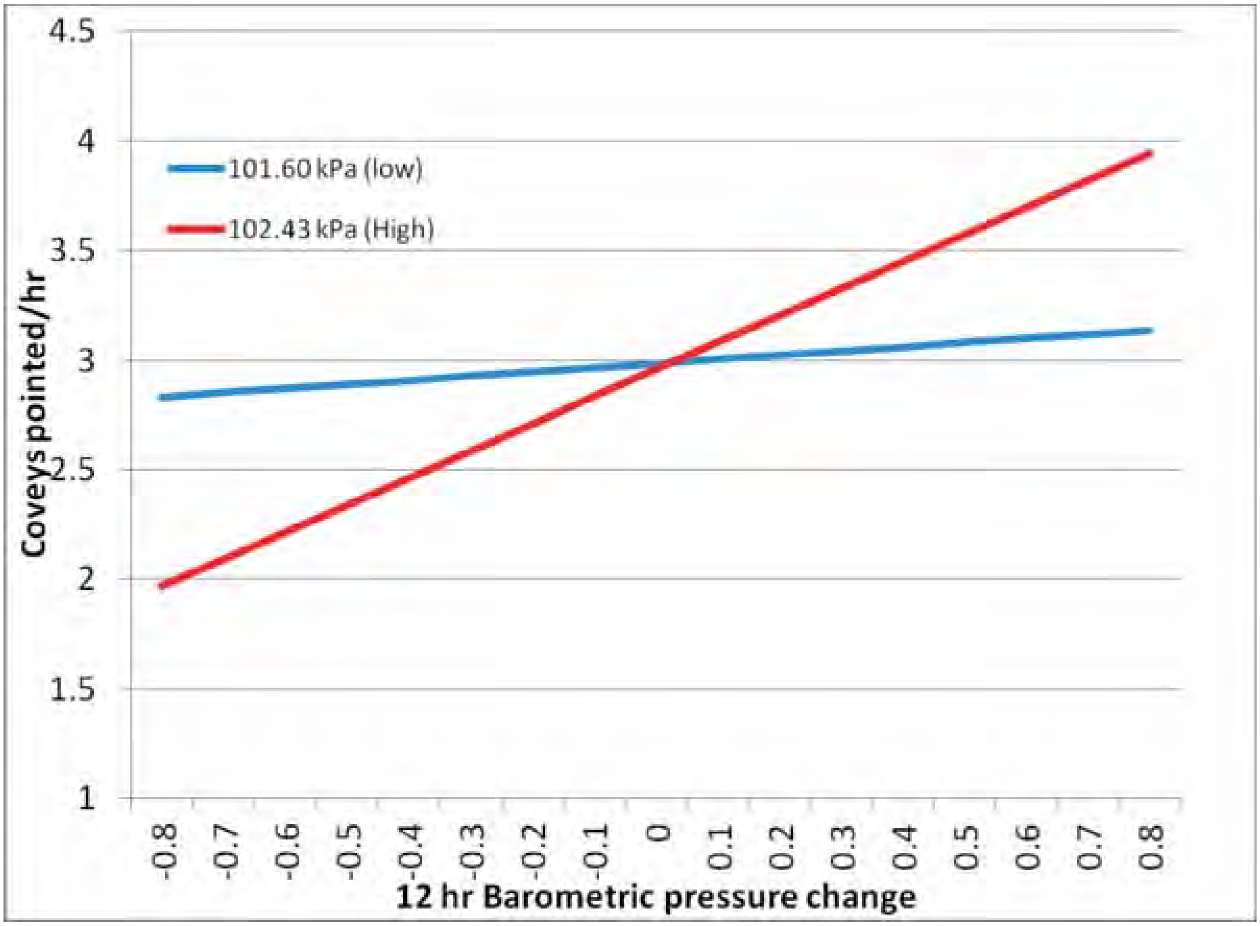

Fig. 1. Predicted bobwhite coveys pointed/hr from the selected best model for Grady Plantation, 2006-07 to 2009-10. Prediction lines include a low (101.60 kPa) and a high (102.43 kPa) barometric pressure value in relation to the 12-hr barometric pressure change prior to the hunt. All other model variables were fixed using data means.

mental feeding on coveys pointed/hr. Supplemental feeding data were not collected during the 2006-07 hunting season. Multiple regression revealed a significant year effect ($F_{2,129} = 14.5$, $P = 0.0001$), a significant effect of days since supplemental feeding ($F_{1,129} = 6.17$, $P = 0.01$), and a significant effect of the interaction between these variables ($F_{2,129} = 6.19$, $P = 0.002$) (Fig 2A). Days since supplemental feeding had an overall inverse relationship ($\beta = -0.1152 \pm 0.0565$) to coveys pointed/hr, but that negative trend was only observed in 1 of 3 years (Fig 2A).

We reviewed 432 hunting records from Baker Plantation during the same 4 hunting seasons (2006-07 to 2009-10); the number of hunts for each season ranged from 100 to 127 and the number of coveys pointed/hr averaged 4.76 ± 0.16. Hunting success, similar to Grady Plantation, varied among hunting seasons with the 2007-08 season having below average coveys pointed/hr and the 2009-10 season having above average coveys pointed/hr (Table 1). Minimal differences were observed between early season (mean = 4.79 ± 0.27, n = 157) and late season hunting success (mean = 4.74 ± 0.20, n = 275) with no consistent pattern among years (Table 1). Conversely, we observed higher hunting success for afternoon hunts (mean = 5.13 ± 0.22, n = 217) compared to morning hunts (mean = 4.39 ± 0.22, n = 215), which was consistent among all years (Table 1).

We used the same 23 models on Baker Plantation for the weather analysis as on Grady Plantation. Baker Plantation had the same selected best model as Grady Plantation ($AIC_c = 1635$; $\Delta AIC_c = 0.0$; $wi = 0.89$). Variable parameter estimates were similar, which included intercept (32.47 ± 57.92), time of day (AM) (–0.86 ± 0.33), AIRPRES (–0.27 ± 0.35), PRESCHANGE (–155.59 ± 106.38), and AIRPRES x PRESCHANGE (1.53 ± 1.04). The selected best model had a low overall coefficient of determination ($R^2 = 0.07$) even with model convergence and multiple variables with significant slopes.

There were 295 observations on Baker Plantation from 3 hunting seasons, 2007-08, 2008-09, and 2009-10, used to analyze the impact of days since supplemental feeding on coveys pointed/hr. Multiple regression revealed a significant year effect ($F_{2,289} = 14.9$, $P = 0.0001$), but no effect from days since supplemental feed was spread ($F_{1,289} = 0.02$, $P = 0.88$), nor was there an effect of a year by days since supplemental feed interaction ($F_{2,289}$

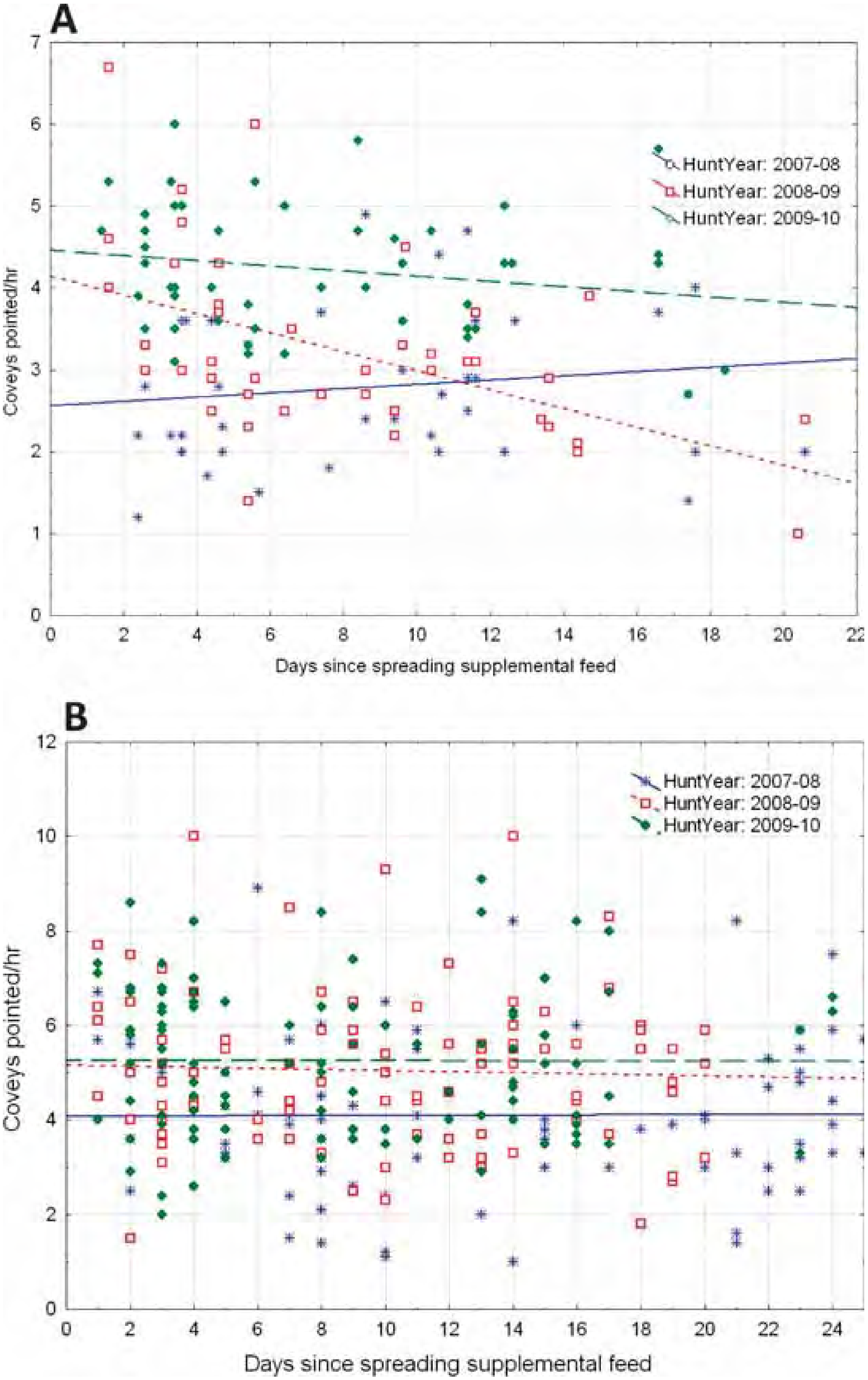

Fig. 2. The relationship between the number of bobwhite coveys pointed/hr and number of days since supplemental food was spread on Grady Plantation (A) and Baker Plantation (B) for the hunting seasons, 2007–08, 2008–09, and 2009–10.

= 0.08, $P = 0.92$) (Fig 2B). The model had a low coefficient of determination ($R^2 = 0.09$).

DISCUSSION

Hunting methods on these plantations were complex and incorporated many variables that potentially impacted hunting success. Our models explained little of the daily variation among hunts on either study area. We anticipated that weather variables, coupled with the consistency of hunting methods, would have had a more significant impact on hunting success. The systematic way hunting is conducted on our study areas, as compared to walk hunting by hunters and their dogs with varied skill levels (Guthery and Mecozzi 2008, Mecozzi and Guthery 2008), should have helped estimate the effect of weather conditions on hunting success. The success of hunting on our study areas was a function of some measured variables, such as time of day, but many unmeasured variables, such as how the hunt manager changed to accommodate to existing conditions, population size, and bobwhite behavior, likely ameliorated the strength of observed relationships. The ability of skilled hunt managers to compensate for environmental conditions appeared to reduce the effect of our measured explanatory variables. The hunting manager had a primary goal of pointing as many coveys possible during the hunt, and adjustments to the routine and style were made on a daily and annual basis to accomplish this goal. Bobwhite coveys were uniformly scattered across managed lands with few areas that are not accessible or covered by dogs. This consistency of habitat likely helped hunters find coveys at some time during the hunt when scenting conditions were not as favorable. Our data on hunting success were summarized by hunt, rather than in continuous time, and may be too crude to assess the effect of highly variable weather conditions on hunting success.

Differences between morning and afternoon hunting success may be caused by when the hunts actually took place during those time periods. The average start time of morning hunts was 0916 hrs, which may have been after most of the covey activity for the morning had occurred for many days. Sisson and Stribling (2009) documented the highest covey activity, on average, for the entire day was from 0730 to 0830 hrs. Lower morning hunting success observed during our study may have been due to hunt times inconsistent with the peak activity periods of coveys. Conversely, afternoon activity periods for coveys peaked from1645 to 1815 hrs (Sisson and Stribling 2009), which were within the typical afternoon hunting period. Our results suggest hunting times that correlated with peak covey activity periods can improve hunt success.

Time of season had minimal effects on hunt success and had no consistent pattern among years or study areas. There are many perceived factors associated with seasonal timing that can influence hunting success such as habitat quality and quantity that decreases as the winter progresses, and covey avoidance behavior that increases as the hunting season progresses. We did not evaluate the effects of these seasonally-correlated variables on hunting success and our results support the hypothesis that their overall impacts were minimal when analyzed seasonally on plantations. This hypothesis is based within the context of those hunting plantations where hunting pressure was light with a hunting course being visited every 2 to 3 weeks. We also investigated the monthly effects on key weather parameters used in the analysis. There were some differences in the monthly averages for all weather parameters, but they all had broad distributions that overlapped the monthly averages. This outcome supported the conclusion that weather effects on hunting success are not correlated with seasonal impacts.

Changes in weather had the potential to improve hunt success in 2 ways in our study; (1) by increasing bobwhite activity and the probability of detection, and (2) by improving the pointing-dogs' abilities to detect and point bobwhite coveys through better scenting conditions. Hunts for both study areas associated with rapid increases in barometric pressure resulting in high barometric pressure had the highest hunting success. These types of weather events in South Georgia were associated with a rapidly passing low pressure system followed by a high pressure system with a strong frontal boundary. As a high pressure system moves in, it typically brings colder temperatures, more stable air, and wind directions from the west and north. These weather conditions, tend to be short-lived, but could have significant impacts on bobwhite activity and scenting conditions. Sisson and Stribling (2009) observed more activity by coveys when there was colder weather, higher humidity, and light winds, which are similar conditions to hunts we observed with the highest hunting success. Higher bobwhite covey activity may be a potential factor for increased hunting success.

We observed no differences in hunting success between both study areas for 5 of 6 years relative to the number of days since supplemental feed was broadcast on a hunting course. There should be higher hunt success immediately after spreading feed and a decline in hunt success as food resources decline, if supplemental feed was acting as bait and concentrating coveys along feed lines. We observed no change in hunting success regardless of the number of days since supplemental feed was broadcast out to 25 days. An exception was during the 2008-09 hunt year on Grady Plantation, which had 2 below average hunts after 20 days since spreading feed that greatly affected the linear relationship. However, the majority of hunts for most years were conducted up to 15 days since spreading feed when supplemental food was still available (Miller 2011) and average hunt success remained consistent.

MANAGEMENT IMPLICATIONS

Successful bobwhite hunts are a function of bobwhite populations, daily timing, weather, habitat conditions, knowledge of the hunting party, and skill of the pointing dogs. Time of hunting had a significant effect with afternoon hunting adding 1–3 more coveys per 3-hr hunt.

We found that weather has a minor impact on hunting success on average on intensively managed lands with high density bobwhite populations. Experience indicates that at times unsuitable weather impacts hunting success temporarily, but it would be difficult to attempt to schedule hunts based on weather conditions to maximize hunting success. A better perspective would be to schedule hunting based on convenience rather than based on conditions, recognizing that certain conditions outlined in this paper may potentially impact hunting success. We recognize the best way to have high hunt success is for hunt managers to focus on maintaining high bobwhite densities through sound habitat management and using high quality bird dogs.

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We thank the owners, managers, and staff of the 2 plantations for allowing us to review and analyze their hunting records. We especially thank members of Tall Timbers Research Station who support our work. We appreciate the efforts of many technicians and interns for much of the data entry including J. T. Kamps, J. R. Garrow, A. B. Bostick, M. A. Mayo, S. D. Sofferin, and S. K. Smith.

LITERATURE CITED

Brennan, L. A., J. M. Lee, and R. S. Fuller. 2000. Long-term trends of northern bobwhite populations and hunting success on private shooting plantations in northern Florida and southern Georgia. Proceedings of the National Quail Symposium 4:75–77.

Burnham, K. P., and D. R. Anderson. 1998. Model selection and multi-model inference. Second edition. Springer-Verlag, New York, USA.

Guthery, F. S., and G. E. Mecozzi. 2008. Developing the concept of estimating bobwhite density with pointing dogs. Journal of Wildlife Management 72: 1175–1180.

Mecozzi, G. E., and F. S. Guthery. 2008. Behavior of walk-hunters and pointing dogs during northern bobwhite hunts. Journal of Wildlife Management 72:1399–1404.

Miller, R. S. 2011. Space use and foraging behavior of northern bobwhite in relation to resource availability in managed pine grassland ecosystems. Thesis. Mississippi State University, Starkville, USA.

Palmer, W. E., S. D. Wellendorf, L. A. Brennan, W. R. Davidson, and F. E. Kellogg. 2002. Hunting success and northern bobwhite density on Tall Timbers Research Station: 1970–2001. Proceedings of the National Quail Symposium 5:213–216.

Rosene Jr., W. 1969. The bobwhite quail; its life and management. Rutgers University Press, New Brunswick, New Jersey, USA.

SAS Institute Inc. 2008. SAS/STAT® 9.2 Users guide. SAS Institute Inc., Cary, North Carolina, USA.

Sisson, D. C., and H. L. Stribling. 2009. The Albany quail project, March 1992–December 2007. Tall Timbers Research Station and Land Conservancy, Miscellaneous Publication 18.

Sisson, D. C., H. L. Stribling, and D. W. Speake. 2000a. Effects of supplemental feeding on home range size and survival of northern bobwhites in South Georgia. Proceedings of the National Quail Symposium 4:128–131.

Sisson, D. C., H. L. Stribling, and D. W. Speake. 2000b. Efficiency of pointing dogs in locating northern bobwhite coveys. Proceedings of the National Quail Symposium 4:109.

Stribling, H. L., and D. C. Sisson. 2009. Hunting success on Albany, Georgia plantations: the Albany Quail Project's modern quail management strategy. Proceedings of the National Quail Symposium 6: 289–298.

FIELD APPLICATION OF SUSTAINED-YIELD HARVEST MANAGEMENT FOR NORTHERN BOBWHITE IN TEXAS

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ABSTRACT

Sustained-yield harvest (SYH) is considered a potentially viable strategy for managing harvest of northern bobwhites (*Colinus virginianus*). However, application of SYH has not been evaluated for northern bobwhites. We evaluated the application of using SYH as a harvest management strategy for bobwhite during the 2007–2008 and 2008–2009 hunting seasons in 2 ecoregions of Texas (Rolling Plains, South Texas Plains). We collected field data at 3 study sites/ecoregion (900–1,900 ha each; 2 hunted sites and 1 control) to estimate 4 demographic parameters (fall and spring density, overwinter survival in the absence of hunting, and harvest rate). We used these data to parameterize the additive harvest model for bobwhites and compare predictions of spring abundance of the model with field estimates. The additive harvest model, compared to field estimates, consistently underestimated spring population density (mean ± SE) by 55.7 ± 17.8% (2007–2008) and 34.1 ± 4.9% (2008–2009) in the Rolling Plains, and by 26.4 ± 25.3% (2007–2008) and 49.1 ± 2.1% (2008–2009) in the South Texas Plains. Implementing SYH in the field, despite its potential benefits, will be challenging given the need for reliable estimates of 3 key population parameters (fall and spring density, and natural mortality in the absence of hunting) and the high variation often associated with them. Conservative harvest prescriptions based on the lower 95% CIs of fall density estimates may permit sustainable harvest despite variation in density estimates.

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Key words: *Colinus virginianus*, northern bobwhite, South Texas, sustained-yield harvest

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A MID-ATLANTIC AND A NATIONAL POPULATION MODEL OF NORTHERN BOBWHITE DEMOGRAPHIC SENSITIVITY

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ABSTRACT

Numerous field studies have estimated fecundity and survival rates for northern bobwhites (*Colinus virginianus*), but a synthetic population model based on life-stage simulation analysis (LSA) was only recently developed to examine demographic sensitivity of the finite rate of population change. We compare local demographic parameters of bobwhite versus a national compilation to identify limiting demographic factors for improved regional habitat planning and management. The national compilation provided a useful overview but combined parameters across populations at different latitudes and under different management regimes. We parameterized our LSA model to examine the sensitivity of the finite rate of growth (λ) to simulated variation in 9 demographic parameters primarily estimated from field studies for one population in regional decline in New Jersey. Our model results predicted population declines in New Jersey ($\lambda = 0.55$) comparable to the national estimate ($\lambda = 0.54$), but notable differences occurred in sensitivity of demographic variables. The national model predicted winter survival of adults made the greatest contribution to variance of λ ($r^2 = 0.42$) followed by summer survival of adults ($r^2 = 0.13$), and survival of chicks ($r^2 = 0.11$). Our regional model for New Jersey also predicted winter and summer survival of adults would make the greatest contribution to variance of λ ($r^2 = 0.33$ and $r^2 = 0.13$). The New Jersey model, in contrast to the national model, showed that annual variation in components of fecundity had a large effect on Var(λ): including clutch size ($r^2 = 0.18$ vs. national $r^2 = 0.01$), nest success ($r^2 = 0.20$ vs. national $r^2 = 0.06$), and the number of young produced per nest that survived 30 days ($r^2 = 0.53$ vs. national $r^2 = 0.16$). Slopes of linear regression between simulated variation in each demographic variable against λ were similar between the national and regional models. The slope for number of young produced per nest that survived 30 days with one exception was lower in the New Jersey data indicating more young are required to realize a stationary population. Our simulation results suggest management practices that improve winter survival or the number of young surviving 30 days will have the greatest potential to increase bobwhite population growth rate in New Jersey. Future linkage of models of demographic performance to experimental habitat manipulations will aid regional scientific planning to improve necessary habitat management.

Citation: Williams, C. K., B. K. Sandercock, B. M. Collins, M. Lohr, and P. M. Castelli. 2012. A Mid-Atlantic and a national population model of northern bobwhite demographic sensitivity. Proceedings of the National Quail Symposium 7:163–172.

Key words: *Colinus virginianus*, fecundity, life-stage simulation analysis, New Jersey, northern bobwhite, population model, survival

INTRODUCTION

The northern bobwhite is an upland gamebird of conservation concern because of widespread population declines primarily caused by habitat loss and degradation (Brennan 1991, Guthery et al. 2000, Williams et al. 2004, Veech 2006). Population roadside counts from the Breeding Bird Survey (BBS) indicate a range-wide decline of 3.9%/year between 1980 and 2007 (Sauer et al. 2011), despite being a short-lived species with high reproductive potential (Sandercock et al. 2008). Some of the most marked declines in bobwhite populations are occurring at the northern periphery of the species' range, including the upper Mid-Atlantic states with an average decline of 8.8%/year (Fig. 1). It is unknown which population vital rates or stages of the annual life cycle are most limiting and how they account for recent population declines.

Numerous northern bobwhite field studies have estimated vital rates (compiled by Sandercock et al. 2008), and early population models used simulations, time-series, and structured models based on age ratios to model population dynamics (Roseberry 1979, Guthery

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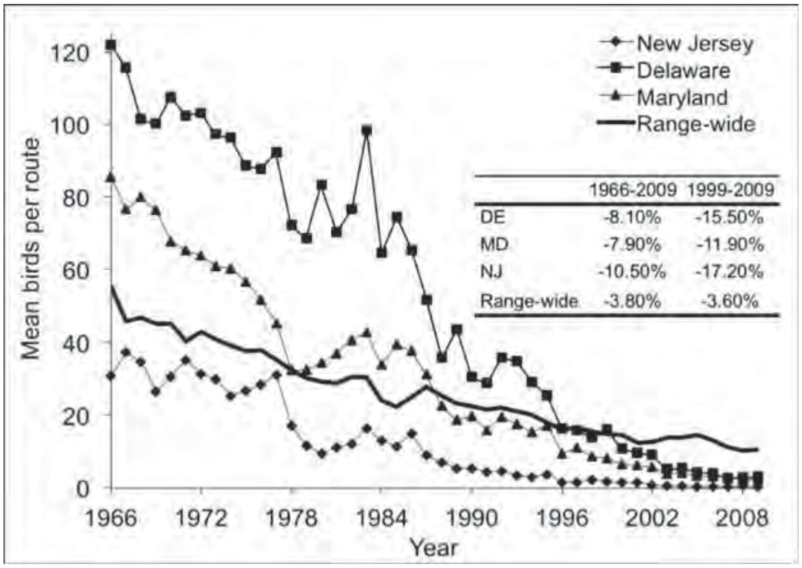

	1966-2009	1999-2009
DE	-8.10%	-15.50%
MD	-7.90%	-11.90%
NJ	-10.50%	-17.20%
Range-wide	-3.80%	-3.60%

Fig. 1. Population trends of northern bobwhite in 3 Mid-Atlantic states and range-wide as estimated from the Breeding Bird Survey (1966–2009).

1997, Guthery et al. 2000, Thogmartin et al. 2002, Williams et al. 2003). However, it was not until recently (Sandercock et al. 2008), that a structured population model was developed. That model was an important first step because it provided a framework for investigating the impacts of underlying demographic parameters on population growth of northern bobwhites. We developed a model based on life-stage simulation analysis (LSA; Wisdom and Mills 1997, Wisdom et al. 2000), which uses randomization and coefficients of determination (r^2 values) to identify demographic parameters that make the greatest contributions to simulated variation in finite rates of population growth (λ). One advantage of LSA is that exploratory models can be built with limited demographic data. For example, if probability distributions of parameters are unknown, LSA models can be built using uniform distributions bounded by the range of possible values.

We used life-stage simulation analyses to develop a regional model of the demography of bobwhite in New Jersey with the goals to: (1) compare local/regional dynamics to a national model as a baseline, and (2) identify limiting local/regional demographic factors to improve habitat planning and management. Field data were collected during a 3-year study in a declining peripheral population of bobwhite in New Jersey (Collins et al. 2009, Lohr et al. 2011). We improve the national model to guide regional management because 8 of 9 demographic estimates were taken from one population exposed to a common set of ecological conditions. Our demographic model provides an example of the effectiveness of life-stage simulation analysis for local/regional bobwhite populations to guide future management in other regions of the country.

STUDY AREA

This 3-year field study was conducted within a ~125-km^2 area without fixed study area boundaries in west-central Cumberland County, New Jersey (focal area) during the 6-month bobwhite breeding season (1 May–30 Sep, 2006–2008) and nonbreeding season (1 Oct-30 Apr, 2006–2009). The focal area is within the Outer Coastal Plain physiographic region, bordering Delaware Bay. Land use in the focal area was 39.1% forest; 24.9% wetland; 20.0% agriculture, hayland, or pasture; 5.9% developed; 5.4% early successional habitat (including old fields, grasslands, and shrubland habitats); and 4.7% other land use (orchards and nurseries, extractive mining, and barren land) (NJDEP 2008). Forest overstory species were predominantly oaks (*Quercus* spp.) and Virginia pine (*Pinus virginiana*); common understory and edge species were multiflora rose (*Rosa multiflora*), greenbriar *(Smilax* spp.), Russian olive (*Elaeagnus angustifolia*), and mountain laurel (*Kalmia latifolia*). Common grasses were broom sedge (*Andropogon virginicus*), big bluestem (*A. gerardi*), and orchard grass (*Dactylis glomerata*). The focal area was predominantly private land, but included ~1.5 km^2 of managed grassland and savannah on the Buckshutem Wildlife Management Area.

METHODS

Field Collection of Parameter Estimates

We captured bobwhites year round using funnel traps (Stoddard 1931) baited with corn and red millet. Funnel traps were placed in locations with dense overhead vegetation to reduce risk of detection by avian predators. We also captured bobwhites by night-lighting when weather and roosting vegetation allowed (Labisky 1968), and by mist nesting with audio lures in summer. Captured birds were classified to age and gender (Rosene 1969), fitted with an individually-numbered aluminum leg band, and weighed to the nearest gram. We fit birds that weighed $\geq$ 150 g with a 6-g necklace-mounted radio transmitter (Burger et al. 1995). Bobwhites weighing $\leq$150 g were not radiomarked to avoid stress from radio transmitters weighing $\geq$ 5% of an individual's body mass (Samuel and Fuller 1994). We collected the first primary on each wing if no flight feathers were missing for future genetic and stable isotope analysis. We released all bobwhites at location of capture. The Institutional Animal Care and Use Committee at the University of Delaware approved the capture and handling procedures used in this study (IACUC Approval #1142).

Individual bobwhites were allowed to acclimate to radio transmitters for 7 days before being included in survival analysis to reduce potential bias (Tsai et al. 1999). We located all bobwhites 4 to 7 times per week using handheld VHF and H-antennas for the 3-year period between 1 May 2006 and 30 April 2008 until mortality, radio loss, radio failure, or end of study season. Bobwhites were censored (9 of 152 = 6%) because of unknown fate, radio loss, or survival beyond the end of the study season. The midpoint between the last known location and the day the radio stopped moving or was not found was used as the censor date if exact dates of radio loss or disappearance were unknown, and fate was coded as survived. We visually confirmed potential mortalities following 3 consecutive locations at the same point in the first year of the study. Radio transmitters contained a mortality sensor that doubled the transmitter's pulse rate after 12 hrs of inactivity in the second year, allowing for more prompt investigation of mortality events. We recorded likely mortality causes as avian predation, mammalian predation, hunter harvest, study related mortality, unknown source, or other based on evidence present at the mortality site. We used the midpoint between the last day known alive and the date the bird was found dead, when exact mortality dates were not known, as the mortality date. We calculated 6-month summer and winter survival rates with Kaplan-Meier staggered-entry additions (Kaplan and Meier 1958, Pollock et al. 1989) in S-Plus 8.0 (Insightful Co., Seattle, WA, USA).

We identified potential bobwhite nests after 2 consecutive identical location estimates of a radio-marked adult (Burger et al. 1995). We placed a flag 10–15 m from the suspected nest site, and visually confirmed the nest location once the incubating adult was away from the site (Burger et al. 1995, Taylor et al. 1999). We attempted not to flush suspected incubating adults to minimize nest abandonment. We recorded the number of eggs and the location of the nest with a handheld Global Positioning System unit in UTM coordinates if a nest was discovered before the nesting attempt was completed. We monitored the status of each nest 4–7 times/week by locating the incubating adult. We visually inspected nests each time the incubating adult was away from the nest and recorded whether nests were depredated, eggs had hatched, or were undisturbed. We considered undisturbed nests where incubation did not resume within 7 days as naturally abandoned. We considered nests abandoned due to observer disturbance if abandonment occurred immediately after the accidental flush of an incubating bobwhite. We defined successful nests as those hatching $\geq$ 1 egg (Taylor et al. 1999). We considered predated and naturally abandoned nests as failed.

We estimated nest daily survival rates (NEST) using the Mayfield method (Mayfield 1961) for a 24-day incubation period (Burger et al. 1995). We documented 5 other reproductive parameters including: (1) mean size of total clutch laid for all nests (TCL), (2) mean hatching success of eggs in nests that survived incubation (HATCH), (3) re-nesting probability (RENEST), (4) double-clutch attempts (SECOND), and (5) male nesting rates (MALE) by the simple proportion of radio-marked birds incubating a nest. We attempted to capture chicks to radiomark and estimate survival, but our efforts were unsuccessful; thus, we used a national average value for chick survival (S_c) for model formulation (Sandercock et al. 2008).

Population Model

We developed a female-based population model (following Sandercock et al. 2008) based on known bobwhite breeding behaviors that included: (1) all females nest as yearlings, (2) all females produce of at least one clutch, (3) renesting, (4) double-brooding, (5) male-incubated nests, and that (6) all components of fecundity are independent of the age and gender of the attending parent, type of nesting attempt, and seasonal timing of clutch initiation (Burger et al. 1995, Cox et al. 2005, Hernández et al. 2007). We split the year into 2 equal 6-month periods to include summer (S_s, 1 Apr to 31 Sep) and winter survival (S_w, 1 Oct to 31 Mar), and assumed seasonal survival to be density independent.

We first calculated the number of female young produced per nesting attempt that survived to independence at 30 days (*YOUNG*) to estimate yearly λ as:

$$YOUNG = TCL \times NEST \times HATCH \times 0.5 \times S_C,$$

where TCL is the total clutch laid, NEST is nest success, HATCH is the proportion of eggs that hatch, 0.5 is the proportion of young that are female (based on a 1:1 sex ratio at hatching; Lusk et al. 2005), and S_c is chick survival from hatch to independence at 30 days. Second, we calculated productivity for 6 different types of nesting attempts (f_i) (Table 1). Nesting attempts included: first nests incubated by females (f_1), second nests laid after successful hatching of a first clutch (SECOND) and incubated by females (f_2), renests laid after loss of a first nest (RENEST) and incubated by females (f_3), second renests laid after loss of first renests and incubated by females (f_4), first nests incubated by males (MALE) (f_5), and renests after loss of first male clutch and incubated by males (f_6). The formulae for nesting productivity for nesting attempts f_1 to f_6 were:

$$f_1 = YOUNG \times S_S^{3.5/6},$$

$$f_2 = NEST \times SECOND \times YOUNG \times S_S^{1/6},$$

$$f_3 = (1 - NEST) \times RENEST \times YOUNG \times S_S^{2/6},$$

Table 1. Generalized breeding season for northern bobwhites based on reproductive strategies that include renesting, double-brooding, and male-incubated nests. The 6-month breeding season is subdivided into 12 biweekly periods to account for seasonal variation in timing of nest initiation.

	Apr		May		Jun		Jul		Aug		Sep	
Nesting attempt	1	2	3	4	5	6	7	8	9	10	11	12
First nest (f_1)	Laying	Incubation		Chick survival		Fledgling survival						
Second nest (f_2)						Laying	Incubation		Chick survival		Fledgling survival	
First renest (f_3)			Interval	Laying	Incubation		Chick survival		Fledgling survival			
Second renest (f_4)						Interval	Laying	Incubation		Chick survival		Fledgling survival
Male nest (f_5)			Interval	Laying	Incubation		Chick survival		Fledgling survival			
Male renest (f_6)					Interval	Laying	Incubation		Chick survival		Fledgling survival	

$$f_4 = (1 - NEST) \times RENEST \times (1 - NEST) \times RENEST \times YOUNG \times {S_S}^{0.5/6},$$

$$f_5 = MALE \times YOUNG \times {S_S}^{2/6},$$

$$f_6 = (1 - NEST) \times RENEST \times MALE \times YOUNG \times {S_S}^{1/6},$$

where the exponents on the 6-month estimate of summer survival (S_S) account for the number of months of 6 months that each of the 6 different types of productivity survived between independence at 30 days and the end of the summer breeding season. We summed components of productivity using these 6 estimates to estimate seasonal fecundity per breeding female (F):

$$F = \sum_{i=1}^{6} f_i$$

and estimated the finite rate of population change (λ) as:

$$\lambda = (S_s \times S_w) + (F \times S_w),$$

where lambda was the sum of surviving adults and surviving juveniles.

Life-stage Simulation Analysis

We used LSA to examine contributions of the 9 demographic parameters to simulated variation in λ (Wisdom et al. 2000). All simulations were conducted using algorithms implemented in Program R (R Development Core Team 2005). We drew a random set of 9 parameters from uniform probability distributions bounded by the full 100% range of field estimates for each demographic parameter. We combined them to calculate λ with the formulae presented in the population model, and repeated these steps for n = 1,000 iterations. We treated parameters as independent and did not use a covariance structure or a function with density-dependence to select random draws (Wisdom et al. 2000). We used linear regression and coefficients of determination (r^2) to calculate the amount of variation in λ explained by simulated variation in each of the 9 demographic parameters. We also reran the national model using parameter distributions in Sandercock et al. (2008) and compared regression parameter estimates (β) for each demographic variable between the New Jersey model and National model to identify areas of biological difference (paired *t*-test, Clogg et al. 1995). We recognize the robustness of the *t*-test is compromised because the distributions are based on a uniform distribution instead of a normal distribution.

RESULTS

We captured and radiomarked 152 bobwhites including 86 during the breeding seasons of 2006 and 2007. We censored 6 that survived $\leq$7 days leaving 80 (35 juv M, 11 ad M, 25 juv F, 9 ad F) to estimate breeding season survival. We captured 66 bobwhites during the winter seasons of 2006–2007 and 2007–2008. We censored 5 that survived $\leq$ 7 days after capture leaving 61 bobwhites (18 juv M, 12 ad M, 18 juv F, 13 ad F) to estimate winter survival. Estimated survival during the 6-month breeding season was 0.267 (95% CI = 0.172–0.417, Table 2). Survival during the 6-month non-breeding season was higher at 0.308 (95% CI = 0.210–0.453). Annual survival pooled across years was 0.063 (95% CI = 0.029–0.136). We used the 95% CI for each season as the uniform distribution boundary of possible survival rates in the LSA.

We located 23 bobwhite nests (16 in 2006, 7 in 2007) by tracking radio-marked birds during the breeding season. Ten nests hatched over both years, 10 were depredated, 1 was abandoned (incubating adult was killed away from the nest site), and 2 nests were abandoned due to observer disturbance. Interval survival (NEST) (based on 340 monitoring days and a daily survival rate = 0.967 [95% CI = 0.948–0.987]) for the 24-day incubation period was 0.454 (95% CI = 0.282–0.728; Table 2). Mean clutch size (TCL) was 14.2 (range = 10–19). Hatching success of eggs (HATCH) in successful nests that survived incuba-

Table 2. Demographic rates estimated from New Jersey (2006–2009) compared to national median values (Sandercock et al. 2008). Predicted LSA λ estimates based on demographic rates are shown at the bottom.

Demographic parameter	New Jersey Mean (range or 95% CI)	Range-wide Median (range)
Total clutch laid (eggs)	14.2 (10–19)	12.8 (11.2–15.6)
Renesting	0.44 (0.33–0.67)	0.50 (0.0–1.00)
Nest survival	0.454 (95% CI = 0.282–0.728)	0.42 (0.19–0.70)
Double-brooding	–	0.25 (0.15–0.42)
Hatching rate (chicks/egg)	0.96 (0.86–1.00)	0.92 (0.80–0.96)
Male nesting (M-nest/F-nest)	0.27 (0.25–0.27)	0.28 (0.06–0.51)
Chick survival (1 mo)	–	0.41 (0.14–0.72)
Total young survived 30 days per nesting attempt	1.27 (0.35–3.67)	1.01 (0.12–3.77)
Summer survival (6 mo)	0.267 (95% CI = 0.172–0.417)	0.39 (0.01–0.92)
Winter survival (6 mo)	0.308 (95% CI = 0.210–0.453)	0.26 (0.01–0.73)
λ (Median and 95% CI)	0.548 (0.263–1.124)	0.543 (0.034–2.175)

tion was 96.1 (range = 86–100%). Nine females had a failed first nest attempt, and 4 (44.4%) renested (RENEST, inter-year variation = 33.3–66.6%). The ratio of the number of male-incubated nests per female-incubated nesting attempt (MALE) was 0.267 (range = 0.25–0.273). No females were observed to initiate a second nest (SECOND) after fledgling young from a successful first nest (0 of 5; 0.0%). Lack of second broods could be a function of high latitude in New Jersey, but we conservatively assumed the possibility of second nesting could occur using the national average (range = 0.15–0.42). We were unable to estimate chick survival S_c and used the national average to parameterize this variable (range = 0.29–0.53).

The median rate of population change for our New Jersey population was $\lambda = 0.548$ (95%CI = 0.263–1.124) which was comparable to the national median rate of population change at $\lambda = 0.543$ (95% CI: 0.034–2.175; Table 1). Simulated variation in the New Jersey winter survival, like the national model, made the greatest contribution to variance in λ ($r^2 = 0.331$; Fig. 2), although it was lower than the national model ($r^2 = 0.420$; Fig. 3). However, the estimates of the slopes of the two linear regressions were not different (New Jersey = 1.82 vs. national = 1.95, $t_1 = 0.914$, $P = 0.361$). A 1% change in winter survival would produce a change in λ of 1.8% for regional and national models. The New Jersey model predicted 56.1% overwinter survival would be required to produce $\lambda = 1$ while the national model predicted 53.5% survival would be required. Summer survival of New Jersey adults ($r^2 = 0.185$) was also similar to the national model ($r^2 = 0.127$), and regression slope parameter estimates did not differ (New Jersey = 1.16 vs. national = 0.97, $t_1 = 0.443$, $P = 0.658$). A 1% change in summer survival would produce a λ change of 1.1% in the New Jersey model and 1.8% in the national model. The New Jersey model predicted 65.5% summer survival would be required to produce $\lambda = 1$ while the national model predicted 75.4% survival would be required.

The rate of population change was not sensitive to hatching success, probability of renesting, or male-incubated nests per female nest in either the New Jersey and national models ($r^2 < 0.01$) and showed no difference in regression parameter estimates ($t_1 < 0.934$, $P > 0.350$). National values were used for chick survival ($r^2 = 0.13$), and second nesting ($r^2 = 0.001$) and we did not compare regression betas. The var (λ) for bobwhite in New Jersey, unlike the national model, showed strong responses to clutch size ($r^2 = 0.175$; national $r^2 = 0.005$) and nest success ($r^2 = 0.201$; national $r^2 = 0.063$) (Figs. 2, 3). Neither parameter showed differences in the predicted regression slopes (Clutch Size: New Jersey = 0.04 vs. national = 0.04, $t_1 = 0.047$, $P = 0.963$ and Nest Success: New Jersey = 0.79 vs. national = 0.92, $t_1 = 0.897$, $P = 0.370$, respectively). A 1-egg change in clutch size would produce a 3.6% change in λ in the New Jersey model compared to 3.3% in the national model. The New Jersey model predicted a clutch size of 26 would be required to produce $\lambda = 1$ while the national model predicted a clutch size of 22. A 1% change in nest success would produce a λ change of 0.8% in the New Jersey model and 0.9% in the national model. The New Jersey model predicted 103.4% nest success would be required to produce $\lambda = 1$ whereas the national model predicted 76.0% nest success would be required.

The coefficients of variation were most different in clutch size and nest success, and we combined all nesting variables required to equal the number of YOUNG produced (TLC, NEST, HATCH, and S_c) and compared the model fit between the New Jersey and national models. The estimated coefficient of determination for the New Jersey data was strong ($r^2 = 0.525$; Fig. 2) compared to the national model ($r^2 = 0.160$; Fig. 3), but also indicated a lower slope in the regression lines (New Jersey = 0.315 vs. national = 0.380, $t_1 = 3.928$, $P < 0.001$). Addition of one female young produced per nesting attempt that survived to independence at 30 days would produce a 31.5% change in λ in the New Jersey model compared to 38.0% in the national model. The New Jersey model predicted 2.74 female young produced per nesting attempt that survived to independence at 30 days would be required to produce $\lambda = 1$ while the national model predicted 1.90 female young.

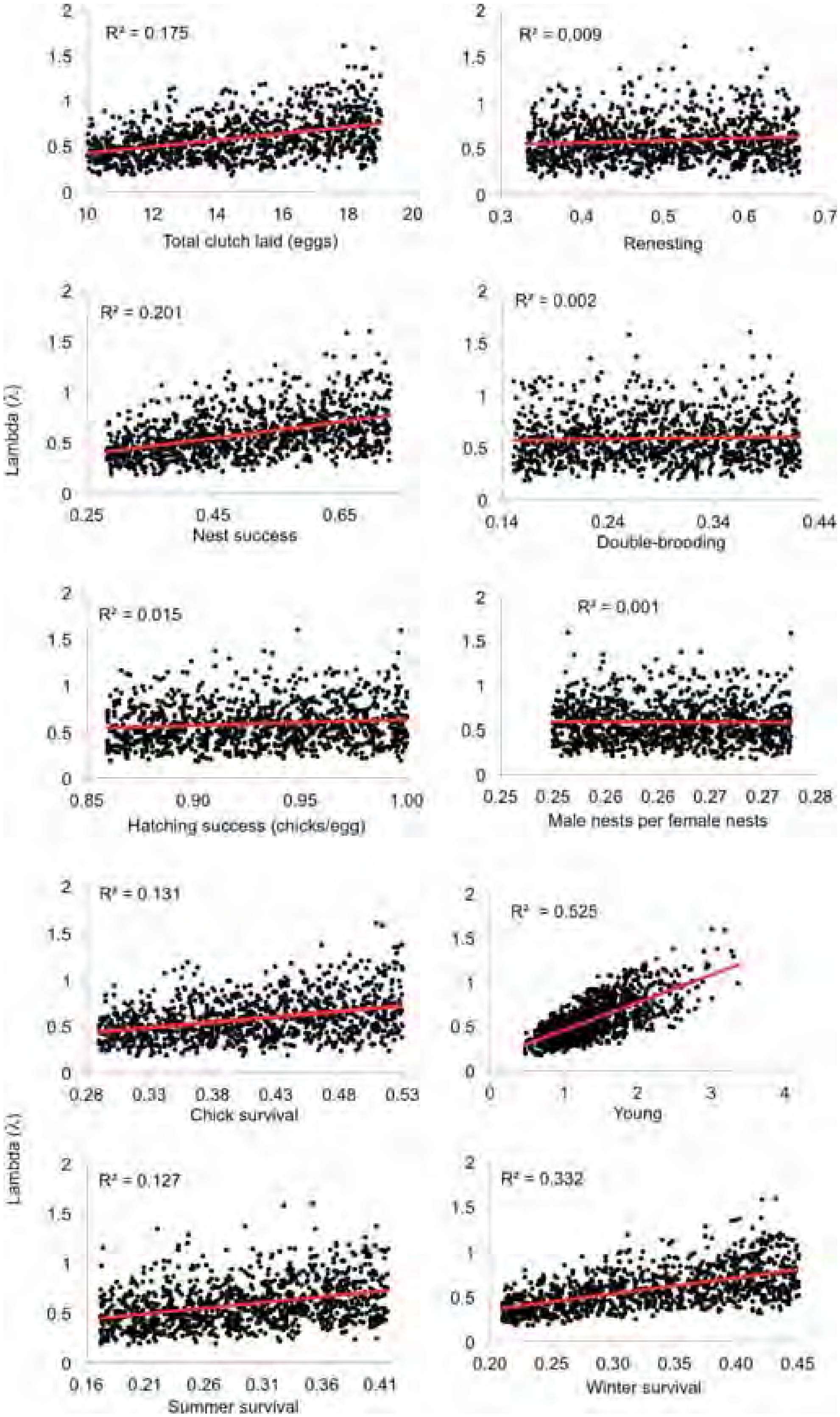

Fig. 2. Life-stage simulation analysis of the finite rate of population change (λ) in response to simulated variation in 10 demographic parameters for northern bobwhites in New Jersey (2006–2009). Coefficients of determination (r^2) indicate the proportion of simulated variance in λ explained by variation in the demographic parameters. Eight demographic parameters were bounded by the minimum and maximum values observed under field conditions. Estimates were drawn from uniform distributions and combined to calculate λ ($n = 1{,}000$ bootstrap iterations). National values (Sandercock et al. 2008) were used for chick survival and the probability of second nesting attempts.

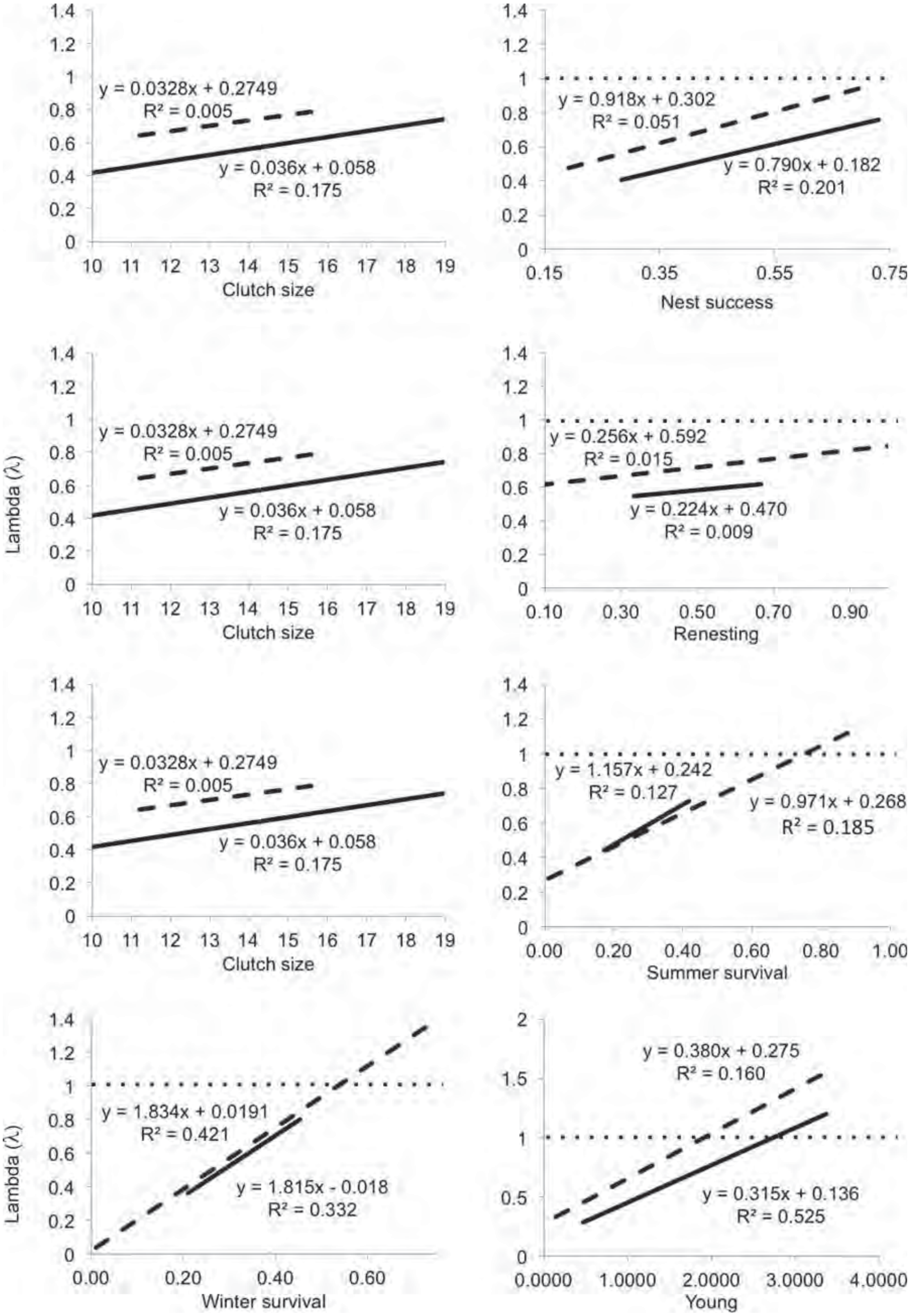

Fig. 3. Estimated regressions of life-stage simulation analysis of the finite rate of population change (λ) in response to simulated variation in 8 demographic parameters for northern bobwhites in New Jersey (solid line, 2006–2009) and national (dotted line, Sandercock et al. 2008). Coefficients of determination (r^2) indicate the proportion of simulated variance in λ explained by variation in the demographic parameters. The national values for chick survival and probability of second nesting attempts were used in the state model but are not compared in this figure.

DISCUSSION

Our demographic analyses for northern bobwhites in New Jersey addressed 2 goals; first to illustrate the use of life-stage simulation analysis for local or regional studies of population viability, and second, to inform regional management of a declining population of bobwhites at the northern periphery of the species' geographic range. Multiple quantitative methods are available for modeling populations, including LSA (Wisdom and Mills 1997, Wisdom et al. 2000, Sandercock et al. 2008) and parametric matrix models (Caswell 2001, Fieberg and Ellner 2001). Parametric matrix models are widely used (Oli and Dobson 2003, Stahl and Oli 2006) and have the advantage of using sensitivity or elasticity analysis to ascertain demographic parameters that most influence λ. However, they require large long-term data sets because a probability distribution must be used to bootstrap confidence intervals (Fieberg and Ellner 2001). In contrast, because modeling relies on randomization and coefficients of determination to identify demographic parameters that most influence λ, LSA does not require *a priori* knowledge of a probability distribution and use of uniform distributions can suffice. Simulations have shown that different probability distributions usually have little effect on qualitative results of stochastic population models (Wisdom et al. 2000, Fieberg and Ellner 2001, Kaye and Pyke 2003, Sandercock et al. 2008). A practical advantage of LSA models is that they can be developed with less information or with data from different sources. The LSA approach proved invaluable in our synthetic national northern bobwhite model for pulling together data from many different sources of varying quality. The LSA method may prove useful for local and regional researchers who wish to model populations with less information collected over limited spatial or temporal scales. Regression beta coefficients in the comparisons of our study were similar between the national meta-analysis and the local study indicating biological relevance can be examined through LSA despite different data sources.

Our model for bobwhite in New Jersey was mostly based on demographic parameter estimates from field studies of a single population, whereas the national model combined estimates from different populations exposed to varying ecological conditions. Results of our regional and national model for bobwhite were comparable. Our analyses indicated winter and summer survival had strong influences on variation in rates of population change in a declining population. Changes in survival often have a strong effect on rates of growth in declining populations (Meats 1971), and similar results have been reported for bobwhites (Folk et al. 2007, Sandercock et al. 2008), wild turkeys (*Meleagris gallopavo*, Alpizar-Jara et al. 2001), 2 species of partridge (Bernard-Laurent and Léonard 2000, Bro et al. 2000), and 9 of 10 species of grouse (Sandercock et al. 2005, Hannon and Martin 2006, Tirpak et al. 2006). Guthery (1997) and Guthery et al. (2000) suggested that northern populations of bobwhites tend to have higher fecundity and lower annual survival compared to southern populations. One interesting difference between the New Jersey and national models was a large impact of two key components of reproductive effort: total clutch size (New Jersey: $r^2 = 0.175$; national: $r^2 = 0.005$) and nest success (New Jersey: $r^2 = 0.201$; national: $r^2 = 0.051$) on the rates of population change. The observed New Jersey estimates were slightly higher than the national estimates for both vital rates. We found a strong r^2 value associated with winter survival in New Jersey despite predicted latitudinal variation in bobwhite life histories. The predicted survival rate was higher (31%) than that of the national model average (26%) which was dominated by data from southern states.

High reproductive potential may compensate for greater seasonal losses during cold winters in northern populations. We further calculated the number of female young produced per nesting attempt that survived to independence at 30 days (YOUNG) and found the greatest contribution to variance around λ ($r^2 = 0.525$) compared to the national value of $r^2 = 0.160$. A high contribution of fecundity is consistent with Wisdom and Mills (1997) and Wisdom et al. (2000) who found similar impacts of fecundity for greater prairie-chicken (*Tympanuchus cupido*) population growth. Each reproductive parameter actually produced a lower impact on λ despite the higher predictive power in variance explanation. New Jersey would require 2.74 female young per adult female surviving to 30 days to produce population stability whereas the range-wide estimate of YOUNG predicted 1.90 would be sufficient. Despite the greater coefficient of determination of this data in New Jersey, it also deviated sufficiently from the national data for a lower slope and less of an effect on λ.

We have shown using LSA to model local and regional populations with sparse data sets allows for population predictions and estimates. We encourage state and regional researchers who have conducted demographic and ecological studies of bobwhite to combine their data sources to catalogue the 9 demographic variables used in our national LSA model to produce their own regional assessments. Regional land managers may have an opportunity to identify and adjust management efforts to address demographic limitations of population growth through comparison of demographic differences with a baseline λ = 1 and national results. The National Bobwhite Conservation Initiative (NBTC 2011) has recently increased efforts to improve scientific rigor and develop an information framework. We encourage future researchers to: (1) test the robustness of this methodology with independent measures of λ, and (2) refine local chick survival estimates in New Jersey as well as throughout the bobwhite range. We hope this population model will increase that regional information base in an effort to improve regional management recommendations.

MANAGEMENT IMPLICATIONS

Northern populations of bobwhites should have higher fecundity to compensate for stochasticity in winter survival (Guthery 1997). That high fecundity did not offset high rates of mortality suggests an area for future habitat management with special emphasis on nest success and chick survival. Grassland and early successional habitats are traditionally viewed as good bobwhite nesting and brood-rearing habitat (Edminster 1954, Roseberry and Klimstra 1984), and can improve survival of breeding adults (Lohr et al. 2011). However, New Jersey is on the low end of a range-wide continuum of bobwhite breeding habitat availability and quality due to extensive urban development and cover in forested habitats. Only 8.7% of our study area was early successional habitat in grassland or shrub-scrub versus 49–80% early successional cover at sites in Kansas and Mississippi (Taylor et al. 1999, Taylor and Burger 2000). Steep declines in BBS numbers in New Jersey are likely related to local extinctions resulting from loss of patchily-distributed habitat associated with grassland and early successional habitat. We recommend local managers examine: (1) opportunities to improve or increase grassland habitat to improve breeding demographic parameters, and (2) increase woody escape cover around grassland habitat to improve winter survival.

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LITERATURE CITED

Alpizar-Jara, R., E. N. Brooks, K. H. Pollock, D. E. Steffen, J. C. Pack, and G. W. Norman. 2001. An eastern wild turkey population dynamics model for Virginia and West Virginia. Journal of Wildlife Management 65:415–424.

Bernard-Laurent, A., and Y. Léonard. 2000. Vulnerability of an alpine population of rock partridge (*Alectoris graeca saxatilis*) to climatic events: evaluation with deterministic and stochastic models. Game and Wildlife Science 17:63–79.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

Bro, E., F. Sarrazin, J. Clobert, and F. Reitz. 2000. Demography and the decline of the grey partridge *Perdix perdix* in France. Journal of Animal Ecology 37:432–448.

Burger Jr., L. W., M. R. Ryan, T. V. Dailey, and E. W. Kurzejeski. 1995. Reproductive strategies, success and mating systems of northern bobwhite in Missouri. Journal of Wildlife Management 59:417–426.

Caswell, H. 2001. Matrix population models: construction, analysis and interpretation. Sinauer Associates, Sunderland, Massachusetts, USA.

Clogg, C. C., E. Petkova, and A. Haritou. 1995. Statistical methods for comparing regression coefficients between models. American Journal of Sociology 100:1261–1293.

Collins, B. M., C. K. Williams, and P. M. Castelli. 2009. Reproduction and microhabitat selection in a sharply declining northern bobwhite (*Colinus virginianus*) population. Wilson Journal of Ornithology 121:688–695.

Cox, S. A., F. S. Guthery, J. J. Lusk, A. D. Peoples, S. J. DeMaso, and M. Sams. 2005. Reproduction by northern bobwhites in western Oklahoma. Journal of Wildlife Management 69:133–139.

Edminster, F. C. 1954. American game birds of field and forest– their habits, ecology, and management. Charles Schribner's and Sons, New York, USA.

Fieberg, J., and S. P. Ellner. 2001. Stochastic matrix models for conservation and management: a comparative review of methods. Ecology Letters 4:244–266.

Folk, T. H., R. R. Holmes, and J. B. Grand. 2007. Variation in northern bobwhite demography along two temporal scales. Population Ecology 49:211–219.

Guthery, F. S. 1997. A philosophy of habitat management for northern bobwhite. Journal of Wildlife Management 61:291–301.

Guthery, F. S., M. J. Peterson, and R. R. George. 2000. Viability of northern bobwhite populations. Journal of Wildlife Management 64:646–662.

Hannon, S. J., and K. Martin. 2006. Ecology of juvenile grouse during the transition to adulthood. Journal of Zoology 269:422–433.

Hernández, F., K. M. Kelley, J. A. Arredondo, F. Hernández, D. G. Hewitt, F. C. Bryant, and R. L. Bingham. 2007. Population irruptions of northern bobwhite: testing an age-specific reproduction hypothesis. Journal of Wildlife Management 71:895–901.

Kaplan, E. L., and P. Meier. 1958. Nonparametric estimation from incomplete observations. Journal of the American Statistical Association 53:457–481.

Kaye, T. N., and D. A. Pyke. 2003. The effect of stochastic technique on estimates of population viability from transition matrix models. Ecology 84:1464–1476.

Labisky, R. F. 1968. Nightlighting: its use in capturing pheasants, prairie chickens, bobwhites and cottontails. Illinois Natural History Survey Biological Notes Number 62.

Lohr, M., B. M. Collins, P. M. Castelli, and C. K. Williams. 2011. Life on the edge: northern bobwhite ecology at the northern periphery of their range. Journal of Wildlife Management 75:52–60.

Lusk, J. J., F. S. Guthery, S. A. Cox, S. J. DeMaso, and A. D. Peoples. 2005. Survival and growth of northern bobwhite chicks in western Oklahoma. American Midland Naturalist 153:389–395.

Mayfield, H. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255–261.

Meats, A. 1971. The relative importance to population increase of fluctuations in mortality, fecundity and the time variables of the reproductive schedule. Oecologia 6:223–237.

New Jersey Department of Environmental Protection (NJDEP). 2008. 2002 NJDEP land use/land cover by water management area. New Jersey Department of Environment Protection, Trenton, USA. www.state.nj.us/dep/gis/lulc02cshp.html

National Bobwhite Technical Committee (NBTC). 2011. W. E. Palmer, T. M. Terhune, and D. F. McKenzie, eds. The National Bobwhite Conservation Initiative: a range-wide plan for recovering bobwhites. National Bobwhite Technical Committee, Technical Publication Version 2.0. Knoxville, Tennessee, USA.

Oli, M. K., and F. S. Dobson. 2003. The relative importance of life-history variables to population growth rate in mammals: Cole's prediction revisited. American Naturalist 161:422–440.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53:7–15.

R Development Core Team. 2005. R: a language and environment for statistical computing, reference index. Version 2. R Foundation for Statistical Computing, Vienna, Austria.

Roseberry, J. L. 1979. Bobwhite population responses to exploitation: real and simulated. Journal of Wildlife Management 43:285–305.

Roseberry J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, USA.

Rosene Jr., W. 1969. The bobwhite quail: its life and management. Rutgers University Press, New Brunswick, New Jersey, USA.

Samuel, M. D., and M. R. Fuller. 1994. Wildlife radiotelemetry. Pages 370–418 *in* T. A. Bookhout, ed. Research and management techniques for wildlife and habitats. Fifth edition. The Wildlife Society, Bethesda, Maryland, USA.

Sandercock, B. K., K. Martin, and S. J. Hannon. 2005. Demographic consequences of age-structure in extreme environments: population models for arctic and alpine ptarmigan. Oecologia 146:13–24.

Sandercock, B. K., W. E. Jensen, C. K. Williams, and R. D. Applegate. 2008. Demographic sensitivity of population change in northern bobwhite. Journal of Wildlife Management 2:970–982.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski Jr., and W. A. Link. 2011. The North American Breeding Bird Survey, results and analysis 1966–2009. Version 3.23.2011. USGS, Patuxent Wildlife Research Center, Laurel, Maryland, USA

Stahl, J. T., and M. K. Oli. 2006. Relative importance of avian life-history variables to population growth rate. Ecological Modelling 198:23–39.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. Charles Scribner's Sons, New York, USA.

Taylor, J. D., and L. W. Burger Jr. 2000. Habitat use by breeding northern bobwhites in managed old-field habitats in Mississippi. Proceedings of the National Quail Symposium 4:7–15.

Taylor, J. S., K. E. Church, D. H. Rusch, and J. R. Cary. 1999. Macrohabitat effects on summer survival, movements, and clutch success of northern bobwhite in Kansas. Journal of Wildlife Management 63:675–685.

Thogmartin, W. E., J. L. Roseberry, and A. Woolf. 2002. Cyclicity in northern bobwhites: a time-analytic review of the evidence. Proceedings of the National Quail Symposium 5:192–200.

Tirpak, J. M., W. M. Giuliano, C. A. Miller, T. J. Allen, S. Bittner, D. A. Buehler, J. W. Edwards, C. A. Harper, W. K. Igo, G. W. Norman, M. Seamster, and D. F. Stauffer. 2006. Ruffed grouse population dynamics in the central and southern Appalachians. Biological Conservation 133:364–378.

Tsai, K., K. H. Pollock, and C. Brownie. 1999. Effects of violation of assumptions for survival analysis methods in radiotelemetry studies. Journal of Wildlife Management 63:1369–1375.

Veech, J. A. 2006. Increasing and declining populations of northern bobwhites inhabit different types of landscapes. Journal of Wildlife Management 70:922–930.

Williams, C. K., A. R. Ives, and R. D. Applegate. 2003. Population dynamics across geographic ranges: time-series analyses of three small game species. Ecology 84:2654–2667.

Williams, C. K., F. S. Guthery, R. D. Applegate, and M. J. Peterson. 2004. The northern bobwhite decline: scaling our management for the twenty-first century. Wildlife Society Bulletin 32:861–869.

Wisdom, M. J., and L. S. Mills. 1997. Sensitivity analysis to guide population recovery: prairie-chickens as an example. Journal of Wildlife Management 61:302–312.

Wisdom, M. J., L. S. Mills, and D. F. Doak. 2000. Life-stage simulation analysis: estimating vital-rate effects on population growth for conservation. Ecology 81:628–641.

TEMPORAL AND SPATIAL TRENDS OF NORTHERN BOBWHITE SURVIVAL AND NEST SUCCESS

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ABSTRACT

The northern bobwhite (*Colinus virginianus*) has been declining in abundance across North America for many years. It is unknown, however, if other population variables also exhibit this downward trajectory. We conducted a retrospective-analysis of annual survival and nest success based on a literature review of 64 studies and compared these estimates temporally and spatially. We hypothesized that increased management efforts influenced bobwhite survival in the 1990s. Evidence from linear splining indicated survival trends changed in 1994. Thus, we compared trends across 3 periods: before 1994, after 1994, and overall. Mean (± SD) annual survival was 13.9 ± 9.4% across 31 studies from 1970 to 2007. Annual survival decreased –0.534% per year during 1970–1994 and stabilized thereafter. This stabilization in survival occurred along latitudinal and longitudinal gradients in which survival decreased at the northern and western periphery of the bobwhite range. Our linear splining models did not support the hypothesis that trends in nest success changed in the 1990s; thus, we only compared trends across the overall, 1924–2008 range of studies. Mean nest success across 33 studies was 44.4 ± 15.2% during this interval and increased slightly across the 1924–2008 range of studies. We observed latitudinal gradients in nest success. Nest success was lowest at the northern periphery of the bobwhite range; it decreased –0.90% per degree of latitude. Annual survival stabilized after 1994 despite monotonic declines in bobwhite abundance since at least the 1960s. Range-wide survival and nest success trends may not parallel trends in abundance, particularly after 1990, which suggests biologists may not fully understand the range-wide population ecology of bobwhites. This lends support for the need to monitor other aspects of the bobwhites range-wide population dynamics as supplements to range-wide abundance.

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Key words: abundance, *Colinus virginianus*. habitat management, meta-analysis, nest success, northern bobwhite

INTRODUCTION

The foundation of most formal management programs includes collection of abundance data (Williams et al. 2002). Understanding the direction and magnitude of annual changes in abundance is essential for management because it helps biologists make decisions that sustain population size and harvest intensities. Northern bobwhite population abundance has been declining range-wide at a rate of 3.8% per year (95% CI = ± 0.3) from 1966 to 2011 based on Breeding Bird Survey (BBS) data (Sauer et al. 2011). Surprisingly, it was not until the early 1990s that biologists fully appreciated the magnitude of the decline. Brennan (1991) was one of the first to describe the decline in the literature, and his cautions, along with others, were a harbinger for new management and research priorities directed at mitigating the downward trajectory. However, we are not aware of any studies that attempt to link the research and management attention generated in the 1990s to measures of population demographics. It is unclear if bobwhite populations responded to these management efforts. It is also unknown if active habitat management for bobwhites was disproportionately greater in the 1990s.

Northern bobwhite abundance estimates repeated in time and space (e.g., BBS annual roadside counts) should be reasonable indicators of the population status if estimates are derived from a sufficiently large sample (Lancia et al. 2005). Using abundance alone to gauge the health of bobwhite populations only portrays a portion of the available information on their population; especially given recent range-wide declines in bobwhite habitat (Peterson et al. 2002) and abundance (Sauer et al. 2011). The concept of usable space provides a framework to understand bobwhite habitats. Guthery (1997) proposed the long-term mean abundance of bobwhites varied in

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proportion to the amount of usable space. Bobwhite habitat is declining at accelerated rates across their range—a reduction in usable space—and declines in abundance are axiomatic.

However, it is unclear if other measures of bobwhite populations, such as demography, also share this decline. Measures of demographic parameters might include survival, nest success, clutch size, age ratios, or age at maturity; however, range-wide trends for these parameters are rarely evaluated.

We conducted a retrospective-analysis of 2 population parameters commonly reported for bobwhite populations: annual survival and nest success. Our objectives were to evaluate spatial and temporal trends in these variables, understand the direction and magnitude of change in these variables across the bobwhite's range (specifically between 1991 and 2001), and evaluate the suitability of using these variables as supplements to abundance for range-wide population monitoring.

METHODS

Data Collection

Population Demographics.—Our literature search included the following data bases: Academic Search Premier, BioOne, JSTOR, and SCOPUS. We searched the literature for 4 common parameters used to measure bobwhite populations: clutch size, nest success, survival, and probability of renesting. We also searched for articles in the National Quail Symposia (Church and Dailey 1993, Brennan et al. 2000, DeMaso et al. 2002, Cederbaum et al. 2009). Our search included: clutch size and bobwhite, Kaplan-Meier and bobwhite, nest success and bobwhite, population dynamics and bobwhite, and survival rate and bobwhite. We also used search strings of the same measures of population, but replaced 'bobwhite' with 'northern bobwhite' and 'quail'. We relegated our search to title, abstract, and key words, and excluded queries in other search fields. Additional studies were located using the literature cited sections of retrieved publications.

We selected 2 parameters for further evaluation, survival rate and nest success, because these parameters were reported frequently in the literature. We omitted papers containing research on non-native bobwhites (i.e., translocated or captive-raised birds) with the exception of those that contained control groups of native, resident bobwhites. We also omitted papers that were early publications of larger studies. We used the terminal publication containing all the data. For example, the work by Parry et al. (1997) and Townsend et al. (1999) on the Packsaddle Wildlife Management Area in western Oklahoma from 1991 to 2001 is summarized by Cox et al. (2004, 2005) in a later, and more comprehensive publication. We omitted papers that did not use telemetry or recapture methodologies to collect survival data. These papers generally used direct observation to collect data on survival, and the estimates produced from these studies were variable. For example, one of the earliest survival studies was by Errington (1945) and reported survival estimates between 0.001 and 0.732; this variability would have undue influence on the location of the intercept in regression analyses and could lead to biases in slope estimates. We reduced our analysis to 64 papers using these criteria (Tables 1, 2).

We defined nest success as the proportion of nests with $\geq$ 1 egg/hatch, or an estimate produced from the Mayfield method. We treated nest success estimates for each study area as independent estimates. We used a pooled estimate for analysis when papers reported pooled estimates of nest success across study areas. We converted daily survival rates to apparent estimates of nest success assuming a 23-day incubation period.

We collected the pooled estimates of survival for age, sex, or study area for analysis when authors reported pooled estimates. We collected only 1 of the reported survival rates with a preference for female and adult survival estimates if inferential statistics precluded the pooling of data based on sex or age. For example, if a paper reported adult and juvenile survival rates were similar, but female survival rates were significantly different from males, we collected the estimate of survival for females pooled across age. We chose female survival estimates because we assume population change is most sensitive to female survival. This convention was also used by Sandercock et al. (2008) in their bobwhite meta-analysis. We treated each study area as a unique, independent estimate of survival if inferential statistics precluded the pooling of study areas. We standardized the survival rate to an annual estimate of survival using the equation:

$$\hat{S}_a = S_p{}^{365/t}$$

where $\hat{S}_a$ represents the annual survival estimate, S_p represents the reported survival rate, and t represents the time interval (days) associated with a reported survival rate. This extrapolation was not done for studies which reported annual survival rates.

Some authors did not provide exact dates that survival monitoring started and stopped (e.g., 'we conducted this study from Oct to Mar'). Thus, it is unclear when in October survival monitoring began, and when in March monitoring ceased. We assigned the start and stop date as the mid-point of the beginning and ending month, respectively. Thus, the interval for the survival estimate in the example would have been 15 October to 15 March. We calculated survival rates from mortality estimates by subtracting the mortality rate from 1.0 for studies that reported mortality.

Some papers did not report independent estimates of survival or nest success for each year of study, and presented 1 averaged estimate across the entire study (e.g., Taylor et al. 1999, Staller et al. 2005). We collected the reported estimate and applied it to the median year of the study to control for lack of independence. Using Staller et al. (2005) as an example, they reported an average nest success of 0.44 from 1999 to 2001. Thus, in our analysis, we treated this as a single estimate of nest success (0.44) and associated it with the year 2000.

Habitat Management Trends.—The National Quail Symposia has united researchers, biologists, managers,

Table 1. Published studies on survival of northern bobwhite in North America, 1970–2007.

Citation	Study duration[a]	Study interval	Sample size[b]	Type[c]	State
Burger et al. 1995b	3	1989–91	297	RT	MO
Carter et al. 2002	2	1994–95	131	RT	TX
Cox et al. 2004	10	1991–2000	2,012	RT	OK
DeVos and Mueller 1993	2	1985–86	134	RT	FL
DeVos and Speake 1995	3	1990–92	206	RT	AL
Dixon et al. 1996	1	1991	71	RT	SC
Folk 2006	3	2002–04	319	RT	AL
Guthery et al. 2004	3	2000–02	67	RT	TX
Haines et al. 2004	2	2001–02	63	RT	TX
Hernández et al. 2003	3	1997–99	88	RT	TX
Hernández et al. 2005	2	1999, 2002	102	RT	TX
Holt et al. 2009	2	2000–01	118	RT	MS
Hughes et al. 2005	2	1997–98	64	RT	GA
Liu et al. 2000	3	1990–92	13	RT	TX
Lohr et al. 2011	3	2006–08	154	RT	NJ
Madison et al. 2002	3	1994–96	61	RT	KS
Palmer and Wellendorf 2007	5	1999–2003	3,149	Band	FL
Pollock et al. 1989	14	1970–83	560[d]	Band	FL
Puckett et al. 1995	2	1993–94	218	RT	NC
Robinette and Doerr 1993	2	1987–88	43	RT	NC
Seckinger et al. 2008	4	1998–2001	200	RT	TN
Sisson et al. 2000	3	1993–95	133	RT	GA
Suchy and Munkel 2000	4	1984–87	39	RT	IA
Taylor et al. 1999	3	1991–94	46	RT	KS
Taylor et al. 2000	4	1993–97	52	RT	MS
Terhune et al. 2006	2	1997–98	107	RT	GA
Terhune et al. 2007	6	1997–2002	3,190	Band	GA
Terhune et al. 2009	3	1999–2001	166	RT	GA
Townsend et al. 1999	4	1992–95	877	RT	OK
Williams et al. 2000	3	1993–96	157	RT	KS
Williams et al. 2004	3	1997–99	167	RT	KS

[a] Years.

[b] Units equal radio-marked or banded bobwhites.

[c] RT = radiotelemetry study, Band = band recovery study.

[d] Study reported an average of 560 banded birds/year.

and hunters since 1972. The accompanying *Proceedings* are repositories of information concerning vogue issues related to northern bobwhite. The *Proceedings* are primarily comprised of field studies pertaining to various aspects of bobwhite habitat management and population biology. Papers in the *Proceedings* that document field studies contain descriptions of the study area where the research occurred, and it is conventional to describe past and present management activities on the area. We believe the total number of unique study areas with active management represent a coarse index for bobwhite management effort during the range of years the National Quail Symposia occurred (hereafter, Quail I, Quail II, etc.).

We reviewed Quail I through VI and identified field studies that were actively managing habitat for bobwhite. We defined a field study as one in which the primary data were collected serially at established areas to answer a research question or hypothesis. We excluded the following: papers based on opinion (e.g., invited papers), literature reviews, papers containing meta- and retrospective analyses of secondary data, and papers describing research conducted on other quail species. We ascertained if active bobwhite habitat management was occurring at a study area based on explicit, unambiguous descriptions from the authors. We recorded the proportion of field studies from each *Proceedings* that occurred on habitat actively managed for bobwhites. We pooled the field studies in which active management was occurring, recorded the total number of discreet study areas by study interval, and summed by year (Fig. 1). We intentionally excluded non-discrete study areas to account for pseudoreplication that might result from multiple studies at the same location (e.g., Tall Timbers Research Station in Florida). We pooled nest success and survival data by year and explored correlations with the management index.

Data Analysis

We analyzed the data using a linear mixed-model (with random intercepts and random slopes) to evaluate survival and nest success trajectories through time and across space; AIC*c* comparisons were used to select

Table 2. Published studies on nest success of northern bobwhite in North America, 1924–2008.

Citation	Study duration[a]	Study interval	Sample size[b]	Type[c]	State
Burger et al. 1995a	3	1990–92	159	RT	MO
Carter et al. 2002	2	1994–95	81	RT	TX
Collins et al. 2009	2	2006–07	21	RT	NJ
Cox et al. 2005	10	1991–2000	331	RT	OK
DeVos and Mueller 1993	2	1985–86	134	RT	FL
Errington and Errington 1933	1	1931	69	DO	WI
Folk 2006	3	2002–04	319	RT	AL
Hernández et al. 2001	1	1998	50	RT	TX
Hernández et al. 2003	2	1997–98	15	RT	TX
Hernández et al. 2005	2	1999, 2002	37	RT	TX
Hernández et al. 2007	5	2000–05	148	RT	TX
Hughes et al. 2005	2	1997–98	472	RT	GA
Klimstra and Roseberry 1975	15	1952–66	863	DO	IL
Labrum 2007	1	2006	17	RT	AR
Lehmann 1946	2	1942–43	51	DO	TX
Lehmann 1984	10	1936–39, 1942–43, 1949–52	532	DO	TX
Lusk et al. 2006	2	2001–02	26	RT	TX
Parmalee 1955	1	1951	59	DO	TX
Parsons et al. 2000	3	1990–92	26	RT	TX
Potter et al. 2011	2	2003–05	67	RT	IA
Puckett et al. 1995	2	1993–94	16	RT	NC
Rader et al. 2007	3	2003–05	127	RT	TX
Rolland et al. 2010	6	2003–08	310	RT	FL
Simpson 1973	5	1967–71	680	DO	GA
Singh et al. 2010	5	2002–07	365	RT	FL
Staller et al. 2002	2	1999–2000	30	RT	FL
Staller et al. 2005	3	1999–2001	139	RT	FL
Stoddard 1931	4	1924–27	602	DO	FL
Suchy and Munkel 1993	4	1984–88	16	RT	IA
Taylor et al. 1999	3	1992–94	33	RT	KS
Terhune et al. 2006	2	1997–98	71	RT	GA
Terhune et al. 2009	3	1999–2001	165	RT	GA
Wellendorf and Palmer 2009	3	2003–05	176	RT	FL

[a] Years.

[b] Units equal nests.

[c] RT = radiotelemetry study, DO = direct observation.

variance-covariance structures. One of the features of this approach is that it allows for the possibility that relationships between survival and nest success, respectively, and time might vary from study to study—in some studies, the slope might be positive, whereas in others it might be negative. The same is true for randomly varying intercepts. Several years of data were collected for many of the studies included in the analyses and it is possible this has induced some correlation structure in our data that should be recognized and modeled. This approach recognizes and models the repeated measures nature of the data. We tested the hypothesis that annual survival and nest success, respectively, reversed their negative trends by using a version of a linear spline model commonly called a 'piece-wise' or 'broken-stick' model (Fitzmaurice et al. 2004) with 1 knot. The location of the knot was identified by comparing AIC*c* values of models with knots sequentially from 1991 through 2001.

Our analyses included studies from 14 states. The number of studies by state ranged from 1 to 6 for survival, and 1 to 7 for nest success (Fig. 2). Annual survival and nest success were the response variables, and year, latitude, and longitude were the explanatory variables. We did not include other explanatory variables that may influence quail populations (e.g., precipitation) because we were only interested in evaluating long-term survival and nest success trajectories over time and space. We performed standard regression diagnostics to ensure assumptions of regression were not violated. Regression analyses were performed using SAS (1989–2007).

Spatial autocorrelation is common in ecology when response variables deal with animal population parameters such as abundance because nearby points in space are likely more correlated than expected by chance (Lichstein et al. 2002). We tested for spatial autocorrelation by comparing 2 models, 1 that did not include latitude and longitude, and 1 that included latitude and longitude and a spherical correlation structure whose parameters were based on a semi-variogram (Pinheiro and Bates 2004). The likelihood ratio test (P) associated with a comparison of these 2 models (df $= 2$, $P = 0.67$) indicated a model which assumed spatial independence was adequate.

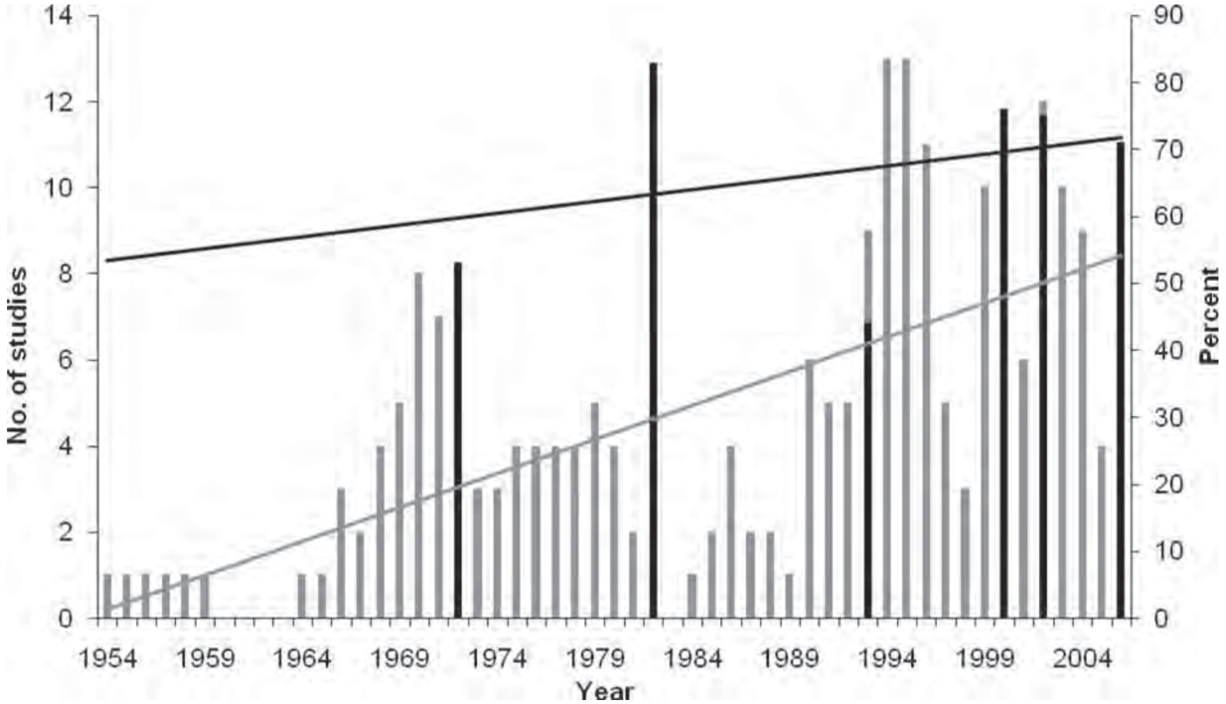

Fig. 1. Eighty-eight field studies on northern bobwhite were identified from the first 6 National Quail Symposia to index active habitat management at bobwhite research study areas. Study durations were recorded and the number of discrete study areas (gray) totaled across years. The proportion of field studies performing active habitat management for bobwhite was recorded for each symposium (black).

Spatial autocorrelation analyses were performed using R (Version 2.12.0; R Foundation for Statistical Computing, Vienna, Austria).

We used a Geographic Information System (GIS; ArcMAP 10; ESRI 1999–2010, Redlands, CA, USA) to identify the approximate geographic center of study areas based on study area descriptions when study area coordinates were not reported. We mapped survival and nest success studies to help conceptualize the distribution of these studies across the bobwhites' range (Fig. 2).

RESULTS

We reviewed 64 studies: 31 reported survival (Table 1) and 33 reported nest success (Table 2). Average (± SD) study duration was 3.5 ± 2.6 years for survival studies and 3.6 ± 3.1 years for nest success studies. Most studies were distributed in the southern and southeastern portions of the bobwhite range (Fig. 2).

Mean (± SD) annual survival for northern bobwhites was 13.9 ± 9.4% across 31 studies from 1970 to 2007; annual survival during this time period did not change. However, our linear spline model identified 2 periods with different survival rates. This analysis identified 1994 as the year when declining annual survival ceased (Fig. 3). Annual survival decreased from 1970 to 1994 at a rate of 0.534% per year (95% CI = ± 0.60%, $t = -1.83$, df = 24, $P = 0.08$). An annual decline in survival was not detected after 1994, and our results indicate survival stabilized during this interval (slope = 0.71%, CI = ± 1.67%, $t = 0.91$, df = 14.6, $P = 0.38$). Average survival before (13.1 ± 9.4%) and after (14.4 ± 9.1%) 1994 supported these trends.

Annual survival rates were highest in the southeastern portion of the bobwhites range, followed by the southwestern and midwestern portions. We modeled survival as a function of time, latitude, and longitude. The relationship between annual survival and latitude and longitude was consistently negative before and after 1994, and we present pooled results from the 1970–2007 range of studies. Our analysis indicated annual survival decreased more rapidly with increases in latitude (–1.49% per degree of latitude; 95% CI = ± 0.24%, $t_{42} = -12.71$, $P < 0.0001$) than with changes in longitude (–0.20% per degree of longitude; 95% CI = ± 0.20%, $t_{42} = -1.97$, $P = 0.0553$). This suggests annual bobwhite survival is lowest at the northern and western edges of the species' range. There was no indication that spatial dependence was occurring according to likelihood ratio tests comparing models with and without a correlation structure based on a semi-variogram. Thus, we did not account for spatial autocorrelation in our regression models.

Average nest success for northern bobwhites was 44.4 ± 15.2% across the 33 studies from 1924 to 2008. We attempted to fit a knot to our nest success data between 1991 and 2001 with our linear spline model, but a knot could not be located. This indicated trends in nest success did not change significantly between 1991 and 2001. Thus, it is only appropriate to present results from the 1924–2008 range of studies. Nest success increased from

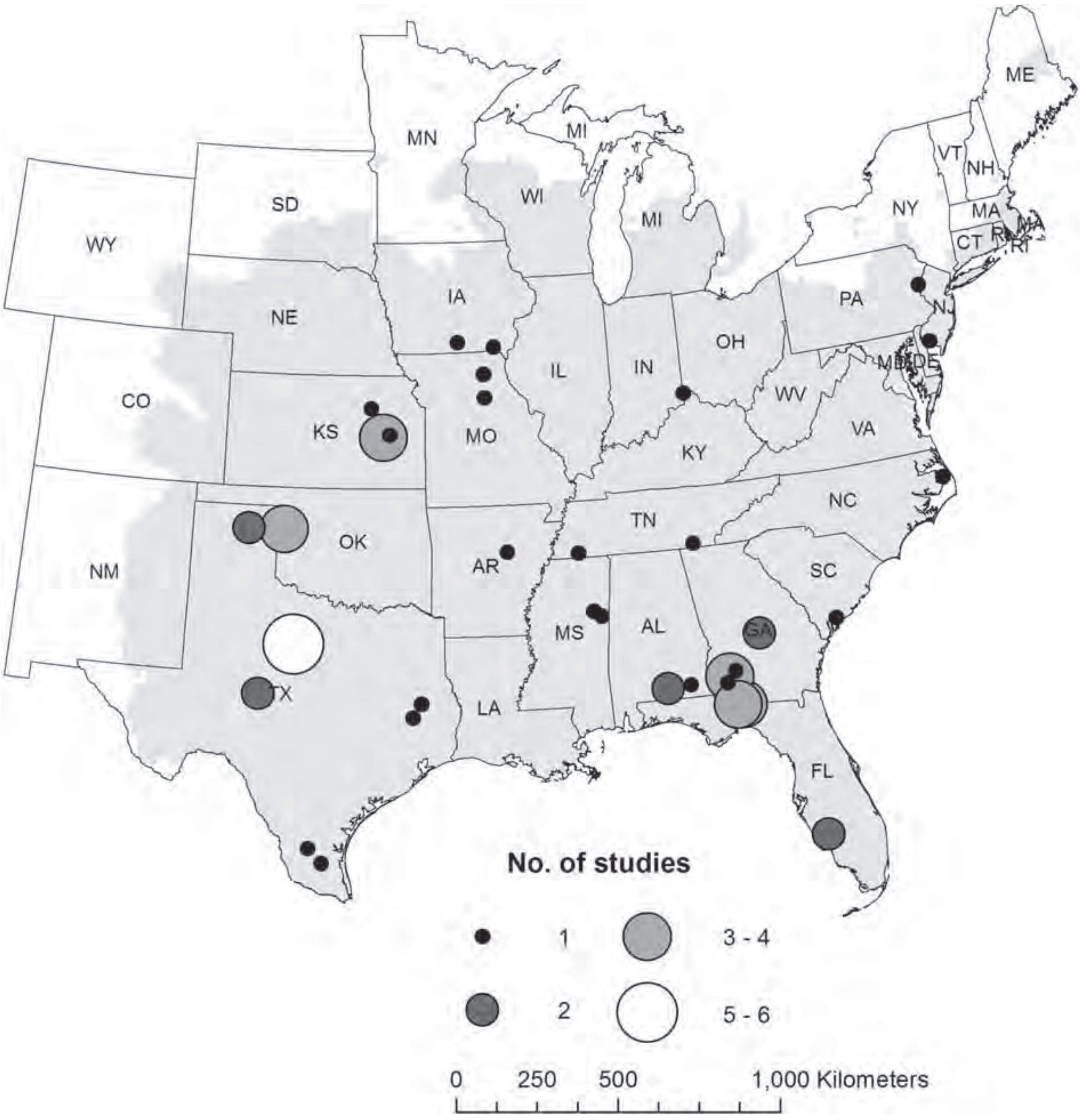

Fig. 2. Distribution of northern bobwhite survival ($n = 31$ studies from 1970 to 2007) and nest success ($n = 33$ studies from 1924 to 2008) across their range in eastern North America. Regions shaded gray represent the 2010 bobwhite range based on Sauer et al. (2011).

1924 to 2008; these trends were statistically significant (slope = 0.15%, 95% CI = ± 0.10%, $t_{97} = 2.55$, $P = 0.012$), but probably not biologically significant. There was some geographic variation in nest success. Our modeling of time, latitude, and longitude indicated nest success decreased significantly with increases in latitude (–0.90% per degree of latitude; 95% CI = ± 0.80%, $t_{41} = -2.26$, $P = 0.0293$); thus, nest success was lower at the northern edge of the bobwhite range.

We identified 88 field studies in Quail I through VI. The proportion of field studies from each *Proceedings* performing active habitat management for bobwhites was on a positive trend with the greatest proportion occurring during Quail II (Fig. 1; Quail I = 10 of 19 studies, Quail II = 5 of 6, Quail III = 4 of 9, Quail IV = 16 of 21, Quail V = 9 of 12, Quail VI = 15 of 21). The number of discrete study areas performing active habitat management increased over time and ranged from 2 to 13 (Fig. 1). Survival and nest success were not well correlated with the number of discrete study areas performing active management (survival, $r = -0.04$; nest success, $r = 0.44$).

DISCUSSION

Survival

Annual survival rates stabilized and increased by 0.71% per year after 1994. We hypothesized that

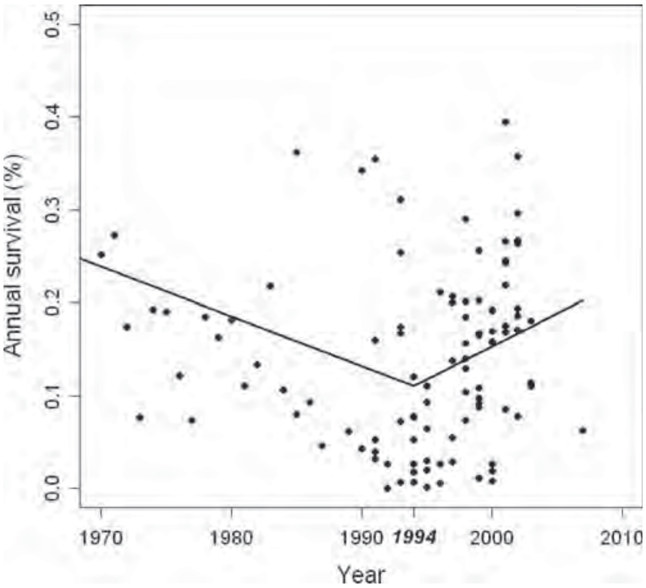

Fig. 3. Annual survival of northern bobwhite in North America from 1970 to 2007. A linear spline model indicated range-wide survival of bobwhites decreased at a rate of 0.53% per year until it stabilized in 1994.

increased management attention beginning in the 1990s was responsible for the stabilization in survival we observed. The mechanism for this relationship was probably the creation of more, high quality habitat that provides bobwhites with essential habitat needs (i.e., forage, nesting cover, escape cover, thermal cover). However, this is not supported by our results; annual survival was not well correlated with our management index. This contrasts with simulations by Sandercock et al. (2008). They conclude that seasonal survival, winter survival in particular, is responsible for a majority of variation in the finite rate of population change, and suggest management practices that improve seasonal survival rates should benefit declining populations. They provide an empirical basis for a relationship between survival and habitat management. Our findings differ from those of Sandercock et al. (2008) and it is possible that differences in how survival was extrapolated created the dissimilarity in results. We note the difference in survival before and after 1994 only differed by 1.3%; such a small effect size is not likely to be explained by management.

It is possible that our management index does not adequately reflect trends in bobwhite management, but these trends appear to reflect recent conclusions about the direction of quail management in the literature (Brennan et al. 2008). The life history of bobwhites makes comparing relationships between survival and habitat management difficult. Bobwhites senesce at a rate of 44% (Guthery 2002). Thus, despite a quail manager's best effort, a large portion of the bobwhite population dies each year as a result of their life history. These difficulties are compounded when abiotic and biotic mortality factors are included. Guthery (2002) suggested it is difficult to augment survival through management as one source of mortality is readily replaced by another.

Our results indicated bobwhite survival decreased at the northern and western edges of their range. This is consistent with literature for spatial variation in survival between northern and southern latitudes (Guthery et al. 2000, Folk et al. 2007a). Presently, there is no evidence in the literature of spatial variation in demographic parameters along longitudes. Guthery et al. (2000) modeled populations in northern and southern latitudes and postulated annual survival is depressed in northern populations by winter weather catastrophes and density-dependent processes. In contrast, annual survival of southern bobwhite populations is depressed by summer weather catastrophes (e.g., drought) and harvest. Folk et al. (2007b), in a retrospective analysis of 2 bobwhite populations at the northern (Wisconsin) and southern (Alabama) extent of their range, concluded non-breeding season survival of young bobwhites was responsible for most changes in population growth in Wisconsin, while fertility was most responsible for changes in Alabama.

One possible mechanism that could be responsible for longitudinal differences in survival from west to east is the diversity of climates given that northern bobwhite abundance's are sensitive to weather variables such as precipitation (Lusk et al. 2002) and drought (Bridges et al. 2001). For example, semi-arid regions of south and west Texas and Oklahoma prone to drought are known for their boom-and-bust population cycles (Hernández and Peterson 2007). Invariably, the effects of drought would extend to survival, and reduce survival rates at the western edge of the bobwhites' range. A second mechanism likely includes changing trends in land use. Increases in average farm size and brush cover on rangelands were much more pervasive from 1978 to 1997 at the western edge of the bobwhites range (Peterson et al. 2002). These changes result in reductions of habitat and, by extension, usable space and population abundance. Changes in land use are also creating habitat loss in the eastern portion of the bobwhites' range. Birds with grassland and grass-shrub affinities like the northern bobwhite are more sensitive to land-use changes when they occur in grasslands at the edge of their range (Johnson and Igl 2001, Brennan and Kuvlesky 2005). The potential for spatial and temporal dependence exists because our analysis used data from studies that were repeated in space and time. We did not detect spatial autocorrelation in our data, and temporal correlation was addressed with a repeated measures analysis that accounted for both between- and within-study effects. Many of the studies that our data included did not take these precautions.

There are potential biases with the data we used to analyze survival trends. This places limitations on our analyses and warrants cautious interpretation of our conclusions on survival trends. We identify 2 possible sources of bias: estimates of survival derived from radiotelemetry studies and our extrapolation of survival intervals to annual survival estimates.

Radiotelemetry became widely used in northern bobwhite field studies beginning in the early 1990s. It was later recognized that radiomarking may handicap bobwhites resulting in estimates of survival that are biased low (Guthery and Lusk 2004). However, others have shown no effect of radiomarking on bobwhite survival (Terhune et al. 2007) and have drawn attention to the possible flaws in the methodology used by Guthery and Lusk (Folk et al. 2007b). If telemetry bias did exist in the studies we evaluated, the effect of telemetry is likely consistent through time for 2 primary reasons. First, radiomarking is a systematic bias because it affects all individuals similarly. Second, nearly all of the studies we evaluated were based on data collected from radiotelemetry (28 of 31 survival studies, 26 of 33 nest success studies, and collectively, 94% of survival and nest success studies after 1990). Thus, we could adjust survival or nest success upwards to appropriately reflect true estimates but this would not change the trends we observed based on the literature.

Few bobwhite survival studies actually monitor survival of individuals over an entire year. Most studies are conducted over some biologically important interval (e.g., breeding season). Survival rates procured during the monitoring interval can be extrapolated to produce estimates of survival during periods that were not monitored (e.g., annual survival). This technique is useful, but is likely biased because the assumption that factors that influence survival are homogeneous through time is rarely satisfied. For example, an annual survival estimate produced from monitoring conducted in spring (i.e., during breeding season) would be much different from annual survival estimates produced during summer or fall (i.e., during harvest). We are unable to make direct study-to-study comparisons without standardizing survival to an annual estimate due to the variety of monitoring intervals. This introduces bias but is an acceptable tradeoff because it allows conclusions to be drawn from a much larger population of studies.

Nest Success

Average nest success between 1924 and 2008 was 44% across 33 studies in the northern bobwhites' range. We observed an increasing trend in nest success from 1924 to 2008. This may not be a biologically significant relationship at a rate of increase of 0.15% per year. There was weak evidence that nest success increased dramatically in the 1990s, which suggests trends in nest success did not respond to the shift in management practices in the early 1990s. The 84-year range of studies is quite long relative to other variables studied for bobwhites. Nest success during this period was stable and suggests that it is not a variable that managers can directly influence.

Biologists have a good understanding of the variety of habitats bobwhites select as nest sites and possess the knowledge to alter the habitat structure and composition to meet these needs. Despite this, there is evidence to suggest managers cannot manage, or have difficulty managing, habitat to influence nest success. Simpson (1973), in southwest Georgia, reported 86% of successful nests occurred in medium or sparse vegetation densities, and 61% of successful nests had poor concealment (Simpson did not classify density and concealment around unsuccessful nests). Klimstra and Roseberry (1975) evaluated the relationship between nest success and nest concealment with land-cover type in Illinois. Nest success was numerically greater in more dense vegetation, but was not statistically significant. Lehmann (1984) reported nest concealment in south Texas was not correlated with nest success for 155 nests. Lusk et al. (2006) demonstrated successful nests in north Texas were characterized by higher canopies and more shrub cover than failed nests, but successful nests also had more bare ground. Rader (2006) studied the factors influencing nest-site selection and nest success in south Texas and concluded bobwhites select nest sites based on the structure and composition of vegetation, as opposed to minimizing the potential for nest predation. Rader (2006) concluded that managers can increase available habitat by influencing nest-site availability, but managers cannot influence nest success.

We observed a decrease in nest success at northern latitudes from 1924 to 2008. This was unexpected because we anticipated poorer success in southern latitudes. Guthery et al. (2001) presented a compelling explanation counter to our findings. They provide empirical evidence demonstrating that excessive thermal conditions created by drought and heat waves inhibit quail reproduction across extensive areas. This includes deaths of embryos in eggs and adults, and inducing premature incubation and staggered hatching.

There is a paucity of research on bobwhite life history at range-wide scales. Our results might contrast with the prevailing conclusions in the literature because of biases associated with apparent nest success. Apparent nest success only considers success of a nest after onset of incubation and ignores the assumption that success decreases exponentially over time. This creates the potential for bias and potentially high estimates of nest success. Use of daily survival rates (DSR) to measure nest survival accounts for additional exposure prior to incubation. Our meta-analysis included 6 (Folk 2006; Terhune et al. 2006, 2009; Collins et al. 2009; Rolland 2010; Potter et al. 2011) studies that reported DSR and we converted these to apparent nest success. It is possible that nest success estimates in the 2000s are artificially high if bias exists as a result of converting to a DSR. Thus, the increasing trend in nest success that we observed in reality could be stabilized, or even decreasing.

MANAGEMENT IMPLICATIONS

We examined (1) if there was a need for a more holistic approach to bobwhite population ecology and management, and (2) if there was an alternate portrayal of range-wide northern bobwhite population ecology. Trends in survival and nest success through time do not parallel trends in abundance. Thus, we are left with an incomplete understanding of range-wide population demographics for bobwhites. A range-wide monitoring program that collects information on abundance as well as other aspects of the bobwhites' population ecology could solve this problem. Range-wide monitoring of survival or nest success could be adequate supplements to range-wide monitoring of abundance based on this meta-analysis.

LITERATURE CITED

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

Brennan, L. A., and W. P. Kuvlesky Jr. 2005. North American grassland birds: an unfolding conservation crisis? Journal of Wildlife Management 69:1–13.

Brennan, L. A., W. E. Palmer, L. W. Burger Jr., and T. L. Pruden, eds. 2000. Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, Florida, USA.

Brennan, L. A., F. Hernández, W. P. Kuvlesky Jr., and F. S. Guthery. 2008. Gamebird management: linking theory and practice in south Texas. Pages 65–74 *in* T. E. Fulbright and D. G. Hewitt, eds. Frontiers in wildlife science: linking ecological theory and management applications. CRC Press, Boca Raton, Florida, USA.

Bridges, A. S., M. J. Peterson, N. J. Silvy, F. E. Smeins, and X. B. Wu. 2001. Differential influence of weather on regional quail abundance in Texas. Journal of Wildlife Management 65:10–18.

Burger Jr., L. W., M. R. Ryan, T. V. Dailey, and E. W. Kurzejeski. 1995a. Reproductive strategies, success, and mating systems of northern bobwhite in Missouri. Journal of Wildlife Management 59:417–426.

Burger Jr., L. W., T. V. Dailey, E. W. Kurzejeski, and M. R. Ryan. 1995b. Survival and cause–specific mortality of northern bobwhite in Missouri. Journal of Wildlife Management 59:401–410.

Carter, P. S., D. Rollins, and C. B. Scott. 2002. Initial effects of prescribed burning on survival and nesting success of northern bobwhites in west–central Texas. Proceedings of the National Quail Symposium 5:129–134.

Cederbaum, S. B., B. C. Faircloth, T. M. Terhune, J. J. Thompson, and J. P. Carroll. 2009. Gamebird 2006: a joint conference of Quail VI and Perdix XII. D. B. Warnell School of Forestry and Natural Resources, University of Georgia, Athens, USA.

Church, K. E., and T. V. Dailey. 1993. Quail III: Proceedings of the Third National Quail Symposium. Kansas Department of Wildlife and Parks, Pratt, USA.

Collins, B. M., C. K. Williams, and P. M. Castelli. 2009. Reproduction and microhabitat selection in a sharply declining northern bobwhite population. Wilson Journal of Ornithology 121:688–695.

Cox, S. A., A. D. Peoples, S. J. DeMaso, J. J. Lusk, and F. S. Guthery. 2004. Survival and cause–specific mortality of northern bobwhites in western Oklahoma. Journal of Wildlife Management 68:663–671.

Cox, S. A., F. S. Guthery, J. J. Lusk, A. D. Peoples, S. J. DeMaso, and M. Sams. 2005. Reproduction by northern bobwhites in western Oklahoma. Journal of Wildlife Management 69:133–139.

DeMaso, S. J., W. P. Kuvlesky Jr., F. Hernández, and M. E. Berger. 2002. Quail V: Proceedings of the Fifth National Quail Symposium. Texas Parks and Wildlife Department, Austin, USA.

DeVos Jr., T., and B. S. Mueller. 1993. Reproductive ecology of northern bobwhite in north Florida. Proceedings of the National Quail Symposium 3:83–90.

DeVos Jr., T., and D. W. Speake. 1995. Effects of releasing pen–raised northern bobwhites on survival rates of wild populations of northern bobwhites. Wildlife Society Bulletin 23:267–273.

Dixon, K. R., M. A. Horner, S. R. Anderson, W. D. Henriques, D. Durham, and R. J. Kendall. 1996. Northern bobwhite habitat use and survival on a South Carolina plantation during winter. Wildlife Society Bulletin 24:627–635.

Errington, P. L. 1945. Some contributions of a fifteen–year local study of the northern bobwhite to a knowledge of population phenomena. Ecological Monographs 15:2–34.

Errington, P. L., and P. E. Errington. 1933. The nesting and the life equation of the Wisconsin bob–white. Wilson Bulletin 45:122–132.

Fitzmaurice, G. M., N. M. Laird, and J. H. Ware. 2004. Applied longitudinal analysis. John Wiley and Sons, Hoboken, New Jersey, USA.

Folk, T. H. 2006. Population ecology of northern bobwhites. Dissertation. Auburn University, Auburn, Alabama, USA.

Folk, T., R. Holmes, and J. Grand. 2007a. Variation in northern bobwhite demography along two temporal scales. Population Ecology 49:211–219.

Folk, T. H., J. B. Grand, W. E. Palmer, J. P. Carroll, D. C. Sisson, M. T. Theron, S. D. Wellendorf, and H. L. Stribling. 2007b. Estimates of survival from radiotelemetry: a response to Guthery and Lusk. Journal of Wildlife Management 71:1027–1033.

Guthery, F. S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 61:291–301.

Guthery, F. S. 2002. The technology of bobwhite management: the theory behind the practice. Iowa State University Press, Ames, USA.

Guthery, F. S., and J. J. Lusk. 2004. Radiotelemetry studies: are we radio–handicapping northern bobwhites? Wildlife Society Bulletin 32:194–201.

Guthery, F. S., M. J. Peterson, and R. R. George. 2000. Viability of northern bobwhite populations. Journal of Wildlife Management 64:646–662.

Guthery, F. S., C. L. Land, and B. W. Hall. 2001. Heat loads on reproducing bobwhites in the semiarid subtropics. Journal of Wildlife Management 65:111–117.

Guthery, F. S., T. L. Hiller, W. H. Puckett Jr., R. A. Baker, S. G. Smith, and A. R. Rybak. 2004. Effects of feeders on dispersion and mortality of bobwhites. Wildlife Society Bulletin 32:1248–1254.

Haines, A. M., F. Hernández, S. E. Henke, and R. L. Bingham. 2004. Effects of road baiting on home range and survival of northern bobwhites in southern Texas. Wildlife Society Bulletin 32:401–411.

Hernández, F., and M. J. Peterson. 2007. Northern bobwhite ecology and life history. Pages 40–64 *in* L. A. Brennan, ed. Texas quails: ecology and management. Texas A&M University Press, College Station, USA.

Hernández, F., S. E. Henke, N. J. Silvy, and D. Rollins. 2001. Comparison of success between actual northern bobwhite and wild turkey nests and simulated nests. Wildlife Society Bulletin 29:1212–1218.

Hernández, F., S. E. Henke, N. J. Silvy, and D. Rollins. 2003. Effects of prickly pear control on survival and nest success of northern bobwhite in Texas. Wildlife Society Bulletin 31:521–527.

Hernández, F., F. Hernández, J. A. Arredondo, F. C. Bryant, L. A. Brennan, and R. L. Bingham. 2005. Influence of precipitation on demographics of northern bobwhites in southern Texas. Wildlife Society Bulletin 33:1071–1079.

Hernández, F., K. M. Kelley, J. A. Arredondo, F. Hernández, D. G. Hewitt, F. C. Bryant, and R. L. Bingham. 2007. Population irruptions of northern bobwhite: testing an age–specific reproduction hypothesis. Journal of Wildlife Management 71:895–901.

Holt, R. D., L. W. Burger Jr., B. D. Leopold, and D. Godwin. 2009. Over–winter survival of northern bobwhite in relation to landscape composition and structure. Gamebird 2006: Quail VI and Perdix XII: 432–446.

Hughes, D. W., T. M. Terhune, D. C. Sisson, and H. L. Stribling. 2005. Demographics of northern bobwhite on agricultural and intensively–managed bobwhite plantation landscapes. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 59:30–42.

Johnson, D. H., and L. D. Igl. 2001. Area requirements of grassland birds: regional perspective. Auk 118:24–34.

Klimstra, W. D., and J. L. Roseberry. 1975. Nesting ecology of the bobwhite in southern Illinois. Wildlife Monographs 41.

Labrum, K. C. 2007. Bobwhite production, brood ecology, and brood movements in response to habitat restoration in northern Arkansas. Thesis. Arkansas Tech University, Russellville, USA.

Lancia, R. A., W. L. Kendall, K. H. Pollock, and J. D. Nichols. 2005. Estimating the number of animals in wildlife populations. Pages 106–153 *in* C. E. Braun, ed. Techniques for wildlife investigations and management. Sixth edition. The Wildlife Society, Bethesda, Maryland, USA.

Lehmann, V. W. 1946. Bobwhite quail reproduction in southwestern Texas. Journal of Wildlife Management 10:111–123.

Lehmann, V. W. 1984. The bobwhite in the Rio Grande Plain of Texas. Texas A&M University Press, College Station, USA.

Lichstein, J. W., T. R. Simons, S. A. Shriner, and K. E. Franzreb. 2002. Spatial autocorrelation and autoregressive models in ecology. Ecological Monographs 72:445–463.

Liu, X., R. M. Whiting Jr., B. S. Mueller, D. S. Parsons, and D. R. Dietz. 2000. Survival and causes of mortality of relocated and resident northern bobwhites in Texas. Proceedings of the National Quail Symposium 4:119–124.

Lohr, M., B. M. Collins, C. K. Williams, and P. M. Castelli. 2011. Life on the edge: northern bobwhite ecology at the northern periphery of their range. Journal of Wildlife Management 75:52–60.

Lusk, J. J., S. G. Smith, S. D. Fuhlendorf, and F. S. Guthery. 2006. Factors influencing northern bobwhite nest–site selection and fate. Journal of Wildlife Management 70:564–571.

Lusk, J. J., F. S. Guthery, R. R. George, M. J. Peterson, and S. J. DeMaso. 2002. Relative abundance of bobwhites in relation to weather and land use. Journal of Wildlife Management 66:1040–1051.

Madison, L. A., R. J. Robel, and D. P. Jones. 2002. Hunting mortality and overwinter survival of northern bobwhites relative to food plots in Kansas. Wildlife Society Bulletin 30:1120–1127.

Palmer, W. E., and S. D. Wellendorf. 2007. Effect of radiotransmitters on northern bobwhite annual survival. Journal of Wildlife Management 71:1281–1287.

Parmalee, P. W. 1955. Some factors affecting nesting success of the bob–white quail in east–central Texas. American Midland Naturalist 53:45–55.

Parry, E. S., S. J. DeMaso, S. A. Cox, and A. D. Peoples. 1997. Recovery rates of banded vs. radiomarked northern bobwhites in western Oklahoma. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 51:342–351.

Parsons, D. S., R. M. Whiting Jr., X. Liu, B. S. Mueller, and S. L. Cook. 2000. Reproduction of relocated and resident northern bobwhites in east Texas. Proceedings of the National Quail Symposium 4:132–136.

Peterson, M. J., X. B. Wu, and P. Rho. 2002. Rangewide trends in landuse and northern bobwhite abundance: an exploratory analysis. Proceedings of the National Quail Symposium 5:35–44.

Pinheiro, J. C., and D. M. Bates. 2004. Mixed–effects models in S and S–plus. Springer-Verlag, New York, USA.

Pollock, K. H., T. M. Clinton, W. R. Davidson, F. E. Kellogg, and G. L. Doster. 1989. Survival rates of bobwhite quail based on band recovery analyses. Journal of Wildlife Management 53:1–6.

Potter, L. M., D. L. Otis, and T. R. Bogenschutz. 2011. Nest success of northern bobwhite on managed and unmanaged landscapes in southeast Iowa. Journal of Wildlife Management 75:46–51.

Puckett, K. M., W. E. Palmer, P. T. Bromley, J. R. J. Anderson, and T. L. Sharpe. 1995. Bobwhite nesting ecology and modern agriculture: a management experiment. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:505–515.

Rader, M. J. 2006. Factors influencing nest success of northern bobwhites in southern Texas. Dissertation. Texas A&M University–Kingsville, USA.

Rader, M. J., L. A. Brennan, F. Hernández, N. J. Silvy, and X. B. Wu. 2007. Nest–site selection and nest survival of northern bobwhite in southern Texas. Wilson Journal of Ornithology 119:392–399.

Robinette, C. F., and P. D. Doerr. 1993. Survival of northern bobwhite on hunted and nonhunted study areas in the North Carolina sandhills. Proceedings of the National Quail Symposium 3:74–78.

Rolland, V., J. A. Hostetler, T. C. Hines, H. F. Percival, and M. K. Oli. 2010. Factors influencing reproductive performance of northern bobwhite in south Florida. European Journal of Wildlife Research 57:717–727.

Sandercock, B. K., W. E. Jensen, C. K. Williams, and R. D. Applegate. 2008. Demographic sensitivity of population change in northern bobwhite. Journal of Wildlife Management 72:970–982.

SAS. 1989-2007. Version 9.2. SAS Institute Inc., Cary, North Carolina, USA.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski Jr., and W. A. Link. 2011. The North American Breeding Bird Survey, results and analysis 1966–2009. Version 3.23.2011. USGS, Patuxent Wildlife Research Center, Laurel, Maryland, USA. www.Mbr–pwrc.Usgs.Gov/bbs/bbs.html

Seckinger, E. M., L. W. Burger, R. Whittington, A. Houston, and R. Carlisle. 2008. Effects of landscape composition on winter survival of northern bobwhites. Journal of Wildlife Management 72:959–969.

Simpson, R. C. 1973. A study of bobwhite quail nest initiation dates, clutch sizes and hatch sizes in southwest Georgia. Proceedings of the National Quail Symposium 1:199–204.

Singh, A., T. C. Hines, H. F. Percival, and M. K. Oli. 2010. Does nest–site selection influence bobwhite nesting success in south Florida? Wildlife Research 37:489–496.

Sisson, D. C., H. L. Stribling, and D. W. Speake. 2000. Effects of supplemental feeding on home range size and survival of northern bobwhites in south Georgia. Proceedings of the National Quail Symposium 4:128–131.

Staller, E. L., W. E. Palmer, and J. P. Carroll. 2002. Macrohabitat composition surrounding successful and depredated northern bobwhite nests. Proceedings of the National Quail Symposium 5:61–64.

Staller, E. L., W. E. Palmer, J. P. Carroll, R. P. Thornton, and D. C. Sisson. 2005. Identifying predators at northern bobwhite nests. Journal of Wildlife Management 69:124–132.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. Charles Scribner's Sons, New York, USA.

Suchy, W. J., and R. J. Munkel. 1993. Breeding strategies of the northern bobwhite in marginal habitat. Proceedings of the National Quail Symposium 3:69–73.

Suchy, W. J., and R. J. Munkel. 2000. Survival rates for northern bobwhites on two areas with different levels of harvest. Proceedings of the National Quail Symposium 4:140–146.

Taylor, J. D., L. W. Burger, S. W. Manley, and L. A. Brennan. 2000. Seasonal survival and cause–specific mortality of northern bobwhites in Mississippi. Proceedings of the National Quail Symposium 4:103–107.

Taylor, J. S., K. E. Church, D. H. Rusch, and J. R. Cary. 1999. Macrohabitat effects on summer survival, movements, and clutch success of northern bobwhite in Kansas. Journal of Wildlife Management 63:675–685.

Terhune, T. M., D. C. Sisson, and H. L. Stribling. 2006. The efficacy of relocating wild northern bobwhites prior to breeding season. Journal of Wildlife Management 70:914–921.

Terhune, T. M., D. C. Sisson, J. B. Grand, and H. L. Stribling. 2007. Factors influencing survival of radiotagged and banded northern bobwhites in Georgia. Journal of Wildlife Management 71:1288–1297.

Terhune, T. M., D. C. Sisson, S. Mitchell, and H. L. Stribling. 2009. Northern bobwhite demographic and population response following an intensive habitat modification to an agricultural landscape. Gamebird 2006: Quail VI and Perdix XII: 232–249.

Townsend II, D. E., R. L. Lochmiller, S. J. DeMaso, D. M. Leslie Jr., A. D. Peoples, S. A. Cox, and E. S. Parry. 1999. Using supplemental food and its influence on survival of northern bobwhite (*Colinus virginianus*). Wildlife Society Bulletin 27:1074–1081.

Wellendorf, S. D., and W. E. Palmer. 2009. Effects of two burn scales on northern bobwhite demographic parameters and home range size. Gamebird 2006: Quail VI and Perdix XII: 271–281.

Williams, B. K., J. D. Nichols, and M. J. Conroy. 2002. Analysis and management of animal populations: modeling, estimation, and decision making. Academic Press, San Diego, California, USA.

Williams, C. K., R. S. Lutz, R. D. Applegate, and D. H. Rusch. 2000. Habitat use and survival of northern bobwhite (*Colinus virginianus*) in cropland and rangeland ecosystems during the hunting season. Canadian Journal of Zoology 78:1562–1566.

Williams, C. K., R. S. Lutz, and R. D. Applegate. 2004. Winter survival and additive harvest in northern bobwhite coveys in Kansas. Journal of Wildlife Management 68:94–100.

DEMOGRAPHIC ANALYSIS OF A DECLINING NORTHERN BOBWHITE POPULATION IN SOUTHWESTERN OHIO

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ABSTRACT

Northern bobwhite (*Colinus virginianus*) populations continue to decline throughout much of their range, especially in the Midwestern United States. Land use and habitat changes are understood to be the primary cause of decline, and it is unclear how vital rates affect growth of regional populations. We estimated relative abundance and population vital rates of bobwhites on 8 private land sites in southwestern Ohio during 2008–2011. Life stage simulation analyses were used to model the influence of 9 demographic parameters on population growth rates (λ). All but one vital rate, chick survival, were modeled with empirical data randomly selected from normal distributions estimated (mean $\pm$ SD) from our study population. The median value of λ after 1,000 simulations was 0.248 (interquartile range $=$ 0.113-0.428). Non-breeding season survival was the dominant vital rate, explaining 50.4% of variation in λ, followed by nest success ($r^2 = 0.163$), and breeding season survival of adults ($r^2 = 0.083$). Chick survival, egg success, and clutch size individually explained in order 1.4 to 4.6% of variation in λ when modeled with survival estimates. Renesting, double-brooding, and male incubation individually explained $< 1\%$ of the variation in λ. Total fecundity modeled as the sum across individual vital rate components explained 36.9% of variation in λ. Non-breeding season survival was the most limiting population vital rate, but age ratios of fall-captured birds and simulated fecundity values indicated partial limitation by recruitment. Population stability ($\lambda = 1$) could be achieved by increasing non-breeding survival from 10.9 to 36.9%. Higher rates of nest success, the second most limiting vital rate, would not stabilize population growth unless survival rates also increased. Bobwhite conservation strategies should emphasize habitat enhancements designed to increase survival rates and useable space during the non-breeding season in Ohio and possibly other Midwestern states.

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Key words: *Colinus virginianus*, fecundity, life stage simulation, nesting, northern bobwhite, Ohio, population, survival, vital rate

INTRODUCTION

Northern bobwhites are currently hunted in only 16 Ohio counties under harvest regulations that are among the most restrictive of any state. The species still engenders broad interest from Ohio citizens, especially among landowners who participate in private lands wildlife habitat development programs. The adage *if you build it they will come* raises expectations that often result in disappointment after landowners create habitat or adopt wildlife-friendly practices on their properties. The history of northern bobwhites in Ohio reflects what has occurred elsewhere in the upper Midwestern United States. State-wide call-count indices have declined 76% since 1984 as the species' range has contracted to a 20-county area of southwestern Ohio (Spinola and Gates 2008). Christmas Bird Counts document a 3.7% annual rate of decline in relative abundance during 1960–2010 (Fig. 1A). Most remembered are the dramatic declines associated with severe winters in 1977 and 1978 and failure of populations to recover despite implementation of wildlife habitat conservation provisions in Federal Farm Bills enacted since 1985. Ohio Division of Wildlife indices based on spring whistle-count surveys document a 2.2% annual decline from 1985 to present (Fig. 1B).

Previous studies demonstrated bobwhite populations in northern portions of the species' range are limited more by survival than reproductive rates compared to southern populations (Guthery et al. 2000, Folk et al. 2007). Loss of early succession habitats and intensified agricultural practices that favor corn-soybean-wheat crop rotations on

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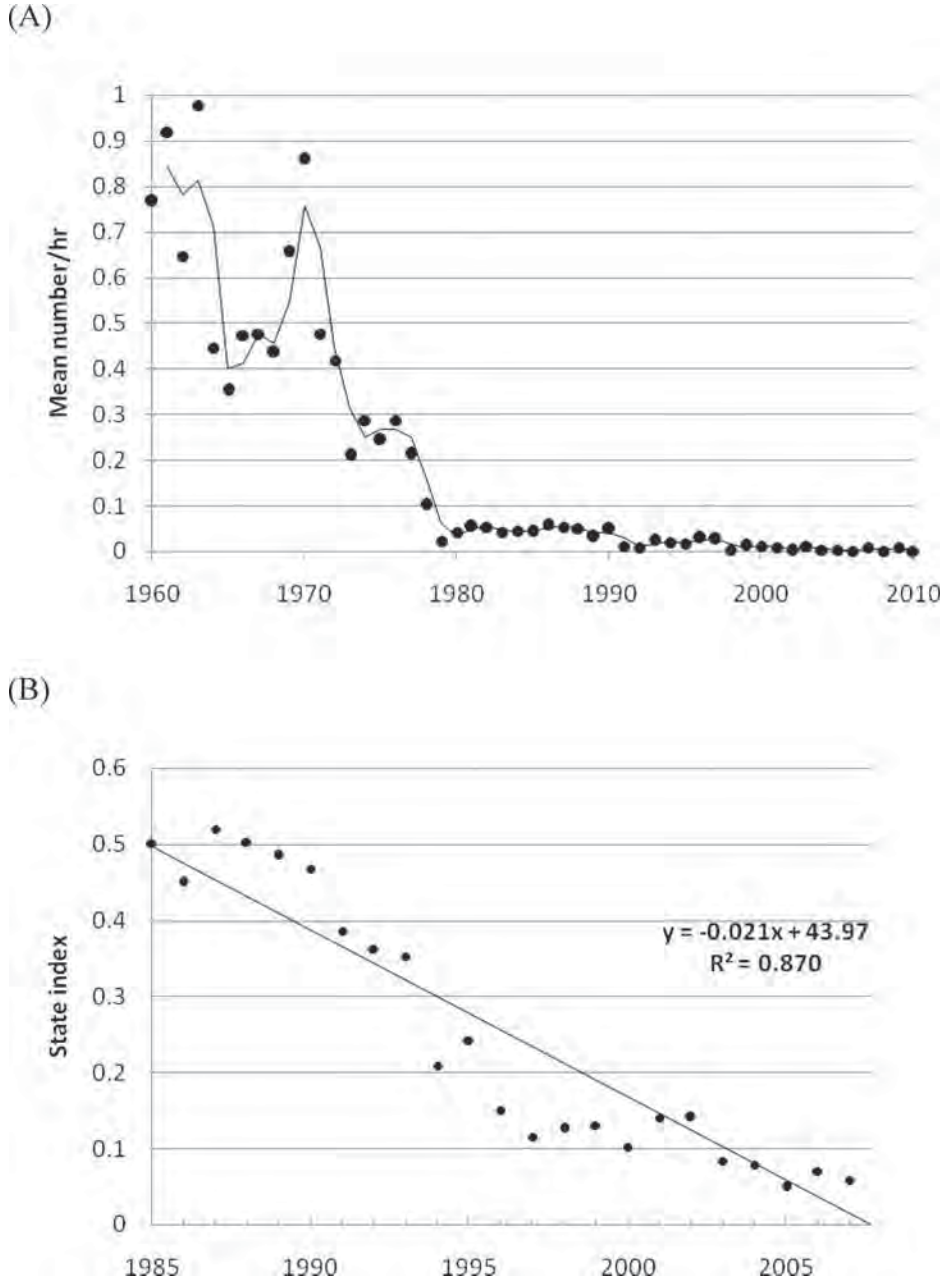

Fig. 1. Northern bobwhite population indices in Ohio from Christmas Bird Counts during 1960–2010 (A) and spring whistle-count surveys conducted by the Ohio Division of Wildlife during 1984–2009 (B).

large fields over farming practices that included small-grain, row crop, and perennial forage crops on small land parcels have negatively impacted northern bobwhites in the upper Midwest (Brennan 1991). Maturation and canopy closure of farmland woodlots and associated development of hard edges (no ecotones) between forests and row croplands has been overlooked in design and implementation of private land conservation practices in the Midwest despite awareness of the effect of forest maturation on northern bobwhites.

Sandercock et al. (2008) investigated sensitivity of bobwhite population growth rates to variation in vital rates (survival and fecundity components) from across the bobwhite's range, but there is little information on how vital rates affect growth for extant populations (e.g., DeMaso et al. 2011) particularly in the upper Midwestern U.S. These analyses can help inform strategies to focus conservation on the most population growth-limiting vital rates. We initiated an investigation of population-habitat relationships of northern bobwhites on private lands in southwestern Ohio to gain a better understanding of factors that affect population growth in agricultural landscapes in the current core of the species' geographic range within the state. Our objectives were to: (1) investigate bobwhite abundance on study sites with apparently suitable habitat, (2) estimate key population vital rates (e.g., breeding and non-breeding survival, components of fecundity), (3) examine the influence of vital rates on population growth rates, and (4) identify conservation strategies to maintain and increase bobwhite populations in Ohio.

STUDY AREA

The study area was in southwestern Ohio (39° 04′ 59″ N, 83° 39′ 10″ W) where the core density of bobwhites in Ohio currently occurs (Spinola and Gates 2008). Weather conditions varied during the study and were generally more severe than long-term averages for winter temperature and snowfall (Janke and Gates 2012). Timing and severity of weather varied among years with relatively mild weather and short duration of snow cover in 2008–2009. Winter 2009–2010 was mild during December-January but a 22-day period of deep snow accumulation and cold temperatures occurred in February. Winter 2010–2011 had consistent snow cover with depths that did not exceed 25 cm during December-January and little snow accumulation in February. Our study sites were open to hunting (28 days, 4 bird bag) but received little hunting pressure and harvest mortality was low (Janke and Gates 2012).

We selected 8 study sites in Adams, Brown, Clinton, and Highland counties. All sites were in private ownership, although a state wildlife management area was adjacent to one study site. Agriculture was the predominant land use on each site with 38–72% row crop (mostly soybeans and corn). Pasture and haylands, defined as herbaceous land cover that were annually grazed or mowed, accounted for 2 to 23% of study sites. Early succession herbaceous vegetation covered 9 to 21% of each site and included fields enrolled in the Conservation Reserve Program (CRP), old fields, fencerows, and agricultural drainage ditches. Early succession grass fields were mostly dominated by fescue (*Festuca* spp.) but some had native warm-season grasses. Early succession woody vegetation (3.1–6.5%) was mostly associated with fencerows, streams, or drainage ditches. Forests accounted for 8–29% of the study sites. Janke and Gates (2012) described the species composition of these land cover types in greater detail.

METHODS

Potential study sites were identified from 2001 National Land Cover Data (NLCD; Homer et al. 2004) merged with an ArcGIS shapefile of lands enrolled in CRP, including parcels enrolled in conservation practices 1, 2, 4, 8, 10, 21, 25, 29, 31, and 33. We overlaid a 5-km^2 (presumptive study site size) hexagonal grid on the merged NLCD/CRP habitat coverage. Proportions of grassland/herbaceous, shrub, agricultural, and developed lands were calculated for each hexagon with the spatial analyst tool in ArcMap. We identified all hexagons with $>$ 10% grassland/herbaceous and shrub cover (presumptive bobwhite habitat) and calculated ratios of agriculture to forest land cover for each hexagon. Hexagons with less than half as much agriculture as forest were eliminated from consideration. The landscape matrix was classified as agricultural if the ratio of agriculture to forest was $>$ 2 and as mixed agriculture-forest if the agriculture: forest ratio was 0.5-2.0. We counted adjacent hexagons with $>$ 10% bobwhite habitat for each hexagon classified as agriculture or mixed agriculture-forest. Potential study sites were randomly selected within strata and examined with aerial photographs and on-site reconnaissance. Hexagons that did not meet classification criteria, or when landowner permission was not available or were otherwise unsuitable were replaced by the next hexagon from the randomized list until the sample matrix was filled (2 sites per stratum).

We gained access to 8 sites that met our selection criteria in Highland, Brown, Clinton, and Adams counties. Permission was not unanimously granted within each study site and we adjusted site boundaries to create a core of contiguous properties that provided 70–100% access to the total area of each study site. Study-site boundaries were adjusted (net expansion) each year as we learned more about local distribution and movements of bobwhites, and availability of suitable habitats. The selection process produced a representative sample of sites that appeared to be most suitable for occupancy by bobwhites within the core of the species' range in Ohio.

We located coveys on all study sites with covey-call surveys (Wellendorf et al. 2004) conducted at systematically-placed survey points during October-December 2008–2011. Covey-call surveys were followed by intensive searches with pointing dogs and track searches when snow cover was present. We also conducted whistle-count surveys (Norton et al. 1961) at systematically-placed survey points distributed across 8 study sites during 2008–2009 and 4 study sites during 2009–2011. Covey-call surveys and dog searches were more regularly and intensively conducted on 4 study sites where we consistently found and radiomarked coveys. Intensive dog searches, snow tracking, and continuous presence of field personnel on 4 study sites helped detect all resident bobwhite coveys present on those 4 sites. Whistle-count detections were compared among years with linear-mixed models using study site as a random effect (Pinheiro et al. 2012). Covey densities were compared between years using paired *t*-tests (R Development Core Team 2012).

We captured, leg-banded, and radiomarked bobwhites on the 4 intensive study sites during the non-breeding season (Oct-Mar). Bobwhites were captured using baited funnel traps (Stoddard 1931) and targeted mist-netting (Wiley et al. 2012) during October-March 2009–2011. We attached an aluminum leg band and recorded age, sex, and body mass of each bird (Rosene 1969). A sample of captured birds weighing $>$ 165 g were marked with 6.6-g ($\leq$ 4% body mass) necklace-style radio transmitters equipped with an 8-hr mortality sensor (Advanced Telemetry Systems, Isanti, MN, USA). All birds were released at capture sites within 30 min. Trapping, handling, and marking techniques were reviewed and approved by the Animal Care and Use Committee at Ohio State University (protocol #2007A0228). Our goal was to place and maintain radio transmitters on 2–4 birds in each

Table 1. Vital rates used in life-stage simulation analyses of northern bobwhite population growth rates in southwestern Ohio, 2009–2010 and 2010–2011.

Vital rate	Estimate ± SD	Range
Incubated clutch size	14.4 ± 2.4	6.9–21.62
Egg success	0.912 ± 0.166	0.466–1.000
Nest success	0.307 ± 0.161	0.000–0.739
Renesting rate	0.647 ± 0.116	0.334–0.994
Double brooding rate	0.250 ± 0.125	0.000–0.626
Proportion of nests incubated by males	0.432 ± 0.094	0.100–0.737
Chick survival	0.842[a]	0.740–0.943[b]
Summer survival (adults)	0.286 ± 0.131	0.000–0.730
Fall-winter survival (adults and juveniles)	0.109 ± 0.069	0.000–0.310

[a] Suchy and Munkel (2000), adjusted from a 38- to a 30-day interval.

[b] Sampled from a uniform distribution because there was no estimate of SD in original estimate.

covey on all sites throughout the non-breeding season. New birds were radiomarked in each covey to replace transmitters lost after death or transmitter failure. This provided a cohort of radio-marked birds as they entered the breeding season, supplemented by opportunistic capture and radiomarking of individuals after covey brea-up in spring.

Nests ($n = 52$) were found by locating radio-marked birds during the breeding season. Nests were marked with flagging placed > 5 m from the nest and attendance was monitored by locating radio-marked birds every 1–2 days. We avoided flushing birds from nests when possible and then only to count the number of incubated and hatched eggs or to identify gender of the incubating adult. Nests were checked when radio-marked birds were off-nest for > 2 days.

Nest fate was ascertained by examining shell fragments or from association of radio-marked adults with chicks after hatching. We estimated nest success using the logistic exposure method (Schaffer 2004). We used only nests ($n = 40$) found with at least 1 egg and excluded nests that were abandoned or depredated < 1 day after discovery to minimize bias caused by investigator-caused nest failure.

Five additional nesting productivity parameters, including total clutch size, egg success, renesting rate, double brooding rate, and male nesting rate also were estimated. Renesting rate was the proportion of radio-marked females that initiated new clutches after failed nesting attempts, while double-brooding rate was the proportion of radio-marked females that initiated new nests after successful nests. Egg success was the proportion of eggs that hatched from successful clutches. Male nesting rate was the ratio of the probability of finding a radio-marked male to that of finding a radio-marked female incubating a nest. Probability of incubation was calculated with a modified version of Trent and Rongstad's (1974) survival estimator as described in Collins et al. (2009). We treated the ratio (male: female) of sex-specific incubation probabilities equivalent to the ratio of male to female incubated nests as reported by Sandercock et al. (2008).

Radio-marked birds were tracked ≥ 6 days/week by homing and triangulation (White and Garrott 1990) from short distances (< 25 m). We located transmitters after detecting mortality signals and assigned the fate of individuals from field signs at recovery sites (Einarsen 1956) or transmitter condition. Survival rates were estimated from radio-tracking histories of radio-marked birds using the Kaplan-Meier estimator adjusted for staggered entry (Pollock et al. 1989). We pooled age and sex classes to estimate breeding season survival rates during April-September 2010–2011 ($n = 99$) and non-breeding season survival rates during October-March 2009–2011 ($n = 256$). We lacked empirical data on chick survival between hatching and fledging and substituted a published estimate from Suchy and Munkel (2000) in Iowa. These authors estimated chick survival over a 38-day period which we rescaled to a 30-day pre-fledging period.

We conducted life-stage simulations of population growth and fecundity following Sandercock et al. (2008) using 9 demographic parameters (Table 1). Simulations were conducted with R (R Development Core Team 2012). We specified mean and standard deviation of each parameter and sampled from normal distributions with 1,000 iterations. We calculated standard deviations for chick survival and renesting, double-brooding, and male nesting rates using the equation for simple proportions. Suchy and Munkel (2000) did not report standard deviation of their chick survival estimate and we sampled this vital rate from a uniform distribution bounded by 95% confidence intervals (proportion) approximated after adjusting the upper and lower limits for a 30-day period. Post-fledging survival of juveniles was assumed to be the same as for adults between fledging and covey formation. We solved univariate equations from regressions of vital rates on simulated population growth rates for $\lambda = 1$ to identify the magnitude of change necessary to achieve stable populations.

RESULTS

Relative Abundance

Mean detection rates of whistling males were highest on 3 of 4 intensive study sites (Wildcat, Fee, and Thurner) during springs 2008–2011 (Fig. 2). Lower detection rates (< 0.5 calls/survey point) occurred on the other 5 sites.

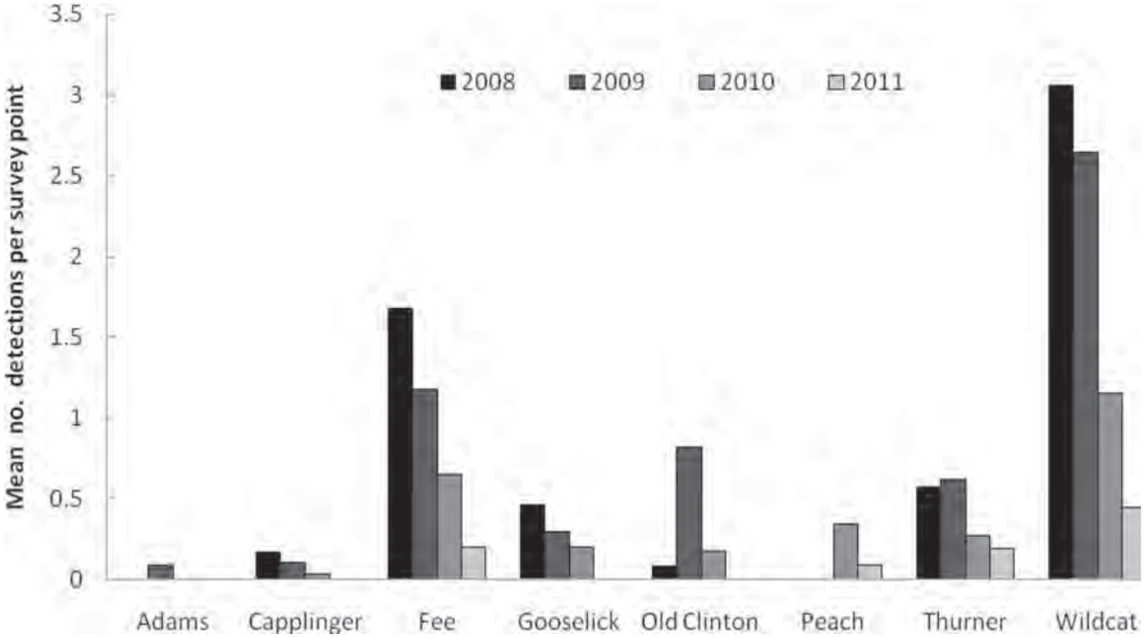

Fig. 2. Mean number of detections/survey point of whistling-male northern bobwhites on 8 study sites in southwestern Ohio, April-June 2008–2011.

We found few or no coveys with covey-call surveys or dog searches on 4 sites (Adams, Capplinger, Gooselick, Old Clinton) during 2008–2010. Call surveys and covey searches were discontinued at these locations in 2011. Whistle-detection rates (calls/survey point) declined ($b = 0.349$, SE $= 0.093$, $P = 0.002$) on all study sites, including the 4 intensive survey sites during 2008–2011 ($b = 0.543$, SE $= 0.112$, $P = 0.001$).

Mean annual covey densities on the intensively-searched study sites ranged from 0.25 to 1.6 coveys/km^2 during 2009–2011. There was no change (paired $t = 0.479$, df $= 3$, $P = 0.6647$) in covey densities between 2009–2010 (0.85 + 0.83, 95% C.I.) and 2010–2011 (0.76 + 0.74, 95% C.I.).

Vital Rates

We monitored 52 nest attempts during summers 2010–2011. Forty of these nests were located after egg-laying and survived > 1 day after discovery. Incubated clutch size (Table 2) was ascertained from 37 nests. Egg success (Table 2) was calculated for 20 nests with known incubated clutch sizes and clutch size at hatch ($n = 295$ eggs). Nests were monitored over 756 exposure days during 2010 ($n = 16$) and 2011 ($n = 24$). Daily nest survival rate (years combined) was 0.973 (SE = 0.563), resulting in a nest success rate of 30.7% assuming our mean observed incubated clutch size (Table 1), 1.2 eggs laid/day, and a 21-day incubation period.

We monitored radio-marked birds over 4,011 radio-days (males) and 3,848 radio-days (females) during the nesting season. We ascertained gender of incubating birds for 38 nest attempts; 28 nests (73.6%) were incubated by females, 9 (23.6%) were incubated by males, and 1 (2.6%) was incubated by both sexes. Nine of 53 (15.1%) radio-marked males incubated nests, compared to 28 of 43 (65.1%) radio-marked females that were found incubating nests. The ratio of probability of finding a radio-marked male incubating a nest (0.291) to that of a radio-marked

Table 2. Regressions of northern bobwhite vital rates on estimates of population growth rates calculated from life-stage simulation analyses following Sandercock et al. (2008). Vital rates were randomly selected ($n = 1{,}000$) from normal distributions with mean and standard deviations based on data collected on northern bobwhites in southwestern Ohio during 2009–2011 (Table 1) .

Vital rate	Intercept	Regression coefficient (b)	SE(b)	r^2
Non-breeding survival	0.001	2.710	0.085	0.504
Breeding survival	0.144	0.531	0.056	0.083
Chick survival	−0.127	0.504	0.130	0.015
Clutch size	−0.011	0.021	0.003	0.046
Egg success	0.046	0.284	0.061	0.021
Nest success	0.095	0.643	0.046	0.163
Male nest rate	0.250	0.108	0.080	0.002
Renesting rate	0.216	0.124	0.067	0.003
Double clutch rate	0.288	0.036	0.063	<0.001

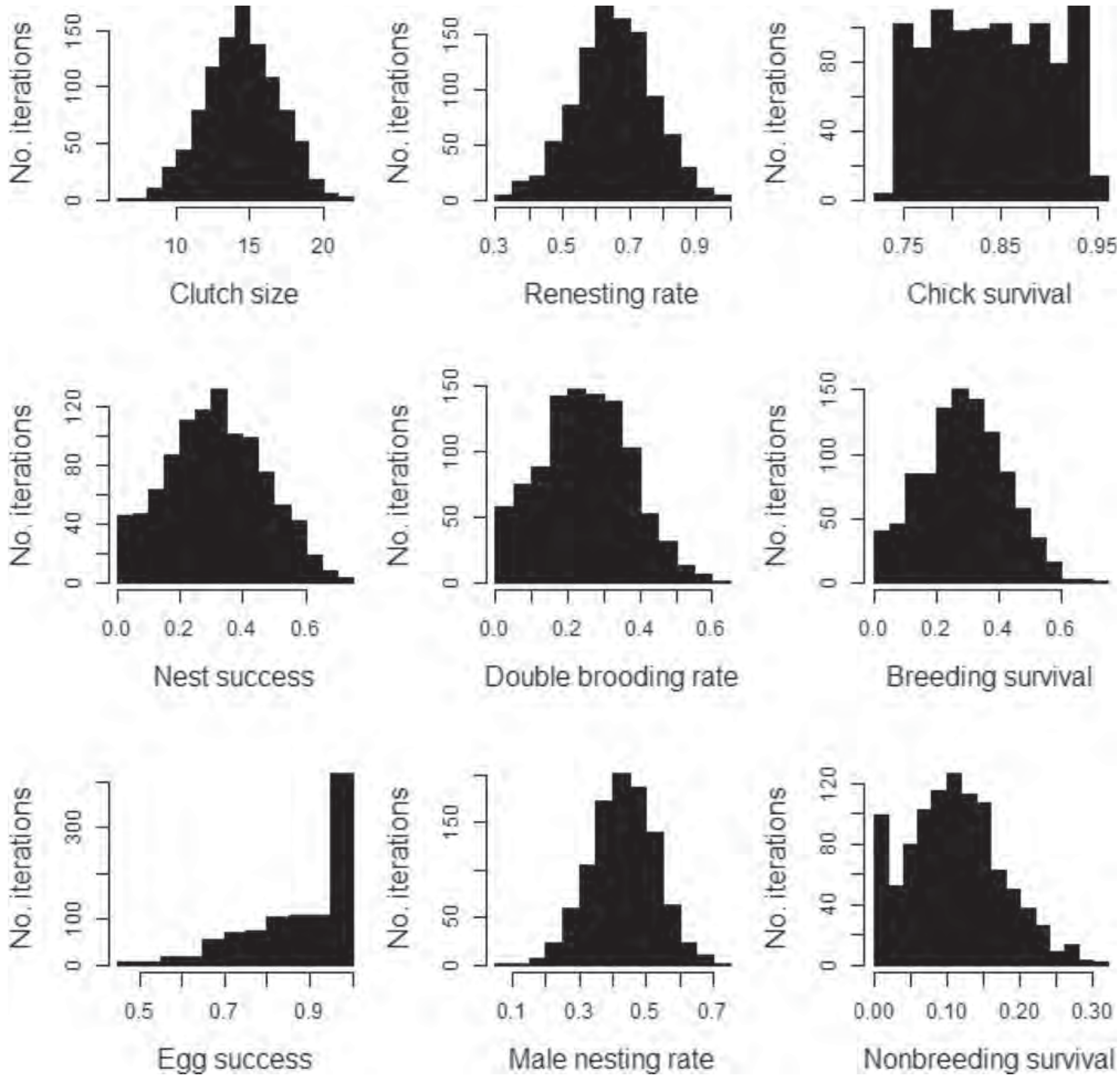

Fig. 3. Values of vital rates randomly selected from normal or uniform (chick survival only) distributions of 9 vital rates for life-stage simulations of population growth rates of northern bobwhites in southwestern Ohio.

female was 0.432 (95% CI = 0.361-0.517). We estimated that 43% of nests were incubated by males assuming that nests were not incubated by both sexes and that all females made > 1 nest attempt (Table 1). Eleven of 17 (64.7%) females initiated new nests after losing a clutch and 3 of 12 (25.0%) females initiated new nests after successful clutches (Table 1).

Kaplan-Meier estimates of breeding season survival were 0.528 (95% CI = 0.348-0.800) in 2010 compared to 0.202 (95% CI = 0.107-0.381) in 2011. The pooled estimate of breeding season survival was 0.286 (95% CI = 0.177-0.462). Non-breeding season survival was 0.057 (95% CI = 0.028-0.117) in 2009–2010 compared to 0.118 (95% CI = 0.068-0.205) in 2010–2011. The pooled estimate of non-breeding season survival was 0.107 (95% CI = 0.073-0.164).

Life Stage Simulations of Population Growth Rate and Fecundity

Life stage simulations of fecundity and population growth rates were based on 8 of 9 vital rates estimated from radiotelemetry data for adults and juveniles during October-March 2009–2010 and adults during April-September 2010–2011 (Table 1; Fig. 3). The median population growth rate from 1,000 combinations of vital rates was 0.296 (0.113-1.694 inter-quartile range). Non-breeding season survival of adults and juveniles was the most dominant vital rate affecting population growth rate

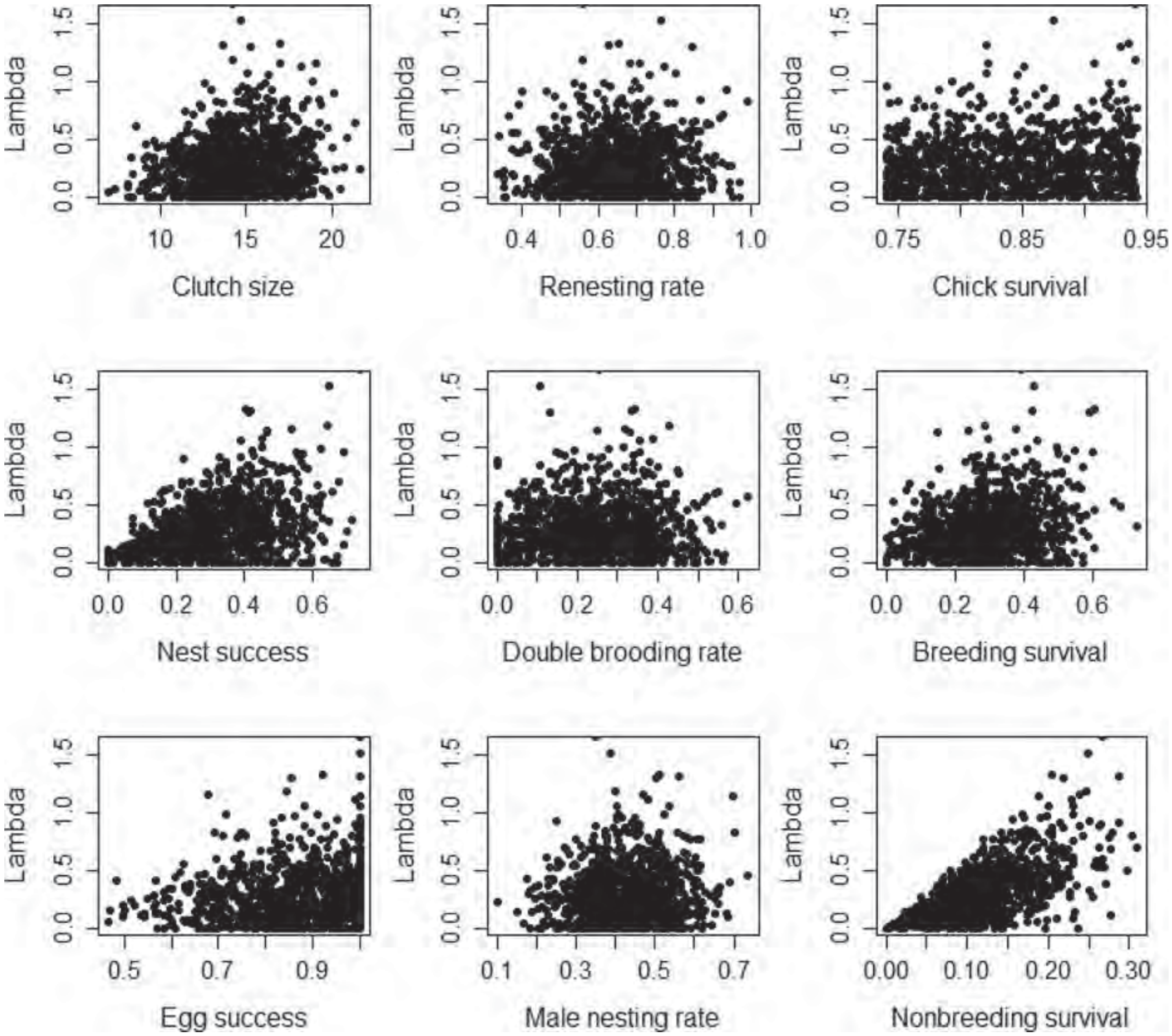

Fig. 4. Simulated growth rates for 9 vital rates used for life-stage analyses of population growth rates of northern bobwhites in southwestern Ohio.

in our simulations, followed by nest success and spring-summer survival (Table 2; Fig 4). Chick survival, egg success, and clutch size in order accounted for 2–5% of variation in λ. Components of nesting propensity were inconsequential in our simulations ($r^2 < 1\%$).

Total fecundity from all sources explained 36.9% of variation in λ. Total fecundity was most strongly influenced by variation in nest success, followed by clutch size, and egg success (Table 3; Fig. 5). Vital rates of nesting propensity were inconsequential ($r^2 < 1\%$). Mean simulated fecundity was lower (2.41 juvenile females/adult female) than we observed in fall-capture age ratios (3.2 juveniles/adult).

Solving univariate equations relating vital rates to λ (Table 2) indicates a stable population could be attained if fall-winter survival of adults and juveniles was raised

Table 3. Regressions of northern bobwhite nesting productivity vital rates on estimates of fecundity rates calculated from life-stage simulation analyses following Sandercock et al. (2008). Vital rates were randomly selected ($n = 1{,}000$) from normal distributions with mean and standard deviations based on data collected on northern bobwhites in southwestern Ohio during 2009–2011 (Table 1) .

Vital rate	Intercept	Regression coefficient (*b*)	SE(*b*)	r^2
Clutch size	0.134	0.158	0.016	0.089
Egg success	0.053	2.679	0.319	0.066
Nest success	0.466	6.210	0.182	0.538
Male nest rate	1.769	1.490	0.426	0.012
Renesting rate	1.068	2.055	0.352	0.033
Double clutch rate	2.360	0.197	0.355	<0.001

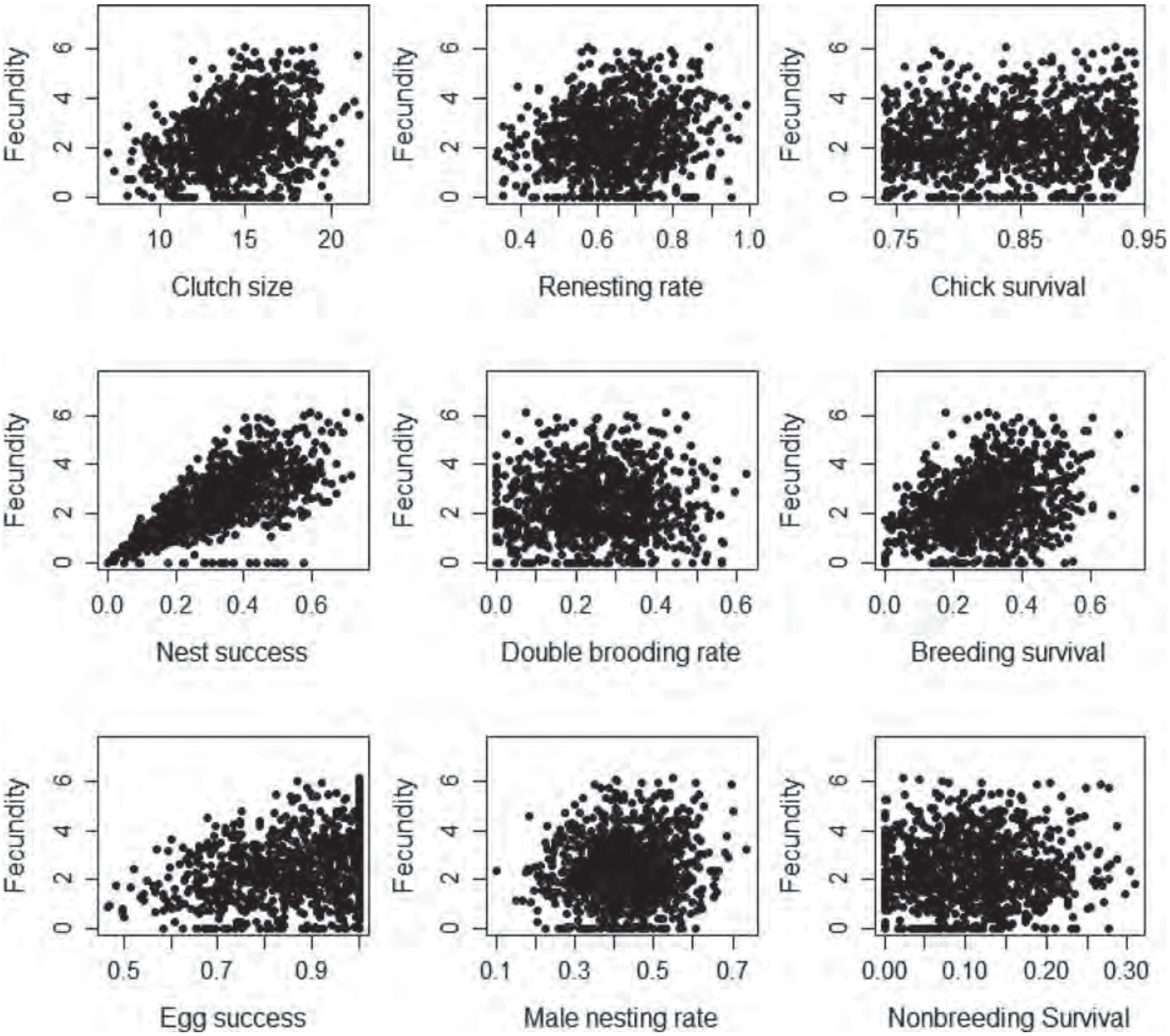

Fig. 5. Total fecundity for 9 vital rates used for life-stage simulation analyses of population growth rates of northern bobwhites in southwestern Ohio.

from 10.9% (observed) to 36.9%. Population stability was not attainable with any biologically reasonable (e.g., total clutch size = 47) or mathematically possible (e.g., chick survival rate = 2.24) increase in any single vital rate. Raising nest success alone to the highest value we simulated (Table 1) would raise λ to only 0.571.

DISCUSSION

Study sites were selected to include only areas with sufficient habitat and densities of bobwhites to investigate habitat relationships and estimate population vital rates. We expected to find viable populations of bobwhites on the majority if not all study sites within the core of the geographic range of bobwhites in Ohio. We did not estimate covey or breeding bird densities on all study sites but only 2 (Wildcat and Fee) sustained populations that could be considered sufficient to provide hunting opportunity (DeMaso et al. 2011). Our findings indicate a highly patchy distribution of bobwhites within the core of the species' range in Ohio. Isolated areas with suitable habitat and microhabitat conditions appear to support metapopulations of bobwhites within a regional population that is steadily declining in southwestern Ohio.

Our estimates of non-breeding and breeding season survival were lower than reported from across the range of bobwhites (Burger et al, 1995a, Sandercock et al. 2008, DeMaso et al. 2011). Nesting productivity and nesting propensity vital rates can be considered within the normal range of values reported from other studies (Burger et al. 1995b, Sandercock et al. 2008, DeMaso et al. 2011). Our life-stage simulations based on empirical information from southwestern Ohio support Guthery et al. (2000), Folk et al. (2007), and Sandercock et al. (2008) in that non-breeding season survival was the most important vital rate affecting growth rates in our population. Renesting, double-brooding, and male incubation have been considered sources of enhanced nesting productivity (Burger et al. 1995b, Guthery and Kuvlesky 1998), but there is little evidence these vital rates affect population growth rate compared to other vital rates, especially survival and to a lesser extent nesting productivity.

The dominance of non-breeding survival in our life-stage simulations with 6 separate breeding vital rates seemed to diminish the influence of reproduction on population growth. Total fecundity had an intermediate univariate contribution to λ ($r^2 = 0.369$), compared to non-breeding ($r^2 = 0.504$) and breeding ($r^2 = 0.083$) season survival rates. This may have been an artifact of the mathematical structure of our life-stage simulations, failure to account for underlying covariance among vital rates, or over-simplicity of univariate regressions of λ on individual vital rates that do not account for complementary effects of variation in factors that affect total fecundity. These issues merit further consideration in future life-stage simulations.

Sandercock et al.'s (2008) life-stage simulations used vital rates sampled from uniform distributions informed by studies across the bobwhite's range. Our simulations were based almost entirely on empirical values observed during 2009–2011 in southwestern Ohio. Simulated vital rates were sampled from normal distributions that should better reflect stochastic annual variation compared to uniform distributions where all possible simulated values are equally probable. Our estimates of non-breeding season survival, nesting success, and other vital rates were from only 2 consecutive years that did not adequately represent the full range of effects of annual variation in weather conditions on population vital rates. Timing, depth, and duration of snow cover varied between years but we observed similar rates of non-breeding season survival (Janke and Gates 2012). Both years were characterized by several snow events that are less frequent in mild winters when non-breeding season survival may be higher than we observed. The breeding season also was extremely wet in 2011 when we observed a lower survival rate (0.202) compared to 2010 (0.528), but nest success did not differ between years.

Our life-stage simulations of population growth rate indicated the vital rates we measured, particularly non-breeding survival, were well below that required to sustain bobwhite populations in southwestern Ohio. Only 1.2% of simulated values for λ exceeded 1, the threshold value for population growth. This is consistent with the continual downward trend in regional population indices (Spinola and Gates 2008) from whistle-counts conducted by Ohio Division of Wildlife (Fig. 1B) that we also observed on our study sites (Fig. 2). Lohr et al. (2011) similarly concluded that survival rates were unsustainably low in a declining population of bobwhites at the northern periphery of the species' range.

Two consecutive years of low survival associated with above-average snow cover (Janke and Gates 2012) caused alarmingly low λ values in our simulations. We hypothesize that growth of this population was limited primarily by weather-mediated predation during winter. Simulated and observed (capture age ratio) fecundity rates were similar to those Roseberry et al. (1979) observed in a declining population that occupied deteriorating habitat in southern Illinois. Age ratios of < 4 juveniles/adult are considered low and generally inadequate to support viable populations (Roseberry and Klimstra 1984, Guthery et al. 2000). Fecundity rates were within the normal range of variation for northern bobwhites but were inadequate to sustain the population after severe winters or to produce surplus individuals that could colonize vacant or low-density habitats.

Covey densities did not differ between 2009-10 and 2010-11 despite low non-breeding survival during 2009–2010 and declining whistle-counts on the 4 intensive study areas. Negative population growth rates suggest our study sites were population sinks but we cannot explain how bobwhite populations were sustained on our intensive study sites except to hypothesize they are supplemented by ingress of birds from out-lying areas during the 'fall shuffle' (Murphy and Baskett 1952, Townsend et al. 2003), or that some birds disperse beyond the study areas to nest during spring and summer and then return with young in fall. This population does not appear to be dispersal-limited, as bobwhites dispersed up to 11.5 km in spring (Liberati and Gates 2012) but we know of no source populations near our study sites.

MANAGEMENT IMPLICATIONS

The future of northern bobwhites in Ohio hinges primarily on raising non-breeding season survival rates to levels that sustain population growth and range expansion to fill vacant habitats. Sandercock et al. (2008) also concluded that management to improve seasonal survival rates has the greatest potential for recovery of declining bobwhite populations. Our life-stage simulations were encouraging in that non-breeding season survival would need to increase by 26% to achieve population stability. Northern bobwhites on our study areas were highly dependent on early succession woody habitats, edges of early succession herbaceous fields, or woodlot edges that provided protective cover near winter food sources (Janke 2011, Janke and Gates 2013). Survival declined through winter and mortality rates were associated with depth, duration, and timing of snow cover during December-February (Janke 2011, Janke and Gates 2012). Improving protective cover near food sources (crop and warm-season grass fields) would increase useable space (Guthery 1997) and could raise non-breeding season survival rates to levels that support population recovery and range expansion in Ohio and perhaps other areas in the Midwestern U.S. We advocate greater emphasis on managing succession of woody cover along field, grassland, and woodlot edges that are heavily used during winter (Janke and Gates 2013). Continued effort to conserve early succession herbaceous habitats is still necessary to sustain nesting and perhaps raise nest success and summer survival rates of adults and fledged young before coveys form in October. Improving breeding season vital rates would augment efforts to raise population growth rates by improving non-breeding season survival.

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LITERATURE CITED

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

Burger, L. W., T. V. Dailey, E. W. Kurzejeski, and M. R. Ryan. 1995a. Survival and cause-specific mortality of northern bobwhite in Missouri. Journal of Wildlife Management 59:401–410.

Burger, L. W., M. R. Ryan, T. V. Dailey, and E. W. Kurzejeski. 1995b. Reproductive strategies, success, , and mating systems of northern bobwhite in Missouri. Journal of Wildlife Management 59:417–426.

Collins, B. M., C. K. Williams, and P. M. Castelli. 2009. Reproduction and microhabitat selection in a sharply declining northern bobwhite population. Wilson Journal of Ornithology 121:688–695.

DeMaso, S. J., W. E. Grant, F. Hernández, L. A. Brennan, N. J. Silvy, X. B. Wu, and F. C. Bryant. 2011. A population model to simulate northern bobwhite populations in southern Texas. Journal of Wildlife Management 75:319–332.

Einarsen, A. A. 1956. Determination of some predator species by field signs. Oregon State College Monographs. Studies in Zoology 10:5–34.

Folk, T. H., R. R. Holmes, and J. B. Grand. 2007. Variation in northern bobwhite demography along two temporal scales. Population Ecology 49:211–219.

Guthery, F. S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 61:291–301.

Guthery, F. S., and W. P. Kuvlesky. 1998. Effect of multiple-brooding on age ratios of quail. Journal of Wildlife Management 62:540–549.

Guthery, F. S., M. J. Peterson, and R. R. George. 2000. Viability of northern bobwhite populations. Journal of Wildlife Management 64:646–662.

Homer, C., C. Huang, C. Yang, B. Wylie, and M. Coan. 2004. Development of a 2001 National Land-Cover Database for the United States. Photogrammetric Engineering and Remote Sensing 70:829–840.

Janke, A. K. 2011. Survival and habitat use of non-breeding northern bobwhites on private lands in Ohio. Thesis. Ohio State University, Columbus, USA.

Janke, A. K., and R. J. Gates. 2012. Temporal variability in survival of non-breeding northern bobwhites in Ohio. Proceedings of the National Quail Symposium 7:194–201.

Janke, A. K., and R. J. Gates. 2013. Home range and habitat selection of northern bobwhite coveys in an agricultural landscape. Journal of Wildlife Management 77: In Press.

Liberati, M. R., and R. J. Gates. 2012. Spring dispersal of northern bobwhites in southwestern Ohio. Proceedings of the National Quail Symposium 7:202–211.

Lohr, M., B. M. Collins, C. K. Williams, and P. M. Castelli. 2011. Life on the edge: northern bobwhite ecology at the northern periphery of their range. Journal of Wildlife Management 75:52–60.

Murphy, A., and T. Baskett. 1952. Bobwhite mobility in central Missouri. Journal of Wildlife Management 16:498–510.

Norton, H. W., T. G. Scott, W. R. Hanson, and W. D. Klimstra. 1961. Whistling-cock indices and bobwhite population in autumn. Journal of Wildlife Management 25:398–403.

Pinheiro, J., D. Bates, S. DebRoy, D. Sarkar, and the R Development Core Team. 2012. *nlme*: linear and nonlinear mixed effects models. R package Version 3.1–104. R Foundation for Statistical Computing, Vienna, Austria. cran.r-project.org/web/packages/nlme.pdf

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies-the staggered entry design. Journal of Wildlife Management 53:7–15.

R Development Core Team. 2012. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, USA.

Roseberry, J. L., B. G. Peterjohn, and W. D. Klimstra. 1979. Dynamics of an unexploited bobwhite population in deteriorating habitat. Journal of Wildlife Management 43:306–315.

Rosene Jr., W. 1969. The bobwhite quail: its life and management. The Sun Press, Hartwell, Georgia, USA.

Sandercock, B. K., W. E. Jensen, C. K. Williams, and R. D. Applegate. 2008. Demographic sensitivity of population change in northern bobwhite. Journal of Wildlife Management 72:970–982.

Schaffer, T. L. 2004. A unified approach to analyzing nest success. Auk 121:526–540.

Spinola, R. M., and R. J. Gates. 2008. Population status and trends of northern bobwhite (*Colinus virginianus*) in Ohio: 1984–2004. Ohio Journal of Science 108:26–30.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner's Sons, New York, USA.

Suchy, W. J., and R. J. Munkel. 2000. Survival rates of northern bobwhite chicks in south-central Iowa. Proceedings of the National Quail Symposium 4:82–84.

Townsend, D. E., D. M. Leslie Jr., R. L. Lochmiller, S. J. DeMaso, S. A. Cox, and A. D. Peoples. 2003. Fitness costs and benefits associated with dispersal in northern bobwhites (*Colinus virginianus*). American Midland Naturalist 150:73–82.

Trent, T. T., and O. J. Rongstad. 1974. Home range and survival of cottontail rabbits in southwestern Wisconsin. Journal of Wildlife Management 38:459–472.

Wellendorf, S. D., W. E. Palmer, and P. T. Bromley. 2004. Estimating calling rates of northern bobwhite coveys and measuring abundance. Journal of Wildlife Management 68:672–682.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, Inc., San Diego, California, USA.

Wiley, M. J., A. K. Janke, and R. J. Gates. 2012. Efficacy of targeted mist-netting to capture northern bobwhites during the non-breeding season in Ohio. Proceedings of the National Quail Symposium 7:235–240.

TEMPORAL VARIABILITY IN SURVIVAL OF NON-BREEDING NORTHERN BOBWHITES IN OHIO

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ABSTRACT

Non-breeding season survival is an important determinant of population growth rates of northern bobwhites (*Colinus virginianus*) and is primarily influenced by hunter harvest, predation, and weather. The collective influence of these factors varies within and among years and across the bobwhite range. Understanding factors that influence variation in survival is important to inform regionally-specific management strategies for declining bobwhite populations. We radiomarked 311 bobwhites from 73 coveys to investigate temporal variation in non-breeding season (Oct-Mar) survival of a declining bobwhite population on private land in southwestern Ohio during 2008–2011. We used the data bootstrapping feature in Program MARK to adjust for overdispersion caused by dependency of survival among members of the same covey. Temporal variation in survival was best modeled ($w_i = 0.935$) with weekly differences in survival rates that varied within and between years. There was only slight dependency in survival due to covey affiliation between the 2 seasons (median $\hat{c} = 1.51$). Non-breeding season survival was low ($\hat{S}_{2009\text{–}2010} = 0.05$, 95% CI = 0.03-0.11, $\hat{S}_{2010\text{–}2011} = 0.12$, 95% CI = 0.07-0.20) in 2 years with data for the entire season. Survival during 10 December-31 March varied among the 3 years ($\hat{S}_{2008\text{–}2009} = 0.45$, 95% CI = 0.29-0.61, $\hat{S}_{2009\text{–}2010} = 0.11$, 95% CI = 0.05-0.21, $\hat{S}_{2010\text{–}2011} = 0.25$, 95% CI = 0.17-0.34). There were 2 periods of low survival; a short period in early fall that coincided with senescence of herbaceous vegetation and the hunting season, and during periods with prolonged snow cover during winter. Late winter survival during periods of snow cover was most variable and winter severity appeared to have the greatest influence on seasonal survival during our study. Management strategies to improve non-breeding season survival in northern populations should focus on managing winter habitat to improve survival during periods of prolonged snow cover.

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Key words: *Colinus virginianus*, harvest, known-fates model, northern bobwhite, Ohio, overdispersion, Program MARK, survival, winter weather

INTRODUCTION

Life-history theory predicts changes in reproduction are most important for short-lived species with high fecundity and low survival (Stahl and Oli 2006). However, survival generally has more influence on growth rates of declining populations (Meats 1971). Demographic analyses support the relationship between survival and growth rates of declining populations of northern bobwhites and have established that non-breeding season survival is the most influential vital rate (Folk et al. 2007, Link et al. 2008, Sandercock et al. 2008, Gates et al. 2012). Variation in non-breeding season survival of northern populations strongly influences population viability (Guthery et al. 2000, Williams et al. 2003a), and management strategies need regional estimates of survival rates upon which to base conservation efforts (Brennan 1991, Cox et al. 2004).

Low non-breeding season survival is characteristic of bobwhite populations in northern parts of their range, but sources of mortality and seasonal variation in survival are less well understood. Previous studies documented the influence of regionally-varying factors such as hunter harvest (Pollock et al. 1989b, Williams et al. 2004a, Rolland et al. 2010) or seasonal variation in weather (Roseberry and Klimstra 1984, Robel and Kemp 1997). The influence of these and other factors that affect non-breeding season survival vary across the species' range and under different management regimes (Williams et al. 2004b).

Seasonal and annual comparisons of survival require understanding of the precision of estimators through time. Variance of temporal survival estimates is affected by 2 factors: overdispersion and variability in sampling effort. Dependency between individuals in survival analyses produces overdispersion, which can misleadingly reduce variance estimates (Schmutz et al. 1995). Previous survival estimates reported for bobwhites from radio-telemetry studies have not explicitly addressed dependency in survival that arises from individuals in the same covey sharing resources and exposed to similar mortality factors (Williams et al. 2003b). Failure to address dependency can potentially provide biased estimates of variability in survival through the season (Schmutz et al.

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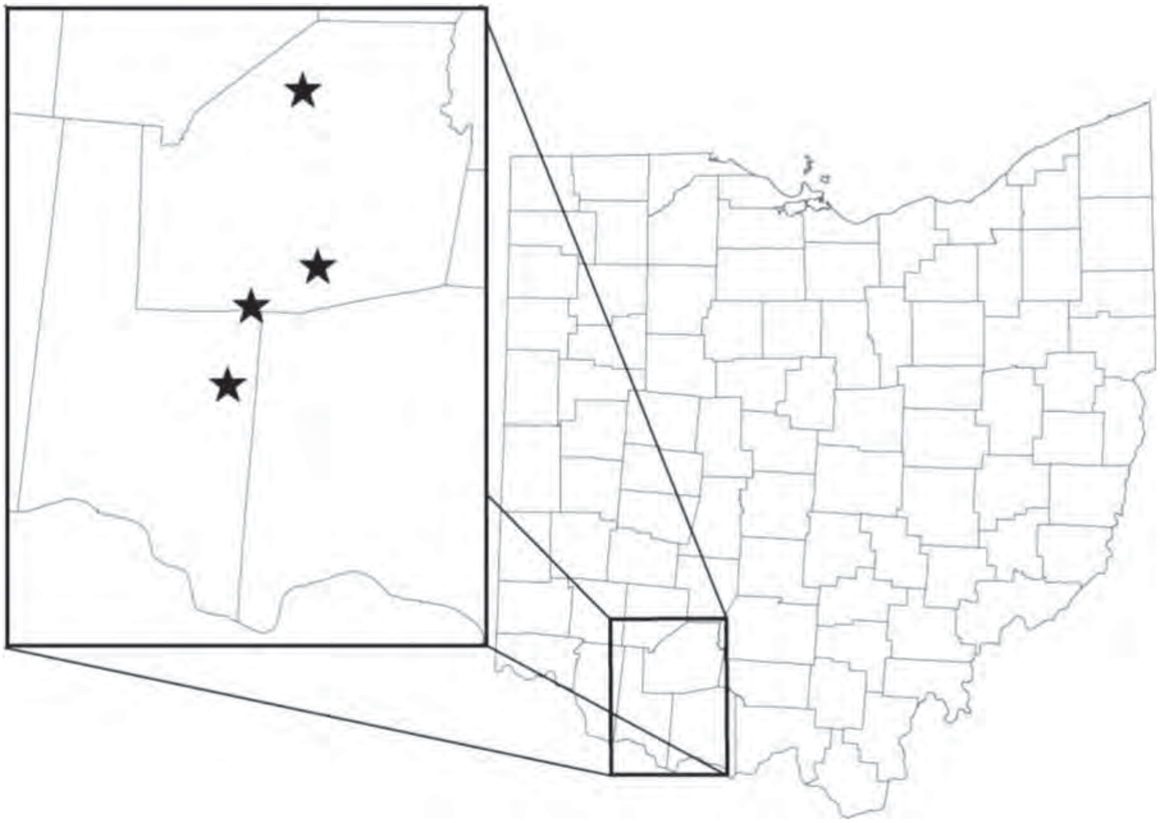

Fig. 1. Location of 4 private land study sites in Highland and Brown counties in southwestern, Ohio, USA.

1995). Inconsistent sampling effort throughout a study can also lead to imprecise variance estimates by confusing process variation with sampling variation (Burnham et al. 1987, Gould and Nichols 1998). Survival analyses can identify periods within seasons with low or highly variable survival rates by first addressing confounding influences of variation in sampling effort and non-independence. That information can be used to focus conservation efforts to improve survival and, ultimately, growth rates of declining populations (Gould and Nichols 1998, Moynahan et al. 2006).

We investigated temporal patterns of variation in non-breeding season survival of a bobwhite population near the northern periphery of the species' range. Our objectives were to: (1) compare the fit of temporal models to understand intra- and inter-seasonal non-breeding season survival and identify periods of lowest survival, and (2) test for overdispersion between covey members in survival analysis to improve variance estimates.

STUDY AREA

We conducted our study within the core bobwhite distribution in Highland and Brown counties (Spinola and Gates 2008) in southwestern Ohio (centered on 39° 04′ 59”, 83° 39′ 10”; Fig. 1). Highland and Brown counties were in the glaciated till plains physiographic region (Ohio Division of Geologic Survey 1998). Primary land use in the region was agriculture, including 39% row crops and 17% pasture and hay (Homer et al. 2004). The region was mostly rural (6% developed). Woodlots and grasslands accounted for 33 and 3% of the landscape, respectively.

We worked on 4 private land study sites (400-1,200 ha) where bobwhite coveys were consistently found during the non-breeding season (Oct-Mar 2008–2011). Composition of the study areas was primarily row crop fields (55%) planted with soybeans and corn. Early succession vegetation, including fields enrolled in the Conservation Reserve Program (CRP), old fields, fencerows, and agricultural drainage ditches collectively accounted for 19% of the area of the study sites. Grass fields were dominated by fescue (*Festuca* spp.) or planted warm season grasses, primarily Indiangrass (*Sorghastrum nutans*), big bluestem (*Andropogon gerardii*), and switchgrass (*Panicum virgatum*). Dominant forbs in grasslands were goldenrod (*Solidago* spp.), Queen Anne's lace (*Daucus carota*), and partridge pea (*Chamaecrista fasciculata*). Early succession woody vegetation was primarily blackberry (*Rubus allegheniensis*) or black raspberry (*R. occidentalis*). Woodlots accounted for 13% of the study area. Upland woodlots were dominated by oaks (*Quercus* spp.) and hickory (*Carya* spp.) whereas wet woodlots were characterized by ash (*Fraxinus* spp.) and black walnut (*Juglans nigra*).

Weather during the study was variable and generally more severe than long-term averages (Table 1). Timing and severity of weather varied among the 3 study years. The winter was relatively mild in 2008-09 with 2 short (7-

Table 1. Non-breeding season (Oct-Mar) weather summary from Dayton, Ohio, 90 km northwest of 4 private land study sites in southwestern Ohio (NCDC 2011).

Winter	Mean temp (°C)	Total snow (cm)	Days $\geq$ 5 cm[a]
2008–2009	9.2	48.5	16
2009–2010	8.5	101.6	31
2010–2011	8.5	67.3	41
30-year average[b]	10.5	67.5	19.8

[a] Number of days within season with $\geq$ 5 cm snow cover at the time of observation.

[b] 1977–1978 through 2007–2008.

12 days) periods of snow cover $>$ 5 cm; total daily accumulation did not exceed 25 cm. The weather was mild during December 2009-January 2010 but a prolonged period (22 days) of deep snow accumulation and cold temperatures occurred during February 2010. Snow accumulation during this period exceeded 25 cm for 9 consecutive days. There was consistent snow cover $>$ 5 cm during December 2010-January 2011 and little snow accumulation in February. The duration of snow cover was prolonged but depth did not exceed 25 cm.

METHODS

We captured bobwhites with baited funnel traps (Stoddard 1931) and targeted mist-netting (Wiley et al. 2012) during October-March 2008–2011. We attached an aluminum leg band and recorded age, gender, and body mass of each bird (Rosene 1969). We fit a subsample of individuals weighing >165 g with 6.6-g ($\leq$ 4% body mass) necklace style radio transmitters (Advanced Telemetry Systems, Isanti, MN, USA). Transmitters were equipped with an 8-hr mortality sensor. All birds were released at the capture site within 30 min. Trapping, handling, and marking protocols were reviewed and approved by the Animal Care and Use Committee at Ohio State University (protocol # 2007A0228).

We tracked all radio-marked birds $\geq$ 6 days/week by homing and triangulation from short distances ($<$ 25 m) (White and Garrott 1990). We immediately located the transmitter after detecting a mortality signal and identified cause of mortality from field sign observed at the recovery site (Einarsen 1956) and condition of the transmitter. We recorded the cause of mortality as predation, hunter harvest, investigator-caused (e.g., transmitter entanglement, trap mortality), other (e.g., vehicle collision, weather), or unknown.

We used the known-fates model with a logit link function in Program MARK to estimate survival rates (White and Burnham 1999). The known-fates model calculates maximum likelihood estimates of survival and allows comparisons of models with multiple parameters to estimate their effect on survival (Murray 2006). We generated encounter histories with daily intervals for all birds that survived a 7-day post-capture exclusion period to control for short-term acute effects of capture and radiomarking (Guthery and Lusk 2004, Holt et al. 2009). We excluded data from the first year of the study in the primary survival analyses because there were few birds radiomarked during 1 October to 9 December.

We compared *a priori* models to examine the appropriate temporal scale for seasonal variation in survival rates. Baseline temporal models tested for weekly, bi-weekly, monthly, and constant variability throughout the season. We also compared 2 models with linear and quadratic trends through the season. We evaluated each model (excluding the null model) with an additive and an interaction year term because we had no *a priori* prediction about differences in survival among years. We used the information theoretic approach to compare support for each model, based on Akaike Information Criterion adjusted for small sample sizes (AIC_c), and considered models with ΔAIC_c scores $\leq$ 2.0 to have equivalent support (Anderson and Burnham 2002). We added additional parameters to the best fitting temporal model to test for differences in age and gender and reported the relative influence of each parameter based on model coefficients and 95% confidence intervals.

We calculated survival of individuals captured in the first year of the study for a shortened interval (10 Dec-31 Mar) with the best fitting temporal model. We estimated survival for the same interval in each of the 2 full years with a shortened encounter history to make comparisons among the 3 seasons.

We used an intercept only random effects model to estimate process variance with the variance components analysis in Program MARK (Burnham et al. 1987, Gould and Nichols 1998, White et al. 2001). We compared the ratio of sampling and process variances for the 2 years and report the estimate of process variance. Sampling variance is an estimate of variability in the parameter that includes variation in sampling effort and natural processes. Process variance removes the sampling variability from the estimate to provide a more precise estimate of the true variation in the population parameter.

We used the bootstrap procedure in Program MARK to estimate an overdispersion parameter (c) to test for dependency in survival among covey members (Bishop et al. 2008). Overdispersion parameters, or variance inflation factors, adjust variance estimates to more correctly model overdispersed data (Schmutz et al. 1995, Anderson and Burnham 2002). The general approach for estimating c is to divide the goodness-of-fit statistic of the model with the most parameters by the degrees of freedom of that model (Anderson and Burnham 2002). However, this approach is sensitive to sample sizes and fails to explicitly consider the cause of overdispersion.

Data bootstrapping can be used to estimate c when the source of dependency is known (Bishop et al. 2008). A common example of known sources of dependency is siblings, where $\geq$ 2 individuals in the survival analysis have the same maternal resources and are exposed to similar environments and mortality sources. The bootstrapping procedure resamples from known groups (e.g., siblings or coveys), rather than by individual encounter histories, to generate survival estimates. The overdispersion parameter ($\hat{c}$) is calculated as $\hat{c} = \mathrm{SD}(\hat{S})^2/\mathrm{SE}(\hat{S})^2$

Table 2. Selection for candidate models to explain inter- and intra-seasonal variation in non-breeding season (Oct-Mar) survival of northern bobwhites in southwestern Ohio, 2009–2011.

Model	AIC_c[b]	ΔAIC_c[b]	w_i[b]	k[b]
Week + Year+Week x Year	1585.479	0.000	0.935	52
BiWeek + Year+BiWeek x Year	1590.822	5.343	0.065	26
Month + Year+Month x Year	1617.168	31.689	0.000	12
Week	1654.372	68.894	0.000	26
Week + Year	1655.735	70.256	0.000	27
BiWeek	1674.825	89.347	0.000	13
BiWeek + Year	1676.236	90.757	0.000	14
Month	1678.458	92.979	0.000	6
Month + Year	1680.189	94.711	0.000	7
tt + Year+tt x Year	1680.235	94.757	0.000	6
t + Year+t x Year	1692.596	107.118	0.000	4
tt	1693.162	107.683	0.000	3
tt + Year	1694.938	109.459	0.000	4
Constant	1697.542	112.064	0.000	1
Constant + Year	1698.906	113.428	0.000	2
t	1699.384	113.906	0.000	2
t + Year	1700.785	115.307	0.000	3

[a] Temporal effects modeled as constant through year, linear time trend (t), quadratic time trend (tt), and weekly, bi-weekly, and monthly periods.

[b] AIC_c = Akaike's Information Criterion adjusted for small sample sizes, ΔAIC_c = difference between AIC_c of best fitting and current model, w_i = Akaike's weight, k = number of parameters in model.

where $SD(\hat{S})$ is the standard deviation of bootstrapped survival estimates and $SE(\hat{S})$ is the standard error of the survival estimate from the maximum-likelihood analysis (Bishop et al. 2008).

We generated 10,000 estimates of $\hat{S}$ with the most parsimonious temporal model ($\Delta AIC_c < 2$ and fewest parameters). Using the best fitting temporal model removes variability that could be misinterpreted as overdispersion. The procedure removed individuals from randomly selected coveys and estimated $\hat{S}$ for the subset of data during each iteration (Bishop et al. 2008). Total sample size for each iteration depended on the number of radio-marked individuals in each covey in the subset data. Covey affiliation was specified as an individual covariate in the encounter history. We used the median $\hat{c}$ estimate from the 2 years in the bootstrapping analysis to approximate the variance inflation factor for the study (Anderson and Burnham 2002). We considered overdispersion to be present in the data if the $\hat{c}$ estimate was >1.2 as an *a priori* rule (Bishop et al. 2008).

A covey was defined as ≥ 2 individuals that were together for ≥ 7 consecutive days. Some investigators have reported dynamic covey affiliation among individuals through the non-breeding season (Yoho and Dimmick 1972, Williams et al. 2004a), but individuals rarely changed covey affiliations during our study (Janke 2011). We identified the resulting group when 2 formerly unique coveys combined as a unique covey in the analysis, right-censored individuals in the covey, and re-entered them in the risk set as a new individual with the combined covey.

There was a 23-day hunting season with a 4 bird bag limit during the last 3 weeks of November each year. We did not restrict or influence hunter effort or access on any of the sites. We distributed log books to hunters and landowners on each site to monitor hunting effort and success. We calculated a cumulative incidence function (CIF) to estimate cause-specific mortality related to hunter harvest to measure the contribution of harvest to non-breeding season mortality (Heisey and Patterson 2006). The cumulative incidence function calculates the relative influence of a specific mortality factor on survival in a population exposed to multiple risk factors (in addition to the factor[s] of interest, i.e., harvest.). This approach uses the staggered entry design of the Kaplan Meier estimator (Pollock et al. 1989a) to generate survival estimates and cause-specific mortality rates sensitive to problems of staggered entry (individuals that die early are not available for capture later in the study and affect differential survival rates through the season with variable sample sizes). The CIF approach also respects the property of 'conservation of mortality' raised by the existence of multiple mortality sources (Heisey and Patterson 2006: 1545). We used the wild1 package in R to calculate the CIF for harvest with data from all individuals surviving the 7-day exclusion period during the last 2 years of the study (Sargeant 2011).

Table 3. Survival estimates from maximum likelihood and bootstrapping procedures in the known-fates model in Program MARK for radio-marked northern bobwhites during the non-breeding season (Oct-Mar), 2009–2011.

	Maximum likelihood		Bootstrap		
Year	$\hat{S}$	$SE(\hat{S})$	$\bar{\hat{S}}$	$SD(\bar{\hat{S}})$	$\hat{c}$[a]
2009–2010	0.055	0.021	0.058	0.028	1.84
2010–2011	0.121	0.033	0.122	0.036	1.18

[a] Variance inflation factor; estimated by $SD(\hat{S})^2/SE(\hat{S})^2$.

RESULTS

We included 311 bobwhites in survival analyses after a 7-day exclusion period (55 in 2008–2009, 130 in 2009–2010, and 126 in 2010–2011). The sample comprised 75% juveniles with slightly more males (54%) than females (46%). Five individuals were censored due to investigator-caused mortalities and 27 were censored due to radio transmitter failure. We included 256 individuals from 2 years (2009–10 and 2010–11) in the temporal analysis. All daily intervals in the analysis had ≥ 3 radio-marked birds and the mean (± SD) number of radio-marked individuals per daily interval was 31 ±11.1 (range = 3–60).

We identified 73 coveys (15 in 2008–2009, 27 in 2009–2010, and 31 in 2010–2011). Two coveys joined and were identified as a new covey on 2 occasions in 2009–2010 and 4 occasions in 2010–2011. The mean (± SD) number of radio-marked individuals in each covey was 4.6 ± 2.3.The mean (± SD) number of radio-marked individuals/covey/day was 2.3 ± 0.8.

The best fitting temporal model included weekly effects and the interaction of week with year (Table 2). There was little support for other temporal models, but the high ranking of heterogeneous models (biweekly and monthly models) with the annual interaction term indicated there was substantial inter- and intra-annual variation in survival. Additional covariates for gender and age did not improve model fit and were not included in the final model. There was no difference in survival between genders ($\beta_{\text{Female}} = 0.044$, 95% CI = - 0.278-0.367). Adults generally had higher survival than juveniles ($\beta_{\text{Adult}} = 0.286$, 95% CI = - 0.093-0.665) although models without age effects had equivalent support and the confidence interval for the age coefficient contained zero. The ratio of the standard error of process variance to observed variance in weekly survival intervals was 1, indicating the observed variation in survival was not attributable to differential sampling effort across weeks. The bootstrapping analysis revealed there was modest overdispersion in the data due to dependency between covey mates (Table 3; median $\hat{c} = 1.51$).

Non-breeding season survival estimates were low each year ($\hat{S}_{2009–2010} = 0.055$, 95% CI = 0.026-0.113, $\hat{S}_{2010–2011} = 0.121$, 95% CI = 0.069-0.203). Survival rates during 10 December- 31 March were variable among the 3 years ($\hat{S}_{2008–2009} = 0.449$, 95% CI = 0.295-0.613, $\hat{S}_{2009–2010} = 0.114$, 95% CI = 0.059-0.217, $\hat{S}_{2010–2011} = 0.247$, 95% CI = 0.170-0.345). Daily survival rates consistently declined through the non-breeding season and the lowest estimates occurred during December-February (Fig. 2). Periods of lowest survival coincided with increases in regional snow cover. Fall survival (Oct-Nov) was lower than other snow-free periods and the highest survival rates occurred in March.

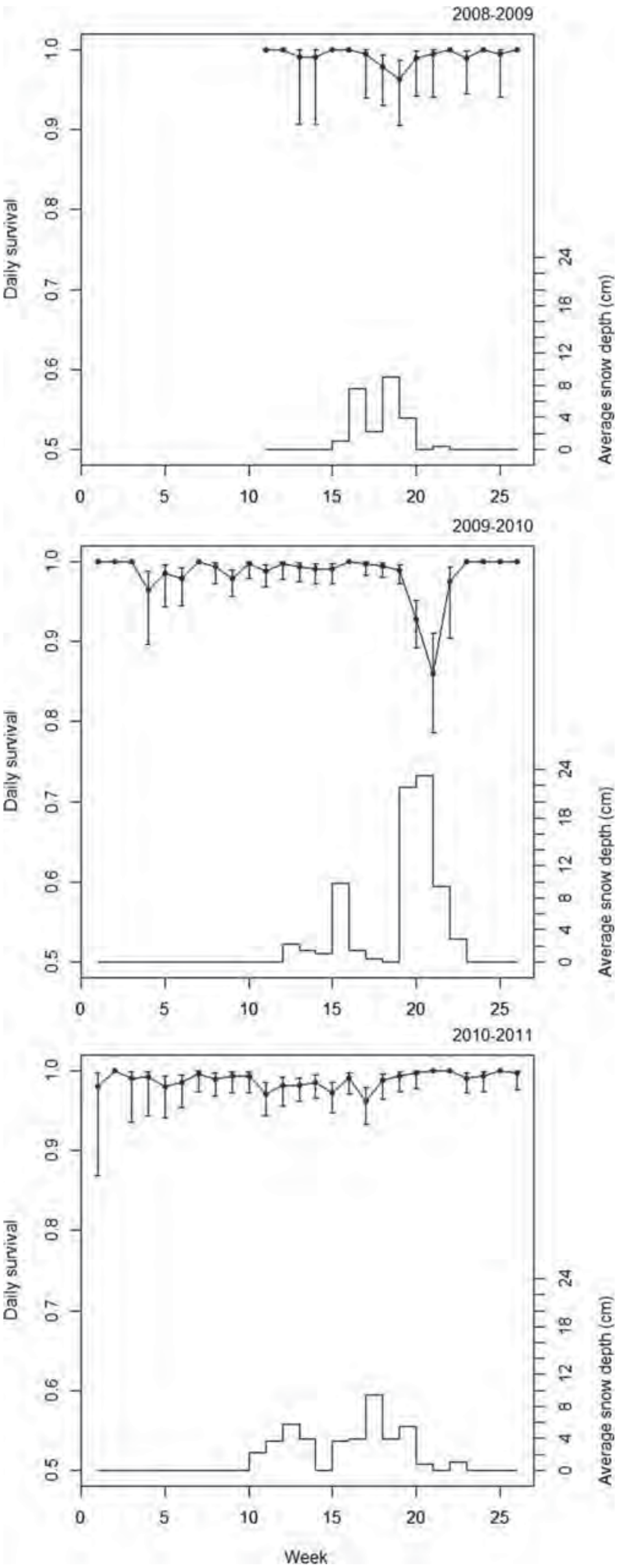

Fig. 2. Daily survival estimates ($\hat{S}$) and 95% CI for northern bobwhites over weekly intervals during the non-breeding season (1 Oct–31 Mar) in Ohio, 2008–2011. The lower line represents average snow depth (cm) from a regional weather station in Dayton, Ohio (90 km northwest of the sites) for each weekly interval (NCDC 2011). Daily snow observations within sites during 2009–2011 correlated with regional observations from the Dayton station, but were not available for the entire study period (Janke 2011).

Table 4. Inferred mortality causes from evidence at recovery locations of radio-marked northern bobwhites ($n = 186$) during the non-breeding season in southwestern Ohio, 1 October–31 March 2008–2011.

Cause	%
Hunter harvest	5.4
Investigator[a]	2.7
Other	1.1
Predation	
Avian	23.7
Mammalian	16.1
Unclassified	38.7
Unknown	10.2
Weather	2.2

[a] Capture or transmitter-related mortality.

Predation was the primary cause of mortality (78.5%), and avian predators were implicated in a majority of predation events (Table 4). Avian predators were also suspected in a majority of mortality cases recorded as unclassified predation, although evidence at the recovery site was insufficient to directly implicate avian predators. We confirmed predation by red (*Vulpes vulpes*) or gray (*Urocyon cinereoargenteus*) fox, mink (*Neovision vision*), feral cats (*Felis catus*), Cooper's (*Accipiter cooperii*), and sharp-shinned (*A. striatus*) hawks. We documented 13 hunting parties during 2009–2011 with hunter log books and observations in the field. Only 8 (6 in 2009-10, 2 in 2010-11) of 105 (57 in 2009-10, 48 in 2010-11) bobwhites radiomarked during the season were harvested. The CIF for harvest related mortality was 0.068 (95% CI = 0.012-0.123).

DISCUSSION

Survival is an important determinant of growth rates in bobwhite populations, and non-breeding season survival has been identified as the most important vital rate for populations near the northern extent of their range (Folk et al. 2007, Gates et al 2012). Weekly survival rates during our study were dynamic and appeared to be most influenced by snow accumulation, which led to low non-breeding season survival. The ratio of process variance to sampling variance in our analysis indicated weekly survival estimates were robust to variation in sampling effort and the data bootstrapping procedure showed that variance was not heavily influenced by dependency among covey members.

Covey affiliation was mostly static during our study (Janke 2011), which we predicted would result in high dependency among individuals in the same covey (Williams et al. 2003b). However, dependency among individuals was modest, likely because of consistently low survival rates documented across the entire population, driven primarily by severe winter weather. Dependency may be higher in populations subject to less widespread mortality factors (e.g., local variation in habitat quality, hunting pressure). The presence of $\hat{c} > 1.2$ does, however, show that covey-mates in our analysis were not entirely biologically independent as assumed in survival analyses. Thus, model selection in future analyses may consider using the data bootstrapping procedure to estimate $\hat{c}$ (Bishop et al. 2008).

Comparison of temporal variation in survival assumes that any bias associated with radio transmitters is constant within and among seasons. Increased energy demands and diminished food availability during winter may lower body mass (Robel and Linderman 1966, Roseberry and Klimstra 1971) and negatively affect survival of radio-marked birds by increasing the proportional weight of transmitters relative to body mass (Johnson and Berner 1980, Burger et al. 1991). Janke (2011) found that body mass of radio-marked bobwhites in our study did not consistently decline during periods of snow cover, suggesting inferences from radio-marked birds during periods of snow cover are likely not negatively biased relative to other periods within the season or among years. Comparisons among intervals in our study and with previous radiotelemetry studies should still be valid, despite the potential for a systematic bias caused by transmitters (Guthery and Lusk 2004).

Variation in survival among years in our study was consistent with the variable non-breeding season survival estimates reported in an 11-year study in Oklahoma (Cox et al. 2004). Thus, within-season variation in mortality factors can have strong influence on seasonal survival rates and, ultimately, population growth rates. Estimates from the 3 seasons included in our analysis suggest variation in winter severity was the primary factor affecting non-breeding season survival. Winter survival was highest during 2008–2009 when snow accumulation and temperatures were closest to long-term averages, while survival during the severe winter of 2009–2010 was among the lowest estimates reported in the literature (Sandercock et al. 2008). Weekly survival rates declined considerably in association with snow accumulation in the region. The influence of severe winter weather on inter-seasonal population estimates was previously established by Roseberry and Klimstra (1984) and Robel and Kemp (1997) in Illinois and Kansas, respectively. Lohr et al. (2011) used radiotelemetry to estimate survival in a population near the northern portion of the bobwhite's range and reported comparatively high non-breeding season survival during 2 mild winters (Lohr 2009). The co-ocurrence of snow accumulation and low weekly survival rates in our study corroborates the link between winter severity and low non-breeding season survival in northern populations.

Errington and Hamerstrom (1935) reported the 2 primary periods affecting non-breeding season survival of bobwhites in northern populations were coincident with senescence of herbaceous vegetation and crop harvest in early fall and snow accumulation during winter. Winter survival was most variable during periods of snow accumulation in our study, and we documented a similar decline in fall survival during the hunting season and crop harvest. The co-occurrence of crop harvest and hunting season limited our ability to separate influences of each on observed survival. A high proportion of the study sites was in corn and soybeans, which were harvested during mid to late fall; thus, significant changes in distribution of suitable cover occurred over a short period. Bobwhites in agricultural landscapes use crop fields through the summer (M. R. Liberati, unpublished data; Potter et al. 2011) and crop harvest causes a rapid loss of usable habitat (Errington 1934, Guthery 1997). Reduced availability of usable habitat combined with senescence of herbaceous vegetation during this period likely contributed to the observed decrease in survival.

Hunting mortality has been identified as a primary factor affecting non-breeding season survival of bobwhites in Missouri (Burger et al. 1995), Oklahoma (Cox et al. 2004), and Florida (Rolland et al. 2010). Harvest during the short hunting season in our study appeared to influence weekly survival rates, but our estimates of cause-specific mortality for harvest-related mortality were lower than previously reported rates in populations exposed to hunting pressure (Burger et al. 1995, Cox et al. 2004). The collective influence of low fall survival had little influence compared to that exerted by severe winter weather.

MANAGEMENT IMPLICATIONS

Management strategies directed at increasing bobwhite population growth rates in Ohio should focus on increasing low non-breeding season survival because of its disproportional influence on population growth rates (Sandercock et al. 2008, Gates et al. 2012). Non-breeding season habitat management should specifically focus on microhabitats associated with increased survival during periods of snow accumulation (Roseberry 1964). Further research in northern portions of the bobwhite range should investigate the specific influence of winter weather and habitat quality on daily survival rates to identify appropriate management actions to improve survival.

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LITERATURE CITED

Anderson, D. R., and K. P. Burnham. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer, New York, USA.

Bishop, C. J., G. C. White, and P. M. Lukacs. 2008. Evaluating dependence among mule deer siblings in fetal and neonatal survival analyses. Journal of Wildlife Management 72:1085–1093.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

Burger, L. W., M. R. Ryan, D. P. Jones, and A. P. Wywialowski. 1991. Radio transmitters bias estimation of movements and survival. Journal of Wildlife Management 55:693–697.

Burger, L. W., T. V. Dailey, E. W. Kurzejeski, and M. R. Ryan. 1995. Survival and cause-specific mortality of northern bobwhite in Missouri. Journal of Wildlife Management 59:401–410.

Burnham, K. P., D. E. Andersen, G. C. White, C. Brownie, and K. H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. American Fisheries Society Monograph 5:1–437.

Cox, S. A., A. D. Peoples, S. J. DeMaso, J. J. Lusk, and F. S. Guthery. 2004. Survival and cause-specific mortality of northern bobwhites in western Oklahoma. Journal of Wildlife Management 68:663–671.

Einarsen, A. A. 1956. Determination of some predator species by field signs. Oregon State College Monographs, Studies in Zoology 10:5–34.

Errington, P. L. 1934. Vulnerability of bob-white populations to predation. Ecology 15:110–127.

Errington, P. L., and F. N. Hamerstrom. 1935. Bob-white winter survival on experimentally shot and unshot areas. Iowa State College Journal of Science 9:625–639.

Folk, T. H., R. R. Holmes, and J. B. Grand. 2007. Variation in northern bobwhite demography along two temporal scales. Population Ecology 49:211–219.

Gates, R. J., A. K. Janke, M. R. Liberati, and M. W. Wiley. 2012. Demographic analysis of a declining northern bobwhite population in southeastern Ohio. Proceedings of the National Quail Symposium 7: 184–193.

Gould, W. R., and J. D. Nichols. 1998. Estimation of temporal variability of survival in animal populations. Ecology 79:2531–2538.

Guthery, F. S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 61:291–301.

Guthery, F. S., and J. J. Lusk. 2004. Radiotelemetry studies: are we radio-handicapping northern bobwhites? Wildlife Society Bulletin 32:194–201.

Guthery, F. S., M. J. Peterson, and R. R. George. 2000. Viability of northern bobwhite populations. Journal of Wildlife Management 64:646–662.

Heisey, D. M., and B. R. Patterson. 2006. A review of methods to estimate cause-specific mortality in presence of competing risks. Journal of Wildlife Management 70:1544–1555.

Holt, R. D., L. W. Burger, S. J. Dinsmore, M. D. Smith, S. J. Szukaitis, and K. D. Godwin. 2009. Estimating duration of short-term acute effects of capture, handling, and radiomarking. Journal of Wildlife Management 73:989–995.

Homer, C., C. Huang, C. Yang, B. Wylie, and M. Coan. 2004. Development of a 2001 National Land-Cover Database for the United States. Photogrammetric Engineering and Remote Sensing 70:829–840.

Janke, A. K. 2011. Survival and habitat use of non-breeding northern bobwhites on private lands in Ohio. Thesis. Ohio State University, Columbus, USA.

Johnson, R. N., and A. H. Berner. 1980. Effects of radio transmitters on released cock pheasants. Journal of Wildlife Management 44:686–689.

Link, W. A., J. R. Sauer, and D. K. Niven. 2008. Combining Breeding Bird Survey and Christmas Bird Count data to evaluate seasonal components of population change in northern bobwhite. Journal of Wildlife Management 72:44–51.

Lohr, M. T. 2009. Northern bobwhite winter ecology in southern New Jersey. Thesis. University of Delaware, Newark, USA.

Lohr, M. T., B. M. Collins, C. K. Williams, and P. M. Castelli. 2011. Life on the edge: northern bobwhite ecology at the northern periphery of their range. Journal of Wildlife Management 75:52–60.

Meats, A. 1971. Relative importance to population increase of fluctuations in mortality, fecundity and time variables of reproductive schedule. Oecologia 6:223–237.

Moynahan, B. J., M. S. Lindberg, and J. W. Thomas. 2006. Factors contributing to process variance in annual survival of female greater sage-grouse in Montana. Ecological Applications 16:1529–1538.

Murray, D. L. 2006. On improving telemetry-based survival estimation. Journal of Wildlife Management 70:1530–1543.

National Climate Data Center (NCDC). 2011. Quality controlled local climatological data. U.S. Department of Commerce, Asheville, North Carolina, USA. www.ncdc.noaa.gov/oa/ncdc.html

Ohio Division of Geologic Survey. 1998. Physiographic regions of Ohio. Ohio Department of Natural Resources, Columbus, USA.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989a. Survival analysis in telemetry studies-the staggered entry design. Journal of Wildlife Management 53:7–15.

Pollock, K. H., C. T. Moore, W. R. Davidson, F. E. Kellogg, and G. L. Doster. 1989b. Survival rates of bobwhite quail based on band recovery analyses. Journal of Wildlife Management 53:1–6.

Potter, L. M., D. L. Otis, and T. R. Bogenschutz. 2011. Nest success of northern bobwhite on managed and unmanaged landscapes in southeast Iowa. Journal of Wildlife Management 75:46–51.

Robel, R. J., and K. E. Kemp. 1997. Winter mortality of northern bobwhites: effects of food plots and weather. Southwestern Naturalist 42:59–67.

Robel, R. J., and S. A. Linderman. 1966. Weight dynamics of unconfined bobwhite quail in Kansas. Transactions of the Kansas Academy of Science 69:132–138.

Rolland, V., J. A. Hostetler, T. C. Hines, H. F. Percival, and M. K. Oli. 2010. Impact of harvest on survival of a heavily hunted game bird population. Wildlife Research 37:392–400.

Roseberry, J. L. 1964. Some responses of bobwhites to snow cover in southern Illinois. Journal of Wildlife Management 28:244–249.

Roseberry, J. L., and W. D. Klimstra. 1971. Annual weight cycles in male and female bobwhite quail. Auk 88:116–123.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, USA.

Rosene Jr., W. 1969. The bobwhite quail: its life and management. The Sun Press, Hartwell, Georgia, USA.

Sandercock, B. K., W. E. Jensen, C. K. Williams, and R. D. Applegate. 2008. Demographic sensitivity of population change in northern bobwhite. Journal of Wildlife Management 72:970–982.

Sargeant, G. A. 2011. wild1-R: tools for wildlife research and management. USGS, Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA. cran.r-project.org/web/packages/wild1

Schmutz, J. A., D. H. Ward, J. S. Sedinger, and E. A. Rexstad. 1995. Survival estimation and the effects of dependency among animals. Journal of Applied Statistics 22:673–681.

Spinola, R. M., and R. J. Gates. 2008. Population status and trends of northern bobwhite (*Colinus virginianus*) in Ohio: 1984–2004. Ohio Journal of Science 108:26–30.

Stahl, J. T., and M. K. Oli. 2006. Relative importance of avian life-history variables to population growth rate. Ecological Modelling 198:23–39.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner's Sons, New York, USA.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 (Supplement): S120–S139.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press Inc., San Diego, California, USA.

White, G. C., K. P. Burnham, and D. R. Anderson. 2001. Advanced features of Program Mark. Pages 368–377 *in* R. Field, R. J. Warren, H. Okarma, and P. R. Sievert, eds. Wildlife, land, and people: priorties for the 21st century. Proceedings of the Second International Wildlife Management Congress. The Wildlife Society, Bethesda, Maryland, USA.

Wiley, M. J., A. K. Janke, and R. J. Gates. 2012. Efficacy of targeted mist-netting to capture northern bobwhites during the non-breeding season in Ohio. Proceedings of the National Quail Symposium 7:235–240.

Williams, C. K., A. R. Ives, and R. D. Applegate. 2003a. Population dynamics across geographical ranges: time-series analyses of three small game species. Ecology 84:2654–2667.

Williams, C. K., R. S. Lutz, and R. D. Applegate. 2003b. Optimal group size and northern bobwhite coveys. Animal Behaviour 66:377–387.

Williams, C. K., R. S. Lutz, and R. D. Applegate. 2004a. Winter survival and additive harvest in northern bobwhite coveys in Kansas. Journal of Wildlife Management 68:94–100.

Williams, C. K., F. S. Guthery, R. D. Applegate, and M. J. Peterson. 2004b. The northern bobwhite decline: scaling our management for the twenty-first century. Wildlife Society Bulletin 32:861–869.

Yoho, N. S., and R. W. Dimmick. 1972. Changes in covey affiliation by bobwhite quail in Tennessee. Proceedings of the National Quail Symposium 1:28–32.

SPRING DISPERSAL OF NORTHERN BOBWHITES IN SOUTHWESTERN OHIO

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ABSTRACT

Northern bobwhites (*Colinus virginianus*) historically occurred throughout Ohio but their core range has contracted to 18 southwestern counties. The Ohio Division of Wildlife has used trapping and transplanting to reintroduce wild bobwhites to unoccupied habitats within the species' historic range. Bobwhite dispersal information is necessary to understand population dynamics and the species' capacity to recolonize unoccupied habitats. Bobwhites were captured and radiomarked on 4 private-land study sites in southwestern Ohio. Radio-marked bobwhites ($n = 66$) were tracked by homing or triangulation during spring 2010 and 2011 to ascertain dispersal distances between winter and breeding ranges. The spring dispersal period was defined by break-up of coveys and subsequent occupation of breeding season home ranges. The dispersal period, defined by non-affiliation with coveys, long directional daily movements, and observed breeding activity, varied among individuals and ranged from 2 April to 26 May. Dispersal distances were measured as the net Euclidean distance between locations recorded at the beginning and end of the dispersal period. Dispersers were defined as birds that moved $> 2\times$ the diameter of the mean home-range size (26.1 ha) observed during October-March 2010 and 2011. Movements of 1–2 home-range diameters were classified as home range shifts. Non-dispersing bobwhites traveled < 1 home-range diameter. Mean movement for all birds was 1.54 km. Twenty-eight (42.4%) radio-marked bobwhites were non-dispersers, 15 (22.7%) shifted home ranges, and 23 (34.8%) dispersed. Non-dispersers moved a mean of 0.31 km (range = 0.03–0.56 km), home range shifts averaged 0.78 km (range = 0.60–0.99 km), and dispersers traveled a mean distance of 3.6 km (range = 1.18–11.5 km). Dispersal distance was lowest for adult females and increased in order for adult males, juvenile females, and juvenile males. Dispersal distance decreased as the proportion of early successional wooded habitat within winter home ranges increased. Sex, age, and dispersal distance did not affect survival. Our results suggest Ohio bobwhites are capable of expanding their range into historically-populated areas.

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Key words: Northern bobwhite, *Colinus virginianus*, dispersal, early successional habitat, home range shift, Ohio

INTRODUCTION

Habitat loss has been the primary cause of declining northern bobwhite populations range-wide (Klimstra 1982, Brennan 1991, Guthery et al. 2000, Williams et al. 2004, Veech 2006). Bobwhite habitat in Ohio has been lost to increasing agricultural development and land-use changes that leave residual usable habitats in a fragmented matrix. Habitat losses are compounded by severe winters experienced by populations on the northern fringe of the bobwhite range. The bobwhite range in Ohio contracted concurrent with a state population decline of 76% between 1984 and 2004 (Spinola and Gates 2008). Formerly distributed state-wide, the current geographic core range is now confined to southwestern Ohio (Spinola and Gates 2008, Ohio Breeding Bird Atlas 2012). There is some evidence that bobwhites are patchily distributed even in the core of the species range in southwestern Ohio (Gates et al. 2012).

Avian dispersal provides important ecological and evolutionary benefits such as outbreeding and gene flow (Howard 1960, Greenwood and Harvey 1982, Walters 2000). The ability to colonize vacant habitats and establish new populations may be the most important aspect of this behavior for bobwhites. Dispersal rescue (Townsend et al. 2003) can supplement declining populations or re-establish bobwhite populations in historically-occupied areas (Martin et al. 2000). Dispersal has been viewed as costly for avian species (Bélichon et al. 1996) because individuals are thought to have increased risk of mortality after moving into novel areas (Yoder et al. 2004). Dispersing individuals also risk missed breeding opportunities by moving into areas without conspecifics or by expending time and energy to search for mates and nest sites (Danchin and Cam 2002).

Bobwhites have traditionally been considered a sedentary species because of limited mobility. They are primarily terrestrial and their movements are mostly on foot rather than in flight (Kassinis and Guthery 1996, Guthery 2000). Bobwhites may be particularly susceptible to risks associated with dispersal behavior

The Ohio Division of Wildlife has trapped and transplanted wild bobwhites into historically-occupied areas that contain suitable habitat but lack habitat connectivity with extant populations. The ability of

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Table 1. Physical and land-cover characteristics of 4 study sites in southwestern Ohio on which northern bobwhites were captured and radiomarked prior to and during the breeding seasons of 2010 and 2011.

	Fee	Peach	Wildcat	Thurner
Area (ha)	1,284.4	397.7	838.3	738.8
Mean slope (%)	5.0	9.7	5.1	4.5
Mean covey density (coveys/km^2)	0.59	0.45	1.47	0.7
Mean row crop field size (ha)	12.6	7.6	7.6	10.0
CRP (ha)	123.6	75.2	137.4	25.7
CRP composition (%)[a]				
Cool season grasses	86.9	98.0	88.8	86.5
Warm season grasses	13.1	2.0	11.2	13.5
Landscape composition (%)[b]				
Row crop	61.6	17.6	34.9	31.8
Developed	6.4	4.1	5.2	6.3
Forest	20.7	50.0	32.0	28.1
Grassland/Shrub	0.6	6.8	5.7	6.2
Pasture/Hay	10.4	21.4	21.9	27.1
Other	0.3	0.1	0.2	0.6
Site composition (%)[c]				
ES Herbaceous[d]	12.5	21.5	19.6	12.2
ES Woody[d]	3.4	7.2	3.2	4.9
Forest	8.1	27.8	10.0	14.6
Non habitat	4.0	4.7	3.9	9.3
Pasture/Hay	2.6	2.3	23.6	6.7
Row crop	69.5	36.4	39.8	52.3

[a] Proportion of area of all CRP fields in respective categories.

[b] Proportion NLCD habitat cover within 10-km buffer around the centroid of study site.

[c] Proportion of the maximum extent of the site boundaries from 2 non-breeding seasons (Oct-Mar 2009–2011) in each habitat type.

[d] ES = early successional.

bobwhites to travel and disperse in fragmented agricultural landscapes is unclear and previous studies are not necessarily applicable to Ohio. Opportunistic and anecdotal observations of marked birds provide conservative estimates of dispersal distances and do not effectively capture long-distance movements (Stoddard 1931, Lehmann 1946, Murphy and Baskett 1952, Lewis 1954, Smith et al. 1982). Dispersal studies that use radiotelemetry have been conducted either in areas managed exclusively for bobwhites (Liu et al. 2002; Terhune et al. 2006, 2010) or in ecosystems that differ from the agricultural landscape of Ohio (Liu et al. 2002, Townsend et al. 2003, Cook et al. 2006, Terhune et al. 2006). Application of dispersal information from landscapes dominated by rangelands (Townsend et al. 2003), pine (*Pinus* spp.) plantations (Cook et al. 2006; Terhune et al. 2006, 2010), or forested habitats (Fies et al. 2002, Liu et al. 2002) to fragmented Ohio landscapes dominated by row crops is tenuous at best. In addition, areas managed specifically for bobwhites may not require birds to travel as far to find suitable breeding habitat or mates and may not accurately reflect the cost of dispersal in less hospitable or unmanaged landscapes.

Dispersal is essential to recolonizing historically-occupied areas in Ohio that are now fragmented and isolated. Radiotelemetry was used to study spring dispersal of bobwhites on 4 private-land study sites in southwestern Ohio. Dispersal distances, survival during dispersal, and habitat influences on dispersal distances were evaluated during spring 2010 and 2011. Our objectives were to: (1) ascertain the proportion of dispersing individuals in the population; (2) compare spring dispersal distances among age-sex classes, study sites, and years; (3) examine the effect of dispersal distance on survival of dispersing birds; and (4) investigate the influence of winter home-range composition on spring dispersal distance.

STUDY AREA

This study was conducted on 4 study sites in southwestern Ohio in the current geographic core of the bobwhite range (Spinola and Gates 2008). Sites were in Highland and Brown counties (39° 04′ 59” N, 83° 39′ 10” W) within the Till Plains and Illinois Till Plains regions of Ohio (Ohio Division of Geologic Survey 1998) and the Eastern Tall Grass Prairie Bird Conservation Region of the National Bobwhite Conservation Initiative (NBTC 2011). The region was mostly rural (6% developed; Homer et al. 2004) and agriculture was the primary land use (39% row crops, 17% pasture/hay) with interspersed grassland (3%) and forest (33%). The gently undulating topography resulting from glaciation in these counties was not as favorable for modern, large-scale agricultural production and cropping; land-use limitations along the glacial boundary benefited bobwhite populations where it occurred (e.g., small field sizes).

The 4 study sites (Fee, Peach, Wildcat, and Thurner) represented a gradient from agriculture- to forest-dominated landscapes (Table 1). Land-use at each study site was evaluated using National Land Cover Data (NLCD) within a 10-km buffer around the site centroids. Nesting habitat was considered to be any early successional herbaceous habitat (i.e., grassland/shrub, pasture/hay). The Fee site had the highest proportion of row crops and the lowest proportions of nesting habitat (11.0%) and forests. Wildcat and Thurner were intermediate along the agricultural-forest gradient and had 27.6 and 33.3% nesting habitat, respectively. Peach was the most forested site due to its location on the glacial boundary and also had the lowest proportion of row crops and the second lowest proportion of nesting habitat (28.2%). High proportions of row crops (range = 38.5–72.1%) and large field sizes (range = 7.6–12.6 ha) were considered indicators of reduced habitat connectivity at study sites; these areas were considered fragmented.

Row crop fields were predominantly in no-till soybeans, corn, and winter wheat. Forest composition varied with topography. Dry upland ridges supported communities dominated by shagbark (*Carya ovata*) and pignut hickory (*C. glabra*), and white (*Quercus alba*) and red oak (*Q. rubra*). Lower elevations and depressional areas were dominated by black walnut (*Juglans nigra*), green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), and occasionally pin oak (*Quercus palustris*). Early successional land cover types in our study sites included fields enrolled in the Conservation Reserve Program (CRP), idle fields, fencerows, agricultural drainage ditches, and roadsides. Early successional grass fields were dominated by cool season grasses such as fescue (*Festuca* spp.) and forbs such as goldenrod (*Solidago* spp.) and Queen Anne's lace (*Daucus carota*). Small proportions of the study sites were in warm-season grass CRP fields, primarily planted with Indiangrass (*Sorghastrum nutans*), big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), and partridge pea (*Chamaecrista fasciculata*). Early successional woody habitats included fencerows, ditches (< 50 m in width), and patches of advanced successional growth. Early successional vegetation included woody species such as blackberry (*Rubus allegheniensis*), black raspberry (*R. occidentalis*), trumpet creeper (*Campsis radicans*), poison ivy (*Toxicodendron radicans*), and Japanese honeysuckle (*Lonicera japonica*).

The long-term mean temperature for this region was 11.1 °C and the mean monthly temperature during the study period (Apr-Sep 2010–2011) was 20.2 °C (range 12.2–26.6 °C; NCDC 2011). The long-term mean annual precipitation was 1,102 mm and the mean monthly precipitation during the study period was 277 mm (range = 64–1,775 mm; NCDC 2011). The mean departure from normal during the study period was 97 mm (range = –64–528 mm; NCDC 2011). The 2010 breeding season began with the fourth driest April in Ohio history followed by the third wettest May and slightly below average rainfall through September (NCDC 2011). This area also experienced unprecedented rainfall in spring 2011 with amounts in April that were 285% of normal and the highest since 1882 (NCDC 2011).

METHODS

Data Collection

Bobwhites were continually captured and outfitted with radio transmitters during fall 2009 through summer 2011. Individuals were captured using baited funnel traps and targeted mist-netting (Wiley et al. 2012). Captured individuals were weighed, classified to age and sex (Rosene 1969), and banded with uniquely-numbered aluminum leg bands (size 3 or 3B) that included a phone number for band recoveries. Most individuals were also fitted with an Advanced Telemetry Systems (ATS, Isanti, MN, USA) radio transmitter with an 8-hr mortality sensor. Individuals were radiomarked during the 2010 field season with bib-mounted or necklace-style transmitters; zip-tie style necklace transmitters were used on individuals captured or recaptured after 1 September 2010. The switch to zip-tie attached transmitters significantly improved retention of radio transmitters during the 2011 breeding season and seemed to be the best compromise between transmitter weight and attachment durability. Radio transmitters (6.6 g) were placed only on individuals weighing > 150 g. All trapping, handling, and marking procedures were consistent with guidelines approved by the Ohio State University Institutional Animal Care and Use Committee (# 2007A0228).

Individuals were tracked daily throughout spring dispersal (Apr-May) by homing to within 15–20 m with ATS or Telonics (Mesa, AZ, USA) receivers and a hand-held 3-element yagi antenna. A truck-mounted, null-peak system was used for triangulations when property access was restricted or to avoid disturbing spring wild turkey (*Meleagris gallopavo*) hunters. Global Positioning System (GPS) coordinates were recorded with handheld GPS units (Garmin, Olathe, KS, USA) in the field and later loaded into ArcMap 9.3 (ESRI, Redlands, CA, USA).

The dispersal period was defined by non-affiliation with coveys, long directional daily movements, and observed breeding activity. It concluded with earliest nest initiation dates and a cutoff date of 10 May was used for individuals whose dispersal termination was uncertain. Individuals were assumed to have initiated breeding activity, unless movement patterns or nesting indicated otherwise, even if a nest for that individual had not yet been found. Individuals that died after 1 April while still associated with their winter covey were excluded from analyses. Individuals captured after 1 April while not associated with a covey were excluded from distance analyses because they may have already dispersed. Individuals that lost their transmitters, died during dispersal, or with which radio contact was lost were excluded from distance analysis because they did not have equal opportunity to complete movement during the period. We searched for radio-marked individuals in the area surrounding their last known location for at least 2 hrs with a truck-mounted, whip-antenna and periodic scans with a truck-mounted, null-peak system when radio contact was lost. Attempts to relocate individuals were discontinued after failing to find birds for 3 consecutive days. Missing individuals could have been lost due to transmitter failure or because they dispersed outside our search area. Radio contact was most likely lost due to transmitter failure rather than an inability to relocate dispersing individuals.

Analyses

Locate III was used to calculate location points from triangulations (Nams 2006). Telemetry locations were analyzed using Hawthe's Tools in ArcMap 9.3 (Beyer et al. 2010). Dispersal distances were measured by the net Euclidean distance moved between start and end dates of dispersal. A modified method for classifying dispersal behavior was used as described by Townsend et al. (2003) and used in other bobwhite dispersal studies (Fies et al. 2002). Dispersers were defined as birds that moved > 2x the diameter of their mean home-range size. Non-dispersing bobwhites traveled < 1 home-range diameter and intermediate movements (> 1 to < 2 home-range diameters) were classified as a home range shift. The Townsend et al. (2003) method uses a somewhat arbitrary winter home-range diameter of 1 km. Spring dispersal was classified by comparing dispersal movements to a population-specific mean home range for radio-marked

Table 2. First phase of spring dispersal analysis and ranked models evaluating the influence of design variables on dispersal distances of radio-marked northern bobwhite at 4 study sites in southwestern Ohio during 2010–2011.

Model [a]	k [b]	AIC [c]	AIC_c [d]	ΔAIC_c [d]	w_i [e]
SEX + AGE	4	192.10	192.79	0.00	0.20
AGE	3	192.45	192.85	0.07	0.19
Null	2	193.37	193.57	0.78	0.13
SEX * AGE	5	192.85	193.90	1.12	0.11
SEX	3	193.76	194.17	1.38	0.10
YEAR + AGE	4	194.19	194.88	2.10	0.07
YEAR + SEX + AGE	5	194.06	195.11	2.32	0.06
YEAR	3	194.72	195.13	2.34	0.06
YEAR + SEX	4	195.33	196.02	3.23	0.04
YEAR + SEX * AGE	6	194.73	196.23	3.44	0.04
YEAR * SEX * AGE	9	197.30	200.70	7.91	0.00

[a] HRESW = average proportion of early successional woody vegetation in covey home ranges.
[b] Number of parameters included in models. All models included an intercept and a random effect of covey affiliation.
[c] AIC = Akaike Information Criterion.
[d] AIC_c = Akaike Information Criterion adjusted for small sample sizes.
[e] w_i = Akaike weight.

coveys at the study sites during October-March 2010 and 2011 (26.1 ha, 0.58-km diameter; Janke and Gates 2013).

There were 104 radio-marked bobwhites during the 2010 and 2011 breeding seasons. Six bobwhites were not included in any analyses because they were associated with coveys after death or last known location. Twenty-four individuals were excluded from dispersal analyses because they were either marked after covey break-up, died during the dispersal period, or were not relocated during the dispersal period. Dates of covey break-up and dispersal distances were compared between years with analysis of variance and linear regression using program R (R Development Core Team 2012). Influences of sex, age, and dispersal distances of individuals on survival during spring dispersal were evaluated with known-fates analysis in Program MARK (White and Garrott 1999).

Sixty-three individuals used in our analyses were members of 29 individual coveys. Linear mixed models with covey as a random effect were used to first examine effects of year, age, and sex (with 2-way interactions) on dispersal distance. The distribution of dispersal distances was heavily right-skewed so the dependent variable was $\log_n$-transformed before analysis. Estimated means and confidence intervals were back-transformed (antilog) for graphical presentation of results. Information theoretic methods (Burnham and Anderson 2002) were used to evaluate 11 null and candidate models that included combinations of these covariates (Table 2). Covariates from the top-ranked model in the first step were added to evaluate a second set of 16 candidate models that included the null model, and combinations and interactions of habitat covariates including study site and proportional composition of early successional woody and grass habitats within covey home ranges before the dispersal period (Table 3). All models were specified *a priori* and included a constant intercept term and the random effects variable (covey). Effects (singly and in combination) of sex, age, year, study site, early successional woody and grassland habitat composition of covey home ranges were tested on dispersal distance with a minimum number of

Table 3. Final candidate model set for spring dispersal analysis and ranked models evaluating the influence of habitat and design variables on dispersal distances of radio-marked northern bobwhite at 4 study sites in southwestern Ohio during 2010–2011.

Model [a]	k [b]	AIC [c]	AIC_c [d]	ΔAIC_c [d]	w_i [e]
SEX + AGE	4	192.10	192.79	0.00	0.24
Null	2	193.37	193.57	0.78	0.16
HRESW + SITE	6	192.44	193.94	1.16	0.13
SITE	5	192.90	193.95	1.17	0.13
HRESW	3	193.93	194.34	1.55	0.11
SITE + SEX + AGE	7	192.81	194.84	2.06	0.09
HRESW + SEX + AGE	5	193.80	194.86	2.07	0.08
HRESW + SITE + SEX + AGE	8	193.55	196.21	3.43	0.04
HRGRASS + SEX + AGE	5	201.39	202.45	9.66	0.00
HRGRASS + HRESW + SITE	7	201.03	203.06	10.28	0.00
HRGRASS	3	202.74	203.14	10.36	0.00
HRGRASS + SITE	6	202.25	203.75	10.96	0.00
HRGRASS + HRESW	4	203.17	203.86	11.07	0.00
HRGRASS + HRESW + SEX + AGE	6	202.64	204.14	11.35	0.00
HRGRASS + HRESW + SITE + SEX + AGE	9	201.28	204.68	11.89	0.00
HRGRASS + SITE + SEX + AGE	8	202.10	204.77	11.98	0.00

[a] HRESW = average proportion of early successional woody vegetation in covey home ranges; HRGRASS = average proportion of early successional herbaceous vegetation in covey home ranges.
[b] Number of parameters included in models. All models included an intercept and a random effect of covey affiliation.
[c] AIC = Akaike Information Criterion.
[d] AIC_c = Akaike Information Criterion adjusted for small sample sizes.
[e] w_i = Akaike weight.

Table 4. Dispersal classifications and mean movements for radio-marked northern bobwhites in southwestern Ohio during spring 2010 and 2011. Dispersal classifications were based on the average covey home-range size for the preceding winters (26.1 ha, 0.58 km diameter; Janke and Gates 2013).

	Total		Non-disperser		Range shift		Disperser	
Year	*n*	Distance [a]	*n* (%)	Distance [a]	*n* (%)	Distance [a]	*n* (%)	Distance [a]
2010	34	1.98 ± 1.00	14 (41.2)	0.30 ± 0.06	6 (17.6)	0.88 ± 0.07	14 (41.2)	4.13 ± 1.00
2011	32	1.09 ± 0.52	14 (43.8)	0.32 ± 0.08	9 (28.1)	0.71 ± 0.05	9 (28.1)	2.66 ± 0.52
Pooled	66	1.55 ± 0.58	28 (42.4)	0.31 ± 0.06	15 (22.7)	0.78 ± 0.06	23 (34.8)	3.65 ± 1.30

[a] Mean distance ± 95% confidence interval (km).

candidate models. It was hypothesized that early successional woody habitat would facilitate (i.e., increase) dispersal while higher proportions of early successional herbaceous habitats would inhibit movements by providing nesting habitat near where birds wintered.

The package *lme4* in Program R (R Development Core Team 2012) was used to fit candidate models. Support for each model was compared based on Akaike Information Criterion adjusted for small sample sizes (AIC_c; Burnham and Anderson 2002). Models with $\Delta AIC_c \leq 2.0$ were considered to have equivalent support (Burnham and Anderson 2002). The difference between AIC_c from the best model and all other models (ΔAIC_c) and Akaike weights (w_i) was used to identify the relative support for each candidate model.

RESULTS

Results are based on 66 bobwhites (females = 30, males = 36) in 29 coveys during the 2010 and 2011 breeding seasons. Observed dispersal periods for individual birds ranged from 4 April to 26 May and lasted a mean of 21.0 ± 1.94 days (range = 7-35 days) for the sample population. There were no differences between years for date of covey break-up ($F = 0.23$, $P = 0.634$) or length of the dispersal period ($F = 2.435$, $P = 0.124$), and radio-marked individuals were pooled across years for survival analyses. There was no evidence of differences in survival associated with dispersal distance. Survival models for age, sex, age*sex, and dispersal distance all ranked lower than the null model and had $\Delta AIC_c > 2$.

The mean dispersal distance for all individuals was 1.55 km (Table 4). We classified 28 (42.4%) individuals as non-dispersers, 15 (22.7%) as having a range shift, and 23 (34.8%) as dispersers. Non-dispersers averaged net movements of 0.31 km, range shifts averaged 0.78 km, and dispersal distances averaged 3.56 km.

The 2 highest-ranked candidate models for design variables were within 2 ΔAIC_c units of the null model (Table 2), offering no statistical support for differences in dispersal among age, sex, classes, or years. However, mean values differed substantially among age-sex classes (Fig. 1) and the regression coefficients were significant for age ($P = 0.038$) and not significant ($P = 0.073$) for sex. Adult females dispersed the shortest mean distance, followed in increasing order by adult males, juvenile females, and juvenile males (Table 5, Fig. 1).

Top candidates were within 2 ΔAIC_c units of the null model (Table 3) but did contain significant variable coefficients. The highest ranked model included covariates for sex and age and was the only one to rank above the null. The third ranked model contained variables for study site and the proportion of early successional woody habitat in covey home ranges (HRESW). The coefficient for HRESW was highly significant ($P = 0.006$) and indicated dispersal distance declined with increasing amounts of early successional woody habitat in covey home ranges (Figs. 2, 3). Mean dispersal distance was greater on the Peach site ($P = 0.073$) and did not differ among the other 3 sites (Fig. 4). The Thurner site had the lowest proportion of dispersing individuals (27.3%; Table 6) and the lowest mean dispersal distances (0.58 km; Fig. 4). The Thurner and Wildcat sites had intermediate values but were more similar to the Peach site which had the highest proportion of dispersing individuals (44.4%) and the highest mean dispersal distances (2.84 km). Proportion of grass within covey home ranges had no relationship to dispersal distance ($P > 0.91$; Table 3).

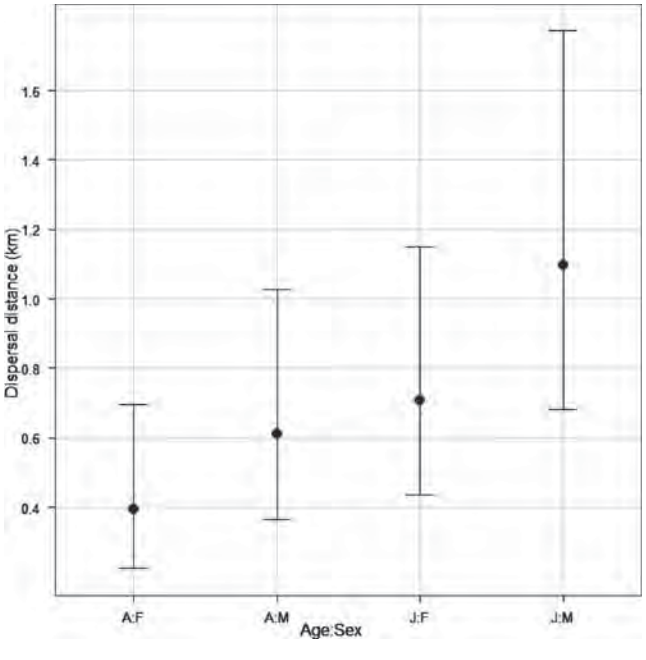

Fig. 1. Mean spring dispersal distances with 95% confidence intervals for radio-marked bobwhites in southwestern Ohio during 2010 and 2011 based on age (A = adult, J = juvenile) and sex (F = female, M = male).

Table 5. Mean dispersal distances ± 95% confidence intervals (km) and dispersal classification percentages for radio-marked northern bobwhites in southwestern Ohio during spring 2010 and 2011.

		Dispersal classification (%) [a]			Distance (km)	
	n	ND	RS	D	Mean	Range
Female						
Juvenile	21	23.8	38.1	38.1	1.82 ± 1.17	0.03–11.49
Adult	9	100.0	0.0	0.0	0.29 ± 0.09	0.07–0.42
Pooled	30	46.7	26.7	26.7	1.36 ± 0.85	0.03–11.49
Male						
Juvenile	20	25.0	30.0	45.0	2.21 ± 1.29	0.06–11.09
Adult	16	56.3	6.3	37.5	1.08 ± 0.72	0.18–6.13
Pooled	36	38.9	19.4	41.7	1.71 ± 0.80	0.06–11.09
Pooled						
Juvenile	41	24.4	34.1	41.5	2.01 ± 0.86	0.03–11.49
Adult	25	52.0	4.0	44.0	0.79 ± 0.48	0.07–6.13
Pooled	66	34.8	22.7	42.4	1.55 ± 0.58	0.03–11.49

[a] ND = non-dispersal; RS = range shift; D = dispersal.

The longest spring dispersal distance documented was for a radio-marked bobwhite during this study. One juvenile male made an initial spring dispersal movement of 3.80 km that ended on 10 May 2010 after which he was observed to be paired with a female. He then made a second movement of 13.87 km, an apparent second breeding season dispersal during 19–24 May 2010 after which he settled and was heard whistling. This bird traveled a net distance of 18.9 km from initial spring location before his transmitter failed on 7 June 2010.

DISCUSSION

Dispersal can rescue declining populations or re-establish them after extinction events (Howard 1960) but dispersing individuals must often traverse unfamiliar areas where their survival is at risk (Bélichon et al. 1996). Dispersal may be particularly important for states like Ohio that are on the northern periphery of the bobwhite range where populations are in decline and extirpation of local populations is common (Williams et al. 2003). Early bobwhite research reported individuals

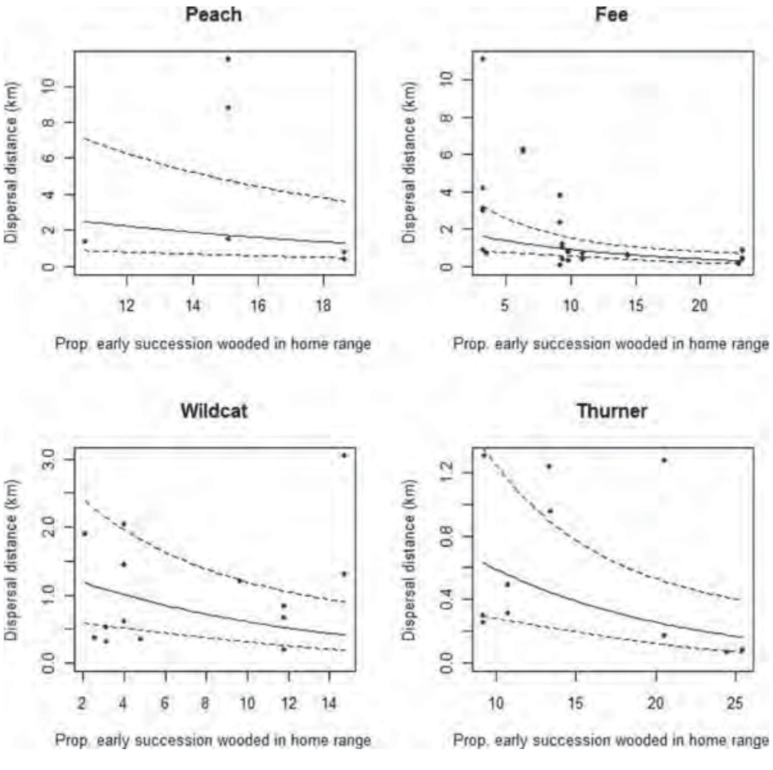

Fig. 2. Spring dispersal distances with 95% confidence intervals versus the proportion of early successional woody habitat in winter home ranges by study site for radio-marked bobwhites in southwestern Ohio during 2009–2011.

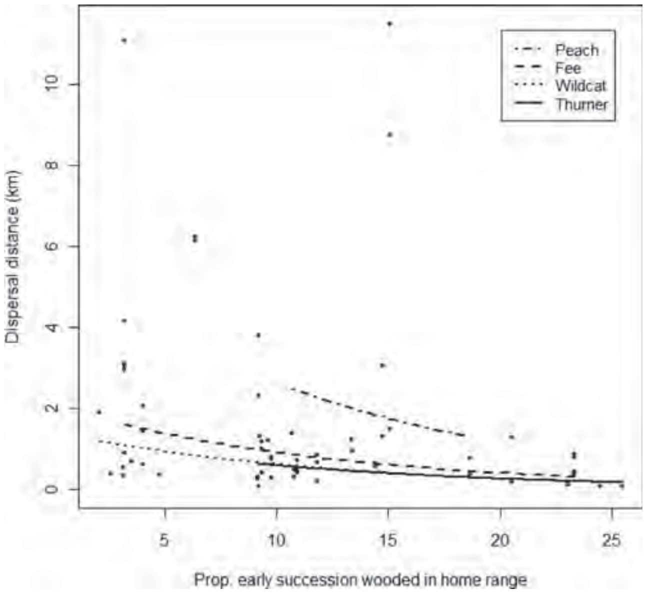

Fig. 3. Spring dispersal distances versus the proportion of early successional woody habitat in winter home ranges by study site for radio-marked bobwhites in southwestern Ohio during 2009–2011.

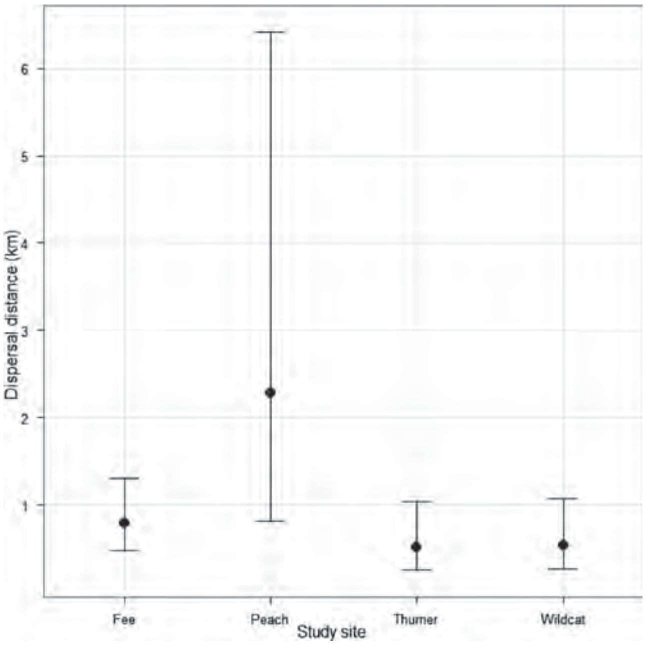

Fig. 4. Mean spring dispersal distances with 95% confidence intervals by study site for radio-marked bobwhites in southwestern Ohio during 2009–2011.

were relatively sedentary (Lehmann 1946, Murphy and Baskett 1952, Lewis 1954). These studies generally used capture-mark-recapture methods that were limited by study site boundaries, low recovery of marked individuals, and anecdotal or opportunistic reporting of longer dispersal movements. Studies that use radiotelemetry provide more complete evaluations of spring movements and dispersal (White and Garrott 1999).

Our results provide additional evidence that bobwhites are highly mobile and regularly travel long distances during spring (Fies et al. 2002, Townsend et al. 2003, Cook et al. 2006). Radio-marked individuals traveled farther between nonbreeding and breeding season ranges compared to those in other bobwhite populations (Fies et al. 2002, Townsend et al. 2003, Cook et al. 2006).

Proportions of individuals classified as range shifts and dispersers during our study (Table 4) were comparable to other bobwhite populations (Fies et al. 2002, Townsend et al. 2003, Cook et al. 2006). Our criteria were based on winter home range diameters observed in our population (Janke and Gates 2013); only Cook et al. (2006) used a biologically-based dispersal criterion. Only 19% (not 35%) of individuals in our study population would have been classified as dispersers if we used the 1-km cutoff proposed by Townsend et al. (2003). Individuals in our study classified as dispersers after Townsend et al. (2003) dispersed further on average (5.23 km) than those in other bobwhite populations. Bobwhite breeding habitats on our study areas were often separated from winter ranges by croplands or other areas devoid of suitable nesting habitat. Thus, it may have been necessary for individuals in our study to move long distances to find mates or suitable nesting habitat (Fies et al. 2002).

Studies have found that both translocated and resident bobwhites had strong site fidelity and small dispersal movements in areas receiving active bobwhite management (Liu et al. 2002; Terhune et al. 2006, 2010). The dispersal proportions and distances during these studies (Liu et al. 2002; Terhune et al. 2006, 2010) are considerably lower than those from other bobwhite dispersal studies (Fies et al. 2002, Townsend et al. 2003, Cook et al. 2006, this paper). Translocation management targets areas that cannot be reached by natural dispersal, have low population densities, and typically occur in areas with managed habitat. Habitat management seems to have dramatic influences on dispersal behavior and underscores the importance of evaluating bobwhite populations in the array of landscapes found in its range, especially those that receive limited management.

Average distances and proportions of range shifts and dispersals (Table 4) may have been higher except for above average spring rainfall during our study, especially during 2011 (NCDC 2011). High rainfall and flooding during spring can negatively affect bobwhite survival (Applegate et al. 2002) or delay covey break-up diminishing length of the dispersal period (Roseberry and Klimstra 1984). April 2011 had the highest amount of precipitation in the past 129 years and May 2011 was the sixth wettest in Ohio history. The study areas received rainfall amounts that were 285% of normal in April 2011 and 147% of normal in May 2011. There was no evidence of differences between years for date of covey break-up or dispersal distances, but the comparison may be constrained by high rainfall during May 2010 which may have limited dispersal.

Table 6. Dispersal classification percentages and average distances for radio-marked northern bobwhite based on study sites in southwestern Ohio during spring 2010 and 2011.

Study site	*n*	Percent at study site Non-disperser	Range shift	Disperser
Fee	32	40.6	28.1	31.3
Thurner	11	63.6	9.1	27.3
Peach	9	33.3	22.2	44.4
Wildcat	14	35.7	21.4	42.9

Age and sex of dispersing individuals were the best predictors of spring dispersal distances for bobwhite in Ohio; this was the only model to rank above the null (Table 3). Juveniles and males in our study traveled furthest during spring dispersal (Fig. 1). Juvenile-biased dispersal is common for avian species and is an adaptation to avoid inbreeding with related individuals (Howard 1960). The juvenile-biased dispersal during our study supports results from other bobwhite dispersal studies (Urban 1972, Smith et al. 1982, Fies et al. 2002, Townsend et al. 2003). Density-dependence within breeding habitats may also bias juvenile dispersal, particularly if dominant adults keep them from preferred breeding areas (Murphy and Baskett 1952, Howard 1960). Female-biased dispersal is the pattern displayed by most avian species but male-biased dispersal is occasionally reported especially for species with polygamous breeding systems (Greenwood and Harvey 1982, Curtis et al. 1993). Other bobwhite studies have documented male-biased dispersal (Hood 1955, Urban 1972, Terhune et al. 2010) while others documented female-biased dispersal (Fies et al. 2002) or no sex-specific differences (Smith et al. 1982, Townsend et al. 2003, Cook et al. 2006, Terhune et al. 2010). Our results for sex-specific dispersal distances support the conclusions of Clarke et al. (1997) that dispersal biases tend to be facultative and should not be assumed to be an unvarying species characteristic.

We hypothesized that early successional woody habitats with generally linear arrangements (i.e., fencerows, ditches, riparian) would facilitate dispersal by providing travel corridors. Cook et al. (2006) reported early successional habitats had negligible effect on dispersal probabilities for radio-marked bobwhites in Georgia but both early successional herbaceous and woody vegetation were included in this category. We separated early succession herbaceous and woody habitat types because we suspected they may differentially affect dispersal. We found that dispersal distances declined with amounts of early succession woody habitat in covey home ranges (Figs. 2, 3).

Woody vegetation provides year-round benefits to bobwhites by providing cover from predators and thermal extremes. Vegetation structure of woody habitat can also create preferred foraging conditions by shading sod-forming grasses and patches of bare ground (Collins et al. 2009). Woody habitats were preferred by coveys at our study sites during the nonbreeding season (Janke and Gates 2013) and this may have continued during spring despite the need for bobwhites to find suitable nesting areas provided by early succession herbaceous habitats. Nest sites (i.e., habitat patches and nesting substrates) may be sufficient in our study areas to not limit reproduction as they do for bobwhite populations in arid regions (Rader et al. 2011).

MANAGEMENT IMPLICATIONS

Bobwhites in Ohio do not appear to be dispersal-limited yet they have failed to expand their range into historically-occupied areas. Gates et al. (2012) found that bobwhite metapopulations in southwestern Ohio were not producing sufficient individuals to rescue local populations or to recolonize historically-populated areas, despite their dispersal capabilities. Dispersal rates were also too low to compensate for high mortality rates in these areas (Gates et al. 2012). Trap and transplant programs in Ohio should focus on providing quality bobwhite habitat within the dispersal range of extant populations. Target areas should contain early successional woody habitats and in proximity to extant populations to connect locally isolated subpopulations and, if successful, supplement extant populations. We recommend areas within 0.73-1.41 km (50th to 75th percentiles of dispersal distances) of existing populations in southwestern Ohio be targeted to avoid creating isolated subpopulations. Habitat management will likely be necessary to create conditions that support sufficiently high survival rates to allow populations to produce surplus individuals.

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LITERATURE CITED

Applegate, R. D., C. K. Williams, and R. S. Lutz. 2002. The effect of flooding on northern bobwhites. Western North American Naturalist 62: 227–229.

Bélichon, S., J. Clobert, and M. Massot. 1996. Are there differences in fitness components between philopatric and dispersing individuals? Acta Oecologica 17:503–517.

Beyer, H. L., D. T. Haydon, J. M. Morales, J. L. Frair, M. Hebblewhite, M. Mitchell, and J. Matthiopoulos. 2010. The interpretation of habitat preference metrics under use-availability designs. Philosophical Transactions of the Royal Society of London, Series B 356:2245–2254.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer-Verlag, New York, USA.

Clarke, A. L., B.-E. Sæther, and E. Rskaft. 1997. Sex biases in avian dispersal: a reappraisal. Oikos 79:429–438.

Collins, B. M., C. K. Williams, and P. M. Castelli. 2009. Reproduction and microhabitat selection in a sharply declining northern bobwhite population Wilson Journal of Ornithology 121:688–695.

Cook, M. P., R. G. Hamrick, and J. P. Carroll. 2006. Effects of sex, age, and habitat on northern bobwhite spring dispersal patterns. Gamebird 2006: Quail VI and Perdix XII: 135–145.

Curtis, P. D., B. S. Mueller, P. D. Doerr, C. F. Robinette, and T. DeVos. 1993. Potential polygmaous breeding behavior in northern bobwhite. Proceedings of the National Quail Symposium 3: 55–63.

Danchin, E., and E. Cam. 2002. Can non-breeding be a cost of breeding dispersal? Behavioral Ecology and Sociobiology 51:153–163.

Fies, M. L., K. M. Puckett, and B. Larson-Brogdon. 2002. Breeding season movements and dispersal of northern bobwhites in fragmented habitats of Virginia. Proceedings of the National Quail Symposium 5:173–179.

Gates, R. J., A. K. Janke, M. R. Liberati, and M. J. Wiley. 2012. Demographic analysis of a declining population of northern bobwhite in southwestern Ohio. Proceedings of the National Quail Symposium 7:184–193.

Greenwood, P., and P. Harvey. 1982. The natal and breeding dispersal of birds. Annual Review of Ecology and Systematics 13:1–21.

Guthery, F. S. 2000. On bobwhites. First edition. Texas A&M University Press, College Station, USA.

Guthery, F. S., M. J. Peterson, and R. R. George. 2000. Viability of northern bobwhite populations. Journal of Wildlife Management 64:646–662.

Homer, C., C. Huang, C. Yang, B. Wylie, and M. Coan. 2004. Development of a 2001 national land-cover database for the United States. Photogrammetric Engineering and Remote Sensing 70:829–840.

Hood, M. R. 1955. Mississippi quail investigation. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 9:157–163.

Howard, W. 1960. Innate and environmental dispersal of individual vertebrates. American Midland Naturalist 61:895–901.

Janke, A. K., and R. J. Gates. 2013. Home range and habitat selection of northern bobwhite coveys in an agricultural landscape. Journal of Wildlife Management 77:In Press.

Kassinis, N. I., and F. S. Guthery. 1996. Flight behavior of northern bobwhites. Journal of Wildlife Management 80:581–585.

Klimstra, W. D. 1982. Bobwhite quail and changing land use. Proceedings of the National Quail Symposium 2: 1–5.

Lehmann, V. M. 1946. Mobility of bobwhite quail in southern Texas. Journal of Wildlife Management 10:124–136.

Lewis, J. B. 1954. Further studies of bobwhite mobility in central Missouri. Journal of Wildlife Management 18:414–416.

Liu, X., R. M. Whiting Jr., D. S. Parson, and D. R. Dietz. 2002. Movement patterns of resident and relocated northern bobwhites in east Texas. Proceedings of the National Quail Symposium 5:168–172.

Martin, K., P. B. Stacey, and C. E. Braun. 2000. Recruitment, dispersal, and demographic rescue in spatially-structured white-tailed ptarmigan populations. Condor 102:503–516.

Murphy, A., and T. Baskett. 1952. Bobwhite mobility in central Missouri. Journal of Wildlife Management 16:498–510.

Nams, V. O. 2006. Locate III user's guide. Pacer Computer Software, Tatamagouche, Nova Scotia, Canada.

National Bobwhite Technical Committee (NBTC). 2011. The National Bobwhite Conservation Initiative: a range-wide plan for recovering bobwhites. W. E. Palmer, T. M. Terhune, and D. F. McKenzie, eds. National Bobwhite Technical Committee Publication, Version 2.0. Knoxville, Tennessee, USA.

National Climate Data Center (NCDC). 2011. Quality controlled local climatological data. Hillsboro, Ohio, USA. www.ncdc.noaa.gov/oa/ncdc/html

Ohio Breeding Bird Atlas. 2012. Ohio breeding bird atlas II, 2006–2011. Ohio State University, School of Environment and Natural Resources, and Ohio Department of Natural Resources, Division of Wildlife. Columbus, USA. www.ohiobirds.org/obba2/SpeciesList.php

Ohio Division of Geologic Survey. 1998. Physiographic regions of Ohio. Ohio Department of Natural Resources, Columbus, USA.

R Development Core Team. 2012. R: a language and environment for statistical computing. Vienna, Austria.

Rader, M. J., L. A. Brennan, K. A. Brazil, F. Hernández, and N. J. Silvy. 2011. Simulating northern bobwhite population responses to nest predation, nesting habitat, and weather in South Texas. Journal of Wildlife Management 75:61–70.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the northern bobwhite. Southern Illinois University Press, Carbondale, USA.

Rosene Jr., W. 1969. The bobwhite quail: its life and management. Rutgers University Press, New Brunswick, New Jersey, USA.

Smith, G. F., F. E. Kellogg, G. L. Doster, and E. E. Provost. 1982. A 10-year study of bobwhite quail movement patterns. Proceedings of the National Quail Symposium 2: 35–44.

Spinola, R. M., and R. Gates. 2008. Population status and trends of northern bobwhite (*Colinus virginianus*) in Ohio: 1984–2004. Ohio Journal of Science 108:26–30.

Stoddard, H. 1931. The bobwhite quail: its habitats, preservation, and increase. Charles Scribner's Sons, New York, USA.

Terhune, T. M., D. C. Sisson, W. E. Palmer, B. C. Faircloth, H. L. Stribling, and J. P. Carroll. 2010. Translocation to a fragmented landscape: survival, movement, and site fidelity of northern bobwhites. Ecological Applications 20:1040–1052.

Terhune, T. M., D. C. Sisson, H. L. Stribling, and J. P. Carroll. 2006. Home range, movement, and site fidelity of translocated northern bobwhite (*Colinus virginianus*) in southwest Georgia, USA. European Journal of Wildlife Research 52:119–124.

Townsend Jr., D. E., D. M. Leslie Jr., R. L. Lochmiller, S. J. DeMaso, S. A. Cox, and A. D. Peoples. 2003. Fitness costs and benefits associated with dispersal in northern bobwhites (*Colinus virginianus*). American Midland Naturalist 150:73–82.

Urban, D. 1972. Aspects of bobwhite quail mobility during spring through fall months. Proceedings of the National Quail Symposium 1: 194–199.

Veech, J. A. 2006. Increasing and declining populations of northern bobwhites inhabit different types of landscapes. Journal of Wildlife Management 70:922–930.

Walters, J. 2000. Dispersal behavior: an ornithological frontier. Condor 102:479–478.

White, G. C., and R. A. Garrott. 1999. Analysis of wildlife radio-tracking data. Academic Press, San Diego, California, USA.

Wiley, M. J., R. J. Gates, and A. K. Janke. 2012. Efficacy of targeted mist-netting to capture northern bobwhites during the non-breeding season in Ohio. Proceedings of the National Quail Symposium 7:235–240.

Williams, C. K., A. R. Ives, and R. D. Applegate. 2003. Population dynamics across geographical ranges: time-series analyses of three small game species. Ecology 84:2654–2667.

Williams, C. K., F. S. Guthery, R. D. Applegate, and M. J. Peterson. 2004. The northern bobwhite decline: scaling our management for the twenty-first century. Wildlife Society Bulletin 32:861–869.

Yoder, J., E. Marschall, and D. Swanson. 2004. The cost of dispersal: predation as a function of movement and site familiarity in ruffed grouse. Behavioral Ecology 15:469–476.

SURVIVAL OF RADIO-MARKED VERSUS LEG-BANDED NORTHERN BOBWHITE IN KENTUCKY

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ABSTRACT

Understanding the impact of radiomarking northern bobwhite (*Colinus virginianus*) survival is essential because of the widespread reliance on radiotelemetry to assess vital population parameters. We conducted an assessment of bobwhite populations within the Central Hardwoods Bird Conservation Region using leg banding and radiotelemetry on Peabody Wildlife Management Area, a 3,330-ha reclaimed surface mine in western Kentucky. We captured bobwhites using baited funnel traps during a 112-day period (23 Jul-11 Nov 2010) and marked 180 with necklace-style radio-transmitters (6 g) and 256 birds with only leg bands. Eighty-five birds were opportunistically recaptured in funnel traps, of which 81 were used in developing survival estimates. We used the Cormack-Jolly-Seber model in Program MARK to estimate periodic survival rates (PSR) of both sample groups. Candidate models which included body mass as a covariate explained the most variability in survival. The estimated PSR was 0.309 ± 0.109 based on the best approximating model and was 0.302 ± 0.108 from model averaging. We calculated a point of inflection for this model, which suggested a mass 'threshold' of 131g, above which survival improved at a decreasing rate. The model including only the radio-transmitter effect had a $\Delta\text{AIC}_c > 3$ and was considered to be non-plausible. Further research with larger samples is needed to develop more robust survival models to fully assess the effects of radiomarking bobwhites. It does not appear, based on our study, that radio transmitters adversely affect survival of northern bobwhite.

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Key words: capture-recapture, *Colinus virginianus,* Cormack-Jolly-Seber, Kentucky, Program MARK, radiomarking, reclaimed mined land

INTRODUCTION

Use of radiotelemetry in northern bobwhite research to estimate survival has become increasingly popular (Burger et al. 1995, Dixon et al. 1996, Taylor et al. 2000, Seckinger et al. 2008, Holt et al. 2009). Researchers assume radio-marked birds have a survival probability similar to unmarked birds (Pollock et al. 1989, Burger et al. 1991). Some studies have questioned this assumption (Parry et al. 1997, Cox et al. 2004, Guthery and Lusk 2004), but few have directly compared contemporary survival estimates of radio-marked versus banded bobwhites within the same population.

Mueller et al. (1988) reported post-capture mortality of radio-marked (27%) versus unmarked (24%) bobwhites

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was not different, based on changes in covey sizes over time. However, using changes in covey size to estimate mortality may be biased because of emigration and immigration of birds (Williams et al. 2004). Parry et al. (1997) directly compared survival rates of radio-marked versus banded bobwhites ($n = 296$ and 308, respectively) through hunting recoveries and re-trapping efforts. They reported radio-marked bobwhites had higher survival ($S = 0.56$) than banded birds ($S = 0.19$). However, these results could have been affected by biased behavior of radio-marked birds including a tendency to hold tight or flush less than banded birds because of potentially lower lipid mass as well as becoming habituated to humans through constant radio-tracking. Palmer and Wellendorf (2007) compared winter survival rates of radio-marked ($n = 951$) versus banded ($n = 3{,}149$) bobwhites in Florida through hunting recoveries. They concluded radio transmitters did not influence survival of males or females as the transmitter effect on survival did not occur in plausible models. Terhune et al. (2007) evaluated summer and winter survival of radio-marked ($n = 2{,}527$) versus banded ($n = 6{,}568$) bobwhites over 8 years through hunting recoveries and re-trapping efforts. They did not find evidence for a radio-transmitter effect on survival of bobwhite and concluded variation in survival within their population was site specific, and was affected by age, sex, and temporal factors. Abbott et al. (2005) suggested trapping and handling birds may be the actual cause of a negative bias related to survival rather than radiomarking birds, because of an increased chance of capture myopathy.

No studies have examined the influence of radio transmitters on bobwhite survival on reclaimed-mined land. Negative biases of radio transmitters may be exacerbated on reclaimed-mined lands because these areas are dominated by species that may not provide adequate food resources (sericea lespedeza, *Lespedeza cuneata*). Our objective was to evaluate possible bias relating to survival of radio-marked bobwhites versus banded bobwhites between summer and fall (excluding the hunting season) on a reclaimed surface mine in western Kentucky.

STUDY AREA

We conducted the study on a reclaimed coal mine managed by the Kentucky Department of Fish and Wildlife Resources as Peabody Wildlife Management Area (WMA) (3,323 ha) in Muhlenberg (37° 14′ N, 87° 15′ W) and Ohio (37° 17′ N, 86° 54′ W) counties in western Kentucky, USA. The study area consisted of open herbaceous vegetation (36%) dominated by sericea lespedeza and annual forbs including common ragweed (*Ambrosia artemisiifolia*), sumpweed (*Iva annua*), and goldenrod (*Solidago* spp.). Shrub vegetation (25%) was characterized by an abundance of black locust (*Robinia pseudoacacia*), winged sumac (*Rhus copallinum*), and blackberry (*Rubus* spp.). Deciduous forests (22%) primarily consisted of eastern cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), and American sycamore (*Platanus occidentalis*); forests typically had a well-developed understory consisting of blackberry (*Rubus* spp.) and honeysuckle (*Lonicera japonica* and *L. maakii*). More recently, native warm-season grasses (NWSG), including mixtures of big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*), have been established (8%). Small lakes, wetlands, and annual grain food plots comprised the remainder (9%) of our study area.

METHODS

We captured bobwhites continuously during 2010 using funnel traps (Stoddard 1931) covered by burlap and vegetation to help reduce stress and predation of captured birds, and evaluated survival of marked birds during a 112-day period (23 Jul-11 Nov 2010). We placed traps ($n = 120$) in areas thought to have bobwhites or where bobwhites were heard or seen. We attached radio transmitters to captured birds that weighed > 120 g. We used 6-g necklace-style radio transmitters (crystal-controlled, 2-stage design, pulsed by a CMOS multivibrator, American Wildlife Enterprises, Monticello, FL, USA). We double leg banded all captured birds including those radiomarked. We classified each bird by sex and age, and weighed all bobwhites before releasing them at the capture site. Our trapping and handling methods complied with the University of Tennessee's Institutional Animal Care and Use Committee Permit (#2042-0911). We opportunistically recaptured radio-marked and banded birds throughout the period of the study.

Statistical Analysis

We calculated survival estimates for radio-marked and banded birds using the Cormack-Jolly-Seber (CJS) model within Program MARK (White and Burnham 1999). We adjusted the radio-marked sample to match the banded data set by randomly censoring selected juveniles and males until the ratios between male: female and juvenile: adult groups were equal. Trapping on a daily basis during the study period provided 111 encounter occasions for both samples combined. We assumed equal recapture rates (Seber 1982). We used a model-selection approach based on Akaike's Information Criterion to identify the model that best explained survival. We included null, time dependent, sex dependent, age dependent, mass dependent, covariate (radio-marked vs. banded) dependent, and additive models in our survival analysis (Table 1). We also included an interactive model between mass and radio-marked or banded variables to test whether there were confounding factors related to the difference in mass between radio-marked versus banded bobwhites. We used a ΔAIC_c value of < 3 (Palmer and Wellendorf 2007) to examine relative validity of a model for explaining variance in survival. We used Akaike weights (*wi*) to examine the overall strength of a model relative to candidate models within $\Delta\text{AIC}_c < 3$ for explaining variance in survival. We obtained daily survival rates from the best approximating model and

Table 1. Metrics used to assess effects of radiomarking on survival of northern bobwhites on Peabody WMA, Kentucky, USA, 23 July-11 November 2010.

Metric	Description
Age	juvenile or adult
Radio	presence/absence of radio transmitter
Sex	male/female
Time	temporal scale
Mass	body mass (g) of bobwhite

Table 2. Age and sex of captured bobwhites on Peabody WMA, Kentucky, USA, 23 July-11 November 2010.

	Banded only	Radiomarked
Male	25 (61%)	25 (61%)
Female	16 (39%)	16 (39%)
Juvenile	30 (73%)	30 (73%)
Adult	11 (27%)	11 (27%)
Totals	41 (100%)	41 (100%)

from model averaging using Program MARK. We used the delta method (Powell 2007) to expand estimates to a temporal scale that encompassed the entire 112-day study period. We used Program MARK to plot survival based on the individual covariate receiving the most support within the best approximating model. We calculated the second derivative for the individual covariate plot to identify the point of inflection for the survival function based on that covariate.

RESULTS

We captured and banded 436 bobwhites during the 112-day period (23 Jul-11 Nov 2010) of which 180 were fitted with a radio transmitter. Eighty-five of the 436 birds captured were recaptured. We randomly censored 4 birds (3 juveniles and 1 male) from the data set to remove any age- or sex-related bias; only 8**1** were used in developing survival estimates (Table 2). The average (± SD) body mass of banded-only bobwhites was 101.9 ± 4.1 g; it was 155.9 ± 2.7 g for radio-marked birds. The range of mass measured during our study was 68–196 g.

Five models tested were supported as being plausible for explaining variance in survival based on ΔAIC_c scores; all 5 included the effect of body mass on survival (Table 3). The highest ranked model based on ΔAIC_c scores included the effect of mass on survival ($\beta = 0.021$; CI = 0.005 – 0.036) with equal recapture rates. The Akaike weight for this model (0.34546; Table 3) indicated this was the best approximating model of those examined for survival. The mass variable also had an importance value (*wi*) > 0.98, suggesting a strong effect of this variable on survival (Table 4). The daily survival rate (DSR) using the body mass model was 0.989 ± 0.003 for both samples. The average recapture probability was 0.078 ± 0.005 for both samples and the periodic survival rate (PSR) was 0.309 ± 0.106. The point of inflection was 131g based on the second derivative of the covariate (mass) plot for this model (Fig. 1). The periodic survival rate at the point of inflection was 0.366 ± 0.125 and was 0.288 ± 0.099 at our 120-g marking requirement.

The second strongest model, based on ΔAIC_c scores, was the additive model of mass and radio effects on survival with equal recapture rates ($\Delta AIC_c = 0.8737$; Table 3). This model had an Akaike value (*wi*) of 0.22141 and was 1.5 times less likely than the strongest model. The effect of radio transmitters was negligible based on the beta value of this covariate ($\beta = -0.840$; CI = –2.318–0.637), which did not differ from 0. Our interactive model between mass and radio-marked or banded variables was not a competing model. There was no evidence of confounding factors related to difference in mass between radio-marked versus banded birds. Model averaging was used to examine overall PSR because of ambiguity among competing models. The period survival rate from model averaging was estimated as 0.302 ± 0.108.

DISCUSSION

Body mass was the most influential parameter affecting northern bobwhite survival during our study. There was a positive, third-order polynomial relationship between survival probability and mass. This suggests bobwhites captured below our 120-g requirement for receiving a transmitter would have a lower probability of survival than birds > 120 g. This criteria may have been set too low, given the point of inflection was higher, suggesting a possible 'threshold' at 131g. This threshold, based on the weight of our collars (6 g), is 4.5% of the bird's total weight. This estimate of 131 g is consistent with previous literature (Terhune et al. 2007), which suggests a threshold of > 132 g. Our requirement of a mass of 120 g may have reduced survival, as these birds would have experienced an 8% decrease in periodic survival compared to those marked at the 131-g threshold. The effect of mass observed during our study may be related to a potential lack of food availability on reclaimed-mined lands. Robel and Linderman (1966) suggested higher body mass may be related to higher survival rates, and observed that food availability was the primary causative factor in mass gains for bobwhites. Peabody WMA was initially re-vegetated with species, such as sericea lespedeza, that may not provide optimal food resources.

Bobwhites may not attain acceptable mass gains for radiomarking until at an older age on reclaimed-mined areas, and lighter bobwhites may be prone to decreased survival, as indicated with our top model. The difference in mass between radio-marked and banded bobwhites was not of concern because our interactive model incorporating these variables was not a competing model.

We did not detect any bias for bobwhite survival on Peabody WMA as a result of using radio transmitters. The radio-transmitter effect was included in a model with a $\Delta AIC < 3$, but the effect of this covariate did not differ from 0 based on the beta value confidence interval.

Previous research has shown site, temporal scale, age, and sex of bobwhites to be more influential on survival

Table 3. Model selection statistics from the Cormack-Jolly-Seber model in Program MARK estimating survival (ϕ) and recapture probability (ρ) of northern bobwhites on Peabody WMA, Kentucky, USA, 23 July-11 November 2010.[a]

Model	AIC_c	ΔAIC_c	AIC_c (*wi*)	Model likelihood	Parameters	Deviance
ϕ_{mass} $\rho.$	1861.7956	0	0.34270	1	3	1855.7213
$\phi_{mass+radio}$ $\rho.$	1862.6693	0.8737	0.22141	0.6461	4	1854.5451
$\phi_{mass*weight^2}$ $\rho.$	1863.4558	1.6602	0.14942	0.4360	4	1855.3316
$\phi_{mass+age}$ $\rho.$	1863.5837	1.7881	0.14016	0.4090	4	1855.4595
$\phi_{mass+sex}$ $\rho.$	1863.8434	2.0478	0.12309	0.3592	4	1855.7192
$\phi_{mass\times radio}$ $\rho.$	1869.3143	7.5187	0.00798	0.0233	3	1863.2400
ϕ_{radio} $\rho.$	1869.4884	7.6928	0.00732	0.0214	3	1863.4141
ϕ_{age} $\rho.$	1870.7681	8.9725	0.00386	0.0113	3	1864.6938
ϕ_{sex} $\rho.$	1871.5717	9.7761	0.00258	0.0075	3	1865.4974
$\phi.$ $\rho.$	1872.6933	10.8977	0.00147	0.0043	4	1864.5691
ϕ_{time} $\rho.$	2150.1011	288.3055	0	0	112	1807.8207

[a] Notation generally follows Lebreton et al. (1992): $\phi = P(\text{survival})$, $\rho = P(\text{recapture})$, radio = radio transmitter.

than the presence of a radio transmitter (Palmer and Wellendorf 2007, Terhune et al. 2007). Our study was conducted at only one site and we did not include a site-specific model in our analysis. The temporal scale did not explain variation in survival rates because of the relatively short duration of our study. Additional seasons/years of data and larger sample sizes would help better understand any possible temporal effects that may exist. There was no direct effect on survival in relation to age or sex; these effects were influential in additive models that included mass (Table 3). This suggests body mass is the most influential factor affecting survival among our candidate models. We may have not observed similar age- and sex-related effects on survival as in previous studies because of sample size, seasonality, and temporal scale of our research. Greater discrimination of age (i.e., days post-hatching) at capture would be necessary to better account for a potential age effect. Age and mass were likely confounding influences in our study. Our results suggest body mass is a much more important factor influencing survival.

Recapture rates were extremely low ($\rho = 0.0783$) during the study period, which may have led to the wide confidence limits and the imprecise survival estimates we observed. We were unable to use a Release goodness-of-fit test (White et al. 2001) to calculate a variance inflation factor ($\hat{c}$) to correct for over dispersion of our data.

Table 4. Importance values (*wi*) for parameters used to model northern bobwhite survival in Program MARK on Peabody WMA, Ohio and Muhlenberg counties, Kentucky, USA, 23 July-11 November 2010.

Parameter	Number of candidate models	(*wi*)[a]
Mass	5	0.98465
Radio	2	0.23057
Age	2	0.14518
Sex	2	0.12669

[a] Importance value (*wi*) of a parameter is estimated as the sum of Akaike weights from candidate models containing the parameter.

MANAGEMENT IMPLICATIONS

Our results support use of radio transmitters on northern bobwhites for research as they did not significantly bias survival. Survival estimates of bobwhites obtained through the use of telemetry, specifically in environments without intensive habitat management typical of reclaimed-mined lands, should be viewed as valid. Our results support use of a minimum body mass criterion for attaching radio transmitters to northern bobwhites. Traditional guidelines based on not using transmitters if they were > 5% of body mass may not be sufficiently conservative. Researchers should consider using 4.0 or 4.5% of body mass as a threshold to account for the effects of body mass on survival. Factors that influence survival of bobwhite may vary regionally, and future studies should assess the influence of radio transmitters on survival within different vegetation communities using larger samples over a longer period.

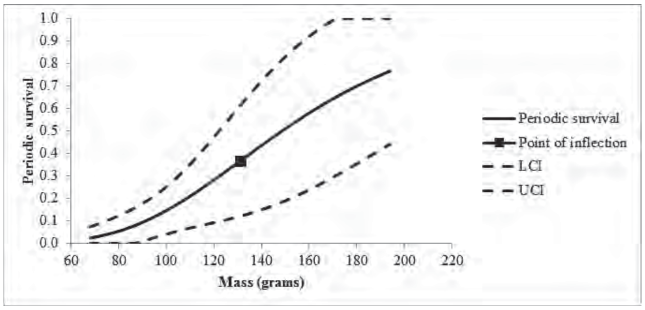

Fig. 1. Individual covariate plot of periodic survival over mass (g) of northern bobwhites, lower (LCI) and upper confidence intervals (UCI) (adjusted where values were below 0 and above 1 to allow for biological meaning), and point of inflection based on estimates in Program MARK derived from the best approximating model (ϕ_{mass} $\rho.$), Peabody WMA, Ohio and Muhlenberg counties, Kentucky, USA, 23 July-11 November 2010.

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LITERATURE CITED

Abbott, C. W., C. B. Dabbert, D. R. Lucia, and R. B. Mitchell. 2005. Does muscular damage during capture and handling handicap radiomarked northern bobwhites? Journal of Wildlife Management 69:664–670.

Burger Jr., L. W., M. R. Ryan, D. P. Jones, and A. P. Wywialowski. 1991. Radio transmitter bias of movements and survival. Journal of Wildlife Management 55:693–697.

Burger Jr., L. W., T. V. Dailey, E. C. Kurzejeski, and M. R. Ryan. 1995. Survival and cause-specific mortality of northern bobwhites in northern Missouri. Journal of Wildlife Management 59:401–410.

Cox, S. A., A. D. Peoples, S. J. DeMaso, J. J. Lusk, and F. S. Guthery. 2004. Survival and cause-specific mortality of northern bobwhites in western Oklahoma. Journal of Wildlife Management 68:663–671.

Dixon, K. R., M. A. Horner, S. R. Anderson, W. D. Henriques, D. Durham, and R. J. Kendall. 1996. Northern bobwhite habitat use and survival on a South Carolina plantation during winter. Wildlife Society Bulletin 24:627–635.

Guthery, F. S., and J. J. Lusk. 2004. Radiotelemetry studies: are we radio-handicapping northern bobwhites? Wildlife Society Bulletin 32:194–201.

Holt, R. D., L. W. Burger Jr., B. D. Leopold, and D. Godwin. 2009. Over-winter survival of northern bobwhite in relation to landscape composition and structure. Gamebird 2006: Quail VI and Perdix XII: 432–446.

Lebreton, J.–D., K. P. Burnham, J. Clobert, and D. R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecological Monographs 62:67–118.

Mueller, B. S., J. B. Atkinson Jr., and T. DeVos. 1988. Mortality of radiotagged and unmarked northern bobwhite quail. Biotelemetry X: International Radio-telemetry Symposium 10:139–144.

Palmer, W. E., and S. D. Wellendorf. 2007. Effect of radiotransmitters on northern bobwhite annual survival. Journal of Wildlife Management 71:1281–1287.

Parry, E. S., S. J. DeMaso, S. A. Cox, and A. D. Peoples. 1997. Recovery rates of banded versus radiomarked northern bobwhite in western Oklahoma. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 51:342–351.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53:7–15.

Powell, L. A. 2007. Approximating variance of demographic parameters using the delta method: a reference for avian biologists. Condor 109:949–954.

Robel, R. J., and S. A. Linderman. 1966. Weight dynamics of unconfined bobwhite quail in Kansas. Transactions of the Kansas Academy of Sciences 69: 132–138.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. Second edition. Griffin, London, United Kingdom.

Seckinger, E. M., L. W. Burger Jr., R. Whittington, A. Houston, and R. Carlisle. 2008. Effects of landscape composition on winter survival of northern bobwhites. Journal of Wildlife Management 72:959–969.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Third edition. Charles Scribner's Sons, New York, USA.

Taylor II, J. D., L. W. Burger Jr., S. W. Manley, and L. A. Brennan. 2000. Seasonal survival and cause-specific mortality of northern bobwhites in Mississippi. Proceedings of the National Quail Symposium 4:103–107.

Terhune, T. M., D. C. Sisson, J. B. Grand, and H. L. Stribling. 2007. Factors influencing survival of radiotagged and banded northern bobwhites in Georgia. Journal of Wildlife Management 71:1288–1297.

White, G. C., and K. P. Burnham. 1999. Program MARK-survival estimation from populations of marked animals. Bird Study 46 (Supplement):120–138.

White, G. C., K. P. Burnham, and D. R. Anderson. 2001. Advanced features of Program Mark. Pages 368–377 in R. Field, R. J. Warren, H. Okarma, and P. R. Sievert, eds. Wildlife, land, and people: priorities for the 21st century. Proceedings of the Second International Wildlife Management Congress. The Wildlife Society, Bethesda, Maryland, USA.

Williams, C. K., R. S. Lutz, and R. D. Applegate. 2004. Winter survival and additive harvest in northern bobwhite coveys in Kansas. Journal of Wildlife Management 68:94–100.

NORTHERN BOBWHITE SURVIVAL, NEST SUCCESS, AND HABITAT USE IN KENTUCKY DURING THE BREEDING SEASON

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ABSTRACT

Northern bobwhite (*Colinus virginianus*) populations have experienced protracted declines over much of their range. There has been an annual decrease of 2.61% since the 1960s in Kentucky, an area representative of the Mid-South where there is a lack of data on basic population parameters. Much of the decline is attributed to prevailing land-use practices and associated habitat loss. We monitored northern bobwhite on a 515-ha farm in Oldham County, Kentucky to assess survival rates, nest success rates, and habitat use in the Mid-South. The farm consisted of row crops, cool-season pastures and hay (primarily tall fescue), fallow native warm-season grass fields, and woods. We captured birds using baited funnel traps and fitted them with harness radio transmitters and monitored them daily during April–August, 2009 and 2010. We radiomarked 88 birds (40 females, 48 males) and monitored 24 nests, 9 (37.5%) of which were successful, over the 2 years. Survival rates were 25.3 and 27.9% for 2009 and 2010, respectively, based on estimates from Program MARK. Home range size (54.0, range = 38.0–55.9 ha) did not differ by sex, age, or year ($P > 0.05$). Quail favored food plots in both years and avoided developed areas.

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Key words: *Colinus virginianus,* habitat use, home range, Kentucky, nest success, northern bobwhite, radiotelemetry; survival rate

INTRODUCTION

Northern bobwhite populations have declined across their range (Sauer et al. 2008) due to habitat alteration and loss resulting from agriculture (Brennan 1991, Burger et al. 1995a), silviculture (Brennan 1991, White et al. 2005), and urbanization (Veech 2006). This decline within Kentucky has occurred at an annual rate of 2.61% since the mid-1960s (Sauer et al. 2008).

Considerable work has been done to document bobwhite population parameters and habitat use in other parts of the species' range (Cox et al. 2004, Terhune et al. 2006, Lohr et al. 2011), but data are lacking in the Mid-South, an area largely congruous with the Central Hardwood Bird Conservation Region (CHBCR). There are several older studies in the region that provide data from the 1960s (e.g., Klimstra and Roseberry 1975, Roseberry et al. 1979), but advances in field research technologies (i.e., radiotelemetry) and analytical tools (i.e., Program MARK), and changes in land-use practices dictate these issues be addressed with new research. This research must be conducted in the appropriate context, representative of the region's prevailing land use practices and landscape configuration.

Landscapes of the Mid-South are dominated by deciduous forests and exotic grass pastures and currently have low bobwhite populations (Applegate et al. 2011). However, certain land management practices have been deemed helpful in maintaining and increasing local northern bobwhite populations. These include planting native grasses, fallow rotations, and planting annual food plots. These practices have not been widely implemented, but many individual landowners have used these techniques. The impacts of these practices at scales appropriate to contemporary conservation paradigms (i.e., National Bobwhite Conservation Initiative; NBTC 2011) are also currently unexamined within the Mid-South. An appropriate framework for research would include both ownership scales and practices that are contextually appropriate to the region.

We conducted research on a site that was representative of the diversified landscapes of the region and, to the extent possible, appropriate to landownership scales and conservation practices likely to be implemented by regional landowners. Our objectives were to use radiotelemetry to examine home range size, adult and nest survival, nest success, nest site attributes, brood habitat,

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and adult habitat use of northern bobwhite during the breeding season on a representative Mid-South site.

STUDY AREA

We conducted our research on a 515-ha farm in Oldham County, Kentucky (38° 26′ 56” N, 85° 27′ 07” W). The farm was within the CHBCR and was within 10 km of the Ohio River. The area was a part of the Outer Bluegrass Physiographic Province with elevations ranging from 190 to 240 m asl. Soils were classified within the Crider-Nicholson Association along ridges and the Beasley-Caneyville Association on lower slope positions; both associations were formed over limestone parent materials (Whitaker 2011). Land use included 4.5 ha (1%) of fields dominated by annual weeds, 40 ha (8%) of annual food plots, 62 ha (12%) of native warm-season grasses (NWSG) that were not being used for forage (grazing or hay production), 77 ha (15%) of rotational corn and soybeans, 76 ha (15%) of cool-season pastures, and 18 ha (3%) of hay fields dominated by tall fescue (*Festuca arundinacea*), 228 ha (44%) of deciduous woodlands, and 10 ha (2%) of developed areas including houses, barns, equipment sheds, and associated curtilage. The scale of our site, while larger than most land holdings in the region (e.g., 60–70 ha), was the smallest scale on which we could work and develop meaningful sample sizes. It was also representative of the scale that may be a realistic goal for landowner cooperatives focused on bobwhite conservation. The other deviation from regional norms at our study site was the presence of considerable area devoted to conservation practices including annual weed fields, food plots, and NWSG plantings. The presence of these habitat features gave us the opportunity to evaluate possible impacts to northern bobwhites and may have been responsible for the greater density of birds on the study site compared to the surrounding landscape (5–10 vs. 1–2 known coveys), making research on this site feasible.

METHODS

We trapped bobwhites using bait and Stoddard funnel traps (Burger et al. 1995a) at known covey locations during March–April 2009 and February–April 2010. We raked each trap site to bare soil and baited it with grain sorghum, corn, millet, or a mixture of the grains. Traps were hidden with freshly cut eastern red cedar (*Juniperus virginiana*) limbs to minimize stress of trapped birds. Traps were checked every evening. We recorded sex, age (adult or juvenile), mass to the nearest gram, and condition for each captured bobwhite, and attached a uniquely numbered, size-4 leg band. We initially fit both males and females with harness-type transmitters (American Wildlife Enterprises, Monticello, FL, USA) weighing 6 g to ensure an adequate sample size. We did not place transmitters on birds with mass <130 g. Transmitters had a signal of 38 pulses/min or, after 12 hrs without movement, a mortality signal of 70 pulses/min. We recovered transmitters from dead birds and tried to classify cause of death (e.g., avian or mammalian). Bobwhites were released at the trap site following processing. All trapping and handling of animals for this project was approved by the University of Tennessee Animal Use and Care Committee, protocol # 561.

We obtained locations for radio-marked birds by approaching to within 25 m and recording the bird’s location on a 1:5,765 scale map; locations were later transferred into an ArcGIS data layer. We located all radio-marked birds every other day until covey break-up in spring (~ late Apr in both years), and then daily to document nest initiation. We marked nests by placing flagging 5 m distant and in four directions, centered on the nest site. We waited until the bird had initiated incubation and was off the nest to count eggs to ascertain clutch size. We also recorded plant species at the nest site and overall habitat type in which it was located. We tracked broods twice daily to document movements and habitat use.

We sampled vegetation at each nest and a randomly-located point (10–50 m from the nest) paired with that nest. We established two perpendicular 20-m lines (centered over the nest) to sample herbaceous species, litter depth, average vegetation height, and cover density. We recorded plant species at 1-m intervals; plants were identified to species whenever possible. More than one plant may have been recorded at each point due to layering of vegetation. We recorded average vegetation height (cm) at 5-m intervals, starting at the 0-m mark, for a total of five measurements per transect. Litter depth (cm) was measured at the first location where litter was present, starting from both ends of the 20-m transect moving toward the center and from the center moving out in each direction for a total of four per transect. We measured cover density using a Robel pole (Robel et al. 1970) placed at the center of each transect. We analyzed means for vegetation variables under a randomized block model using one-way analysis of variance (ANOVA).

We calculated home ranges with a 95% Kernel method for birds having >20 known locations after 1 April using the animal movement extension in ArcView 3.2 (Hooge and Eichenlaub 1997). We compared mean home range sizes among adult males, adult females, juvenile males, and juvenile females using ANOVA with year, sex, and age as main effects and home range size as the dependent variable. We used a known fates model within Program MARK (White and Burnham 1999) to estimate adult and juvenile survival for the season from our radiotelemetry data. We used the Mayfield method (Mayfield 1975) to estimate daily nest survival rates because of our small sample size of nests, We raised daily nest survival to the 23rd power (nest incubation period of northern bobwhite) to calculate nest success. We used 1:12,000 aerial photography (2008; USDA Farm Service Agency) and ground examination to classify the study area into 8 cover types: annual forbs, food plot, NWSG, row crop, cool-season pasture, cool-season hay, woods, and developed. We evaluated habitat use by first clipping the vegetation layer for each useable (i.e., >20 locations) home range and calculated the proportion of each range allocated to the 8 cover types. We used Chi-square tests to examine nest success by substrate and nest selection by

Table 1. Number of northern bobwhite captured in north-central Kentucky, 2009–2010.

	Year	
	2009	2010
Total captured	52	44
Adult males	10*	10
Adult females	6	2
Juvenile males	19*	17
Juvenile females	17	15
Total radiomarked	44	44

*Only 21 males (7 adults and 14 juveniles) were radiomarked in 2009.

habitat. Expected values for nest success by substrate were taken by multiplying total number of nests per substrate by nest success (averaged between both years), and nest selection by habitat by multiplying percent of each habitat by the total number of nests. We used a Chesson Habitat Index (Chesson 1978) to examine habitat use. This approach compares available habitat to what an animal actually used. Use of any cover type for which the lower limit of the 95% confidence interval for that type exceeded proportional use (i.e., 1/8 or 0.125) was considered selected for, and was considered to be selected against where proportional use (1/8 or 0.125) was below that interval.

RESULTS

We had 1,689 trap nights in 2009 and 2,442 in 2010. Fifty-two bobwhites were captured in 2009 and 44 in 2010 for a trap success rate of 3.1 and 1.8%, respectively. We radiomarked 44 birds each year; 8 males captured in 2009 were not instrumented to save transmitters for use on females (Table 1). We calculated home range sizes for 31 birds in 2009 and 24 in 2010 (Table 2). Home range size did not differ by year ($F = 1.59$, $P = 0.21$), sex ($F = 0.51$, $P = 0.48$), or age ($F = 1.01$, $P = 0.32$). Mean (± SE) survival during the 2009 and 2010 breeding seasons and across all sex and age classes was 25.3 ± 9.3% and 27.9 ± 6.9%, respectively; small sample sizes precluded analyses by sex or age class. We recorded 4 avian, 14 mammalian, and 8 unknown mortalities during 2009 and 11 avian, 10 mammalian, and 4 unknown mortalities for 2010.

Sixteen active nests were located in 2009 and 8 in 2010 with 5 (31.3%) and 4 (50.0%) of those being successful, respectively. Nest survival estimates using the Mayfield method were 24.2% for 2009 and 42.0% for 2010. Average clutch size was 13.1 eggs per successful nest and 12.0 eggs per unsuccessful nest, and mean date for nest initiation was 8 June and 10 June for 2009 and 2010, respectively. The species most commonly used by bobwhites for constructing their nests was Indiangrass (*Sorghastrum nutans*) followed by tall fescue (Table 3); nest success did not differ by nest substrate ($X^2 = 5.44$, $P > 0.05$). We did not detect differences ($P > 0.05$) between nest and random sites for nest vegetation measures (Table 4). Fifteen of 24 nests were either in NWSG or on a NWSG edge with another type (Table 3); NWSG was used more than expected and woods less than expected ($X^2 = 96.13$, $P < 0.001$). Radio-marked birds favored food plots both years, NWSG in 2009 and row crops in 2010 (Table 5). Developed areas were avoided both years and cool-season pastures and hay fields were avoided in 2010. We were not able to analyze brood home range sizes, survival, or habitat use because of the small sample size for broods ($n = 2$ for each year). Size (and number of days tracked post-hatching) of these 4 brood ranges were 9.5 (17 days), 4.2 (19 days), 1.7 (19 days), and 1.7 ha (10 days) each (mean = 4.3 ha). Field observation of diurnal habitat use indicated 2 of the 4 broods primarily used areas with prominent shrubby cover (2–3 m tall saplings), while one stayed in and around an annual weed field, and the fourth split its time between a shrubby area and a cool-season pasture.

DISCUSSION

Our data, despite modest sample sizes, present much needed insight into the basic biology of northern bobwhite on a contemporary Mid-South landscape, a region that has been largely understudied with respect to this species. Klimstra and Roseberry (1975) and Roseberry et al. (1979) investigated northern bobwhite populations during the 1950s and 1960s on a landscape somewhat similar to ours and, in broad terms, in the same region of the U. S. (350 km from our study area). However, there have been numerous changes in land use, and agricultural and forestry practices since that time. Better information is clearly needed to inform conservation strategies for this species within the region.

Mean home range size in our study exceeded breeding season estimates of those in New Jersey (38.7 ha; Lohr et al. 2011), but were similar to those in the Flint Hills in Kansas (54–75 ha; Taylor et al. 1999). Terhune et al. (2006), working in high quality habitat managed intensively for bobwhites, reported mean home range sizes (16.8 ha) much smaller than ours. All three studies were conducted in landscape contexts quite different from

Table 2. Mean (± SE) home range size (ha) for northern bobwhite during April–August, 2009–2010 in north-central Kentucky.

	Male				Female				
	Adult	*n*	Juvenile	*n*	Adult	*n*	Juvenile	*n*	Pooled
2009	55.9 ± 11.4	6	77.0 ± 17.0	9	43.7 ± 30.8	6	58.2 ± 23.0	10	61.0 ± 10.4
2010	38.0 ± 12.5	5	56.9 ± 7.8	11	n/a	0	32.6 ± 10.7	8	44.9 ± 5.9
Pooled	47.8 ± 8.5		66.5 ± 9.1		43.7 ± 30.8		46.1 ± 13.2		54.0 ± 6.5

Table 3. Vegetation substrate and cover type associations at 24 northern bobwhite nests during 2009–2010 in north-central Kentucky. Values represent number of nests within a given substrate or cover type.

			Nest cover type			
				Edges		
Nest vegetation substrate			Single type	Pasture	Woods	Totals
Indiangrass (*Sorghastrum nutans*)	10	NWSG	10	1	4	15
Bromus spp.	2	Woods	3			3
Goldenrod *(Solidago* spp.)	3	Pasture	2		1	3
Tall fescue (*Festuca arundinacea*)	8	Annual weeds	2		1	3
Thistle (*Carduus* spp.)	1					
Totals	24		17	1	6	24

ours; however, we are not aware of any work in areas more similar to ours.

Klimstra and Roseberry (1975) did not investigate survival in their nesting season research in southern Illinois. Roseberry et al. (1979), working in Jackson County, Illinois, reported a seasonal (16 Mar–9 Nov) survival rate of 58.9% over a 5-year period based on periodic field censuses using bird dogs. The first study using radiotelemetry in a region and landscape somewhat comparable to ours was in northern Missouri (~ 50% row crop and 10% wooded in Missouri vs. 15% row crop and 44% wooded in Kentucky) during the early 1990s (Burger et al. 1995a). They reported summer survival rates of 33.2% over the 3 years of their study ($n = 406$, pooled across years); those rates did not differ by sex or age. These rates are higher than those we observed during our 2-year study (25.3 and 27.9%, respectively). Sandercock et al (2008) summarized 76 studies of bobwhites conducted within the U. S. that reported estimates of summer survival of which 13 were <20%, 8 were between 20 and 30%, and 51 were >30%. These studies used a variety of techniques and had a wide range of sample sizes and durations, but it is clear survival rates on our study area were well below that in most other investigations.

Nest success in the region has been reported at 33.7% by Klimstra and Roseberry (1975) during their 15-year study and at 46% over a 4-year period by Roseberry et al. (1979). Burger et al. (1995b) reported nest success for females (40.2%) and males (13.5%) over their 3-year study; we did not evaluate success by males and females in our study. Our success rates (31.3 and 50.0% for 2009 and 2010, respectively) appear to be comparable to those reported by others working in the region. Nest initiation dates on our site appear to have been later than reported by others (Klimstra and Roseberry 1975, Burger et al. 1995b) and may have been indicative of second nesting attempts (Burger et al. 1995b). The only other published estimate of nest survival of which we are aware from this region is that of Burger et al. (1995b). Their estimated nest survival, 43.7% for 159 nests using the same method (Mayfield), was higher than ours (24.2 and 42.0%, 33.1% averaged across both years). Fifty-five of 68 nest survival studies evaluated by Sandercock et al. (2008), reported rates >30%, further indication that nest survival on our site was below average.

Table 4. Mean (± SE) vegetation metrics for nests and random locations for northern bobwhites in north-central Kentucky, April–August, 2009–2010. Means were compared with an ANOVA model.

Variable	Nest	Random	*P*
Height (cm)	69.8 ± 4.8	71.8 ± 4.8	0.597
Litter depth (cm)	5.3 ± 0.7	5.7 ± 0.7	0.456
Vertical density (dm)	7.3 ± 0.6	7.5 ± 0.6	0.779
Cover (%)			
NWSG	53.3 ± 12.4	42.1 ± 12.4	0.010
Cool-season grass	82.5 ± 11.6	96.2 ± 11.6	0.083
Forbs	112.8 ± 14.2	114.6 ± 14.2	0.840
Woody	20.5 ± 5.3	19.1 ± 5.3	0.692
Legumes	21.1 ± 4.2	23.8 ± 4.2	0.616
Other warm-season grass	2.4 ± 0.1	2.6 ± 0.1	0.312

Bobwhites on our study area had a strong affinity for 2 key species for nesting substrate: Indiangrass (42%) and tall fescue (33%). Indiangrass was the most common species in the planted NWSG areas and tall fescue comprised the overwhelming majority of the pastures and hayfields in the study area. The much greater amount of tall fescue available than Indiangrass (94 vs. 62 ha) coupled with greater use of the latter species suggests preferential selection for Indiangrass for nesting. The apparent selection is further reinforced by placement of a high proportion of nests in habitat patches or edges associated with NWSG. Broomsedge (*Andropogon virginicus*), perhaps the species in which bobwhites most commonly nest (Rosene 1969, Klimstra and Roseberry 1975), was present on the study area, but did not dominate any cover type and only occurred in scattered clumps. Indiangrass may have served as the primary replacement for broomsedge for nest sites in our study area.

Avoidance of fescue-dominated pastures and hay fields by bobwhites in our study during 2010 was not surprising (Barnes et al. 1995, Washburn et al. 2000). However, we did not expect these cover types to be used in proportion to availability during 2009. We expected use of NWSG in 2009, but not the proportional use observed in 2010. This pattern may have been a result of patterns in use of prescribed fire by the landowner for stand maintenance. The NWSG on this site were dense with few forbs present and probably could have been improved for bobwhite habitat (Millenbah et al. 1996, Kopp et al.

Table 5. Mean proportion of available habitats within home ranges of radio-marked northern bobwhites in north-central Kentucky, April–August, 2009–2010. Bold numbers for confidence intervals indicate a preference while italic numbers indicate avoidance based on the Chesson Habitat Index.

	2009				2010			
	Proportion of home range mean	SE	95% Confidence interval		Proportion of home range (mean)	SE	95% Confidence interval	
Annual weeds	0.099	0.039	0.022	0.175	0.176	0.063	0.053	0.300
Food plot	0.186	0.029	**0.130**	**0.243**	0.213	0.035	**0.146**	**0.281**
NWSG	0.282	0.038	**0.207**	**0.357**	0.170	0.032	0.106	0.233
Row crop	0.111	0.023	0.067	0.155	0.240	0.042	**0.158**	**0.322**
C-S Pasture	0.078	0.033	0.013	0.144	0.027	0.011	*0.006*	*0.047*
C-S Hay	0.092	0.026	0.041	0.143	0.027	0.018	*−0.009*	*0.063*
Woods	0.121	0.016	0.090	0.151	0.118	0.015	0.088	0.148
Developed	0.031	0.009	*0.013*	*0.048*	0.029	0.012	*0.006*	*0.052*

1998, Greenfield et al. 2003) through some additional disturbance such as pyric herbivory (Fuhlendorf et al 2009, Doxon et al. 2011). Use of row crop areas in 2010 may have been a result of extensive planting of no-till corn within this cover type. The height of corn and associated understory weeds and litter, and its earlier planting date, may have provided adequate cover at a time important to breeding bobwhites. However, only limited brooding activity was documented in row crop areas; brood use was primarily associated with fallow fields and areas with moderate brushy components. Woods were not avoided as expected (Veech 2006, Lohr et al. 2011), possibly because our delineation of woods included edges where much of the shrub habitat on the study area occurred. Use of food plot areas in both years was expected given the open nature of the ground layer on most plots, combined with substantial overhead cover (Greenfield et al. 2003).

Our findings of low adult and nest survival, late nest initiation dates, and larger than typical home range sizes support our assumptions about the declining, low-density populations typical of the region. The high proportion of forest and non-native grasslands in our study area likely contributed to marginal habitat quality (Roseberry and Sudkamp 1998, Veech 2006, Seckinger et al. 2008), a problem that apparently was not overcome by substantial annual food plot and NWSG plantings. However, both of these habitat features appeared to be important to bobwhites on this site and the population may have fared worse had these features not been present. Additional changes in land use practices, likely in terms of scale and intensity, will be necessary in typical CHBCR landscapes to improve survival and productivity of northern bobwhite populations.

MANAGEMENT IMPLICATIONS

Annual food plots and NWSG plantings should be encouraged wherever bobwhite management is a goal. Food plots may be more important for providing early successional cover where soil has been exposed, litter reduced, and annual plants encouraged, than for increasing available food. Native grasses managed for wildlife habitat enhancement (as opposed to forage production) should be more diverse and receive more regular disturbances. One alternative is to use managed grazing or pyric herbivory to optimize wildlife benefits in dense, production-type stands. Exotic, sod-forming grasses in production systems (e.g., tall fescue) should be replaced whenever feasible with NWSG as a preferred forage option. Commercial forest thinning coupled with judicious use of prescribed fire, even around forest edges, could help alleviate some problems associated with extensive forest cover. Efforts that foster use of these practices at a large scale will be important for advancing bobwhite conservation within this region.

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LITERATURE CITED

Applegate, R. D., J. Morgan, B. Robinson, S. Fowler, and F. Kimmel. 2011. Mid-South Regional Issues in Bobwhite Conservation. Pages 149–155 in W. E. Palmer, T. M. Terhune, and D. F. McKenzie, eds. The National Bobwhite Conservation Initiative: a range-wide plan for recovering bobwhites. National Bobwhite Technical Committee Technical Publication. Version 2.0. Knoxville, Tennessee, USA.

Barnes, T. G., L. A. Madison, J. D. Sole, and M. J. Lacki. 1995. An assessment of habitat quality for northern bobwhite in tall fescue dominated fields. Wildlife Society Bulletin 23:231–237.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

Burger Jr., L. W., T. V. Dailey, E. W. Kurzejeski, and M. R. Ryan. 1995a. Survival and cause-specific mortality of northern bobwhite in Missouri. Journal of Wildlife Management 59:401–410.

Burger Jr., L. W., M. R. Ryan, T. V. Dailey, and E. W. Kurzejeski. 1995b. Reproductive strategies, success, and mating systems of northern bobwhite in Missouri. Journal of Wildlife Management 59:417–426.

Chesson, J. 1978. Measuring preference in selective predation. Ecology 59:211–215.

Cox, S. A., A. D. Peoples, S. J. DeMaso, J. J. Lusk, and F. S. Guthery. 2004. Survival and cause-specific mortality of northern bobwhites in western Oklahoma. Journal of Wildlife Management 68:663–671.

Doxon, E. D., C. A. Davis, S. D. Fuhlendorf, and S. L. Winter. 2011. Above ground macroinvertebrate diversity and abundance in sand sagebrush prairie managed with the use of pyric herbivory. Rangeland Ecology and Management 64:394–403.

Fuhlendorf, S. D., D. M. Engle, J. Kerby, and R. Hamilton. 2009. Pyric herbivory: rewilding landscapes through the recoupling of fire and grazing. Conservation Biology 23:588–598.

Greenfield, K. C., M. J. Chamberlain, L. W. Burger Jr., and E. W. Kurzejeski. 2003. Effects of burning and discing conservation reserve program fields to improve habitat quality for northern bobwhite (*Colinus virginianus*). American Midland Naturalist 149:344–353.

Hooge, P. N., and B. Eichenlaub. 1997. Animal movement extension to Arcview. Version 1.1. USDI, Geological Survey, Alaska Science Center-Biological Science Office, Anchorage, USA.

Klimstra, W. D., and J. L. Roseberry. 1975. Nesting ecology of the bobwhite in southern Illinois. Wildlife Monographs 41.

Kopp, S. D., F. S. Guthery, N. D. Forrester, and W. E. Cohen. 1998. Habitat selection modeling for northern bobwhites on subtropical rangeland. Journal of Wildlife Management 62:884–895.

Lohr, M., B. M. Collins, P. M. Castelli, and C. K. Williams. 2011. Life on the edge: northern bobwhite ecology at the northern periphery of their range. Journal of Wildlife Management 75:52–60.

Mayfield, H. F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456–466.

Millenbah, K. F., S. R. Winterstein, H. C. Iii, L. T. Furrow, and R. B. Minnis. 1996. Effects of Conservation Reserve Program field age on avian relative abundance, diversity, and productivity. Wilson Bulletin 108:760–770.

National Bobwhite Technical Committee (NBTC). 2011. W. E. Palmer, T. M. Terhune, and D. F. McKenzie, eds. The National Bobwhite Conservation Initiative: a range-wide plan for recovering bobwhites. National Bobwhite Technical Committee Technical Publication. Version 2.0. Knoxville, Tennessee, USA.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295–297.

Roseberry, J. L., and S. D. Sudkamp. 1998. Assessing the suitability of landscapes for northern bobwhite. Journal of Wildlife Management 62:895–902.

Roseberry, J. L., B. G. Peterjohn, and W. D. Klimstra. 1979. Dynamics of an unexploited bobwhite population in deteriorating habitat. Journal of Wildlife Management 43:306–315.

Rosene Jr., W. 1969. The bobwhite quail-its life and management. Rutgers University Press, New Brunswick, New Jersey, USA.

Sandercock, B. K., W. E. Jensen, C. K. Williams, and R. D. Applegate. 2008. Demographic sensitivity of population change in northern bobwhite. Journal of Wildlife Management 72:970–982.

Sauer, J. R., J. E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, results and analysis 1966–2007. Version 5.15.2008. USDI, Geological Survey, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Seckinger, E. M., L. W. Burger, R. Whittington, A. Houston, and R. Carlisle. 2008. Effects of landscape composition on winter survival of northern bobwhites. Journal of Wildlife Management 72:959–969.

Taylor, J. S., K. E. Church, D. H. Rusch, and J. R. Cary. 1999. Macrohabitat effects on summer survival, movements, and clutch success of northern bobwhite in Kansas. Journal of Wildlife Management 63:675–685.

Terhune, T. M., D. C. Sisson, and H. L. Stribling. 2006. Home range, movement, and site fidelity of translocated northern bobwhite (*Colinus virginianus*) in southwest Georgia, USA. European Journal of Wildlife Research 52:119–124.

Veech, J. A. 2006. Increasing and declining populations of northern bobwhites inhabit different types of landscapes. Journal of Wildlife Management 70:922–930.

Washburn, B. E., T. G. Barnes, and J. D. Sole. 2000. Improving northern bobwhite habitat by converting tall fescue fields to native warm-season grasses. Wildlife Society Bulletin 28:97–104.

Whitaker, O. J. 2011. Soil survey of Oldham County, Kentucky. USDA, Natural Resources Cconservation Service, Washington, D.C., USA . soils.usda.gov/survey/online_surveys/kentucky/KY185/oldham.pdf

White, C. G., S. H. Schweitzer, C. T. Moore, I. B. Parnell III, L. A. Lewis-Weis. 2005. Evaluation of the landscape surrounding northern bobwhite nest sites: a multiscale analysis. Journal of Wildlife Management 69:1528–1537.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 (Supplement):120–138.

NORTHERN BOBWHITE SURVIVAL RELATED TO MOVEMENT ON A RECLAIMED SURFACE COAL MINE

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ABSTRACT

Reclaimed coal mines represent opportunity to provide large tracts of early succession habitat essential to northern bobwhite (*Colinus virginianus*) populations. However, little research has been conducted to explore the potential of reclaimed mine sites and examine bobwhite ecology on these unique areas. Reclaimed mines in Kentucky were planted to non-native species, such as sericea lespedeza (*Lespedeza cuneata*) and tall fescue (*Festuca arundinacea*), which do not provide suitable structure for northern bobwhite brood-rearing and movement. Fallow disking (in blocks and linear firebreaks) and planting food plots are part of current management efforts to improve food availability and habitat structure for broods. We trapped and radiomarked 266 northern bobwhites between April 2010 and September 2011 on Peabody Wildlife Management Area, a 3,330-ha reclaimed coal mine in western Kentucky, USA to investigate the effects of current management practices on movement and survival. We calculated seasonal daily movement as the Euclidean distance from a location on day 1 to day 2. Breeding season (1 Apr-30 Sep) movement averaged 128 m in 2010 and 147 m in 2011. Daily movement averaged 163 m during the 2010–2011 non-breeding (1 Oct-31 Mar) season. Multiple regression analysis indicated annual food plots, disk blocks, firebreaks, and roads did not explain variation within daily movement regardless of season ($R^2 \leq 0.04$). Individual bird/covey, precipitation, hours between locations, and average temperature also poorly explained movement variation. We used Program MARK to model the effect of season, year, mean daily movement, mean distance to annual food plots, disk blocks, firebreaks, and roads on survival. The season (breeding/non-breeding) model explained 81% of the variation in survival, and the year model explained 13%, suggesting management was not driving survival. We do not believe disking should be discontinued, although it did not influence movement, as it can improve vegetation structure important to nest-site selection and broods.

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Key words: *Colinus virginianus*, disking, firebreaks, Kentucky, movement, northern bobwhite, reclaimed mined land, survival, telemetry

INTRODUCTION

Northern bobwhites have declined at an annual rate of 3% throughout the species' geographic range for the past 3 decades (Sauer et al. 2008). The decline is attributed to deterioration of early succession habitat resulting from clean farming practices, lack of disturbance, and fragmentation (Stoddard 1931, Brennan 1991, Church and Taylor 1992, Burger 2002). More than 607,000 ha of reclaimed coal mines in the eastern United States provide an opportunity to manage large tracts of usable space for northern bobwhites and other early successional species. Compacted soils and dense stands of non-native, aggressive species may inhibit plant succession; thus, these areas remain in early succession for an extended period. These dense stands may prevent more desirable species from germinating. Sericea lespedeza was frequently planted for

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reclamation, and is capable of creating a dense monoculture (Eddy et al. 2003, Ohlenbusch et al. 2007).

Areas with dense sericea lespedeza provide poor nesting habitat, and can reduce native grass and forb cover by 66 and 70%, respectively (Dimmick 1971, Eddy and Moore 1998). Sericea lespedeza can produce 1,500 seeds per stem but, during a controlled feeding study, consumption led to 'critical' weight loss in northern bobwhite (Newlon et al. 1964, Ohlenbusch et al. 2007). Tall fescue is also commonly used in mine reclamation, and was found to limit bare ground and provided poor vertical structure for bobwhite in Kentucky (Barnes et al. 1995). A pilot study on a reclaimed coal mine in Virginia cited a lack of open structure at ground level and limited nesting cover as a result of dense vegetation as factors limiting to a future bobwhite population (Stauffer 2011). Poor quality habitat could result in increased daily movement and vulnerability to predators (Kabat and Thompson 1963, Fies et al. 2002, Lohr et al. 2011, Stauffer 2011).

Current management practices to address these concerns include disking (in blocks and linear firebreaks) and planting annual food plots. Food plots and other management efforts could decrease bobwhite movement, leading to increased survival rates (Scott and Klimstra 1954, Roseberry 1964, Smith et al. 1982, Robel and Kemp 1997). Roads may be another source of sparsely vegetated and bare ground, and could influence bobwhite movement. It is important to understand the response of northern bobwhites to disked blocks, annual food plots, firebreaks, and roads to influence future management decisions on reclaimed mine sites.

We evaluated the effects of continuous bobwhite management practices on daily movement and survival by: (1) measuring the influence of distance to disked areas, annual food plots, firebreaks, and roads on daily movement, and (2) measuring the influence of distance to disked areas, annual food plots, roads, and daily movement on survival. We hypothesized these management practices could decrease daily movements of resident bobwhite, which could increase survival.

STUDY AREA

Peabody Wildlife Management Area (WMA) encompasses 3,330 ha of Muhlenberg (37° 14′ N, 87° 15′ W) and Ohio (37° 17′ N, 86° 54′ W) counties in western Kentucky, USA. It was surface mined and reclaimed by Peabody and Beaver Dam coal companies before coming under the direction of the Kentucky Department of Fish and Wildlife Resources (KDFWR) in 1995. It is in the Central Hardwoods Region, and its post-mining designated land use is recreation and wildlife habitat. Peabody WMA has been open to public recreation since coming under the direction of KDFWR, and is designated as a focus area in Kentucky's northern bobwhite restoration plan. Current management for bobwhites includes disking (in blocks and linear firebreaks) and planting annual food plots.

We delineated 6 vegetation types on the study area. They included open herbaceous (34%), scrub-shrub (25%), forest (22%), native warm-season grass (8%), water (7%), annual food plots (1%); odd areas (roads, buildings, firebreaks, and wetlands represented <3% of the study site). Open herbaceous was dominated by sericea lespedeza, tall fescue, thistle (*Cirsium* spp., *Carduus* spp.), field brome (*Bromus arvensis*), and goldenrod (*Solidago* spp.). Scrub-shrub was dominated by autumn-olive (*Elaeagnus umbellata*), black locust (*Robinia pseudoacacia*), and common blackberry (*Rubus allegheniensis*). Forests varied from undisturbed hardwoods with oaks (*Quercus* spp.) and maples (*Acer* spp.) to planted monocultures of eastern cottonwood (*Populus deltoides*). Native warm-season grasses included big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*) as well as other grasses and forbs. Water is recognized separately because of fluctuations in wetland areas with seasonal variation in rainfall. Food plots consisted of a mixture of grain sorghum, Illinois bundleflower (*Desmanthus illinoensis*), partridge pea (*Chamaecrista fasciculata*), and Maximillian sunflower (*Helianthus maximilianii*).

Yearly weather data were gathered online from the Kentucky Mesonet (www.kymesonet.org) using a nearby station in Hartford, Kentucky (37° 46′ N, 86° 86′ W). Annual rainfall was 142 cm in 2009, 109 cm in 2010, and 180 cm in 2011. August and September 2010 were particularly dry, receiving <3 cm each month, while April 2011 received 42 cm of precipitation. Yearly average temperature ranged from 13 to 14°C with the minimum of –19 °C in January 2009 and maximum of 39 °C in August 2011.

METHODS

Radiotelemetry

We trapped northern bobwhites year-round using funnel traps baited with cracked corn and grain sorghum as attractants during the breeding (1 Apr-30 Sep 2010, 2011) and non-breeding (1 Oct-31 Mar 2010–2011) seasons (Stoddard 1931). Traps were active $\geq$ 5 days per week and checked every afternoon to minimize stress and predation of trapped bobwhites. Each captured bird was fitted with two aluminum bands (unique numbers on each leg), classified to sex and age (juv or ad), and weighed (g). Age was based on the presence or absence of buff-tipped primary coverts (Rosene 1969). All birds weighing >120 g were fitted with a necklace-style radio-transmitter weighing 6 g (American Wildlife Enterprises, Monticello, FL, USA). Trapping and handling methods followed protocols approved by the University of Tennessee's Institutional Animal Care and Use Committee (Permit # 2042-0911). Once marked, we released birds in the area where trapped. We located birds $\geq$ 3 times per week, homing to 25–50 m to minimize disturbance of marked bobwhites (White and Garrott 1990). We recorded estimated distance to bird, azimuth, vegetation type where the bird was located, and Universal Transverse

Table 1. *A priori* models and associated hypotheses for a survival analysis of northern bobwhite ($n = 266$) on a reclaimed coal mine in western Kentucky from 1 April 2010 to 30 September 2011 ($n = 266$).

Model	Survival hypotheses
Distance to annual food plots	As distance to annual food plots increases, survival decreases
Distance to disk blocks	As distance to disk blocks increases, survival decreases
Daily movement	As daily movement increases, survival decreases
Distance to firebreaks	As distance to firebreaks increases, survival decreases
Distance to roads	As distance to roads increases, survival decreases
Breeding/non-breeding season	Survival will be greater in the breeding than in the non-breeding season
Time	Days will not be important to survival
Year	Year will not be important to breeding season survival

Mercator (UTM) coordinates at our location using a handheld Global Positioning System (GPS) unit. We estimated distance to the bird from the strength of the telemetry signal. Estimation error was measured in a series of 10 trials where one person hid a radio-transmitter in a known location, and the observer homed-in on it. Actual distance and azimuth were measured, and compared to estimated distance and azimuth.

Movements

Locations were sorted by 2 breeding (1 Apr-30 Sep 2010, 2011) and 1 non-breeding seasons (1 Oct-31 Mar 2010–2011). We censored mortality locations from analyses because predators may have moved dead birds. Nesting and breeding locations were also censored because movements would be influenced by nests and chicks. Locations from individuals within the same covey were excluded because of lack of independence, and 1 location that best represented the covey was used per day. Only individuals or coveys with ≥ 20 total locations (consecutive and non-consecutive) were included in the movement analysis. We excluded all locations where the next location for the individual was ≥ 2 calendar days. We estimated daily movement of northern bobwhites in Arc Geographic Information Systems (ArcGIS) as the Euclidean distance from a location on day 1 to the location on day 2 (consecutive locations) (Williams et al. 2000, Lohr et al. 2011). We calculated mean daily movement for individuals, coveys, and the entire sample of radio-marked bobwhites by season. We used a 2-tailed Tukey's test to look for significant differences in mean daily movements between the 2010 and 2011 breeding seasons.

We calculated Euclidean distance (m) from each location on day 1 to the nearest road, firebreak, annual food plot, and disked block using the near tool in ArcGIS. We calculated the distance to the 5 closest disk blocks and selected the closest disk block present at the time of the location. Individual or covey and hours between locations were included in the analysis to account for variation among birds and time. Precipitation and average temperature were also included to learn if variation in weather could influence movement. We conducted multiple regression analysis in SAS (SAS Institute 2009) to learn if precipitation, hours between locations, average temperature, individual/covey, and distance to the nearest road, firebreak, annual food plot, and disk block could explain daily movement distance in each season. Multiple regression allowed us to plot continuous daily movement distances against other variables, where analysis of variance methods would require categories within movements. We used a log transformation to correct normality and severe skews of both breeding and non-breeding season data. We removed variables from the analysis as necessary ($P > 0.05$) to better explain movement variation. We attempted polynomial regression with the variable that explained the most variation in movement data when multiple regression was insufficient ($P > 0.05$).

Survival

We obtained survival estimates using the known-fate model in Program MARK (White and Burnham 1999). All birds were left censored. We used a model selection approach based on a group of *a priori* models (Table 1) and Akaike's Information Criterion (AIC) to identify the model that best explained variation in survival. We included null, year dependent, time dependent, mean daily movement dependent, road dependent, disk block dependent, firebreak dependent, and annual food plot dependent models in our analysis. We grouped birds by breeding or non-breeding season to account for expected variation and to be able to detect if different parameters are important based on season. A ΔAIC_c value of < 2 was used to examine how informative a model was in explaining variance in survival (Burnham and Anderson 2002). Seasonal survival rates were obtained from Program MARK using the survival estimate from each model in model averaging. We used the delta method to expand estimates over the course of our biological seasons (Powell 2007).

RESULTS

Radiotelemetry

We used data collected from 266 captured and marked northern bobwhite for analysis. We radiotracked 53 individuals during the 2010 breeding season with 973 total consecutive locations and 43 individuals during the 2011 breeding season with 700 total consecutive locations. Number of consecutive locations per bird averaged (± SE) 18 ± 1.04 during the 2010 breeding season and

Table 2. Mean (± SE) daily movement (m) and distances (m) of northern bobwhite locations to annual food plots, disk blocks, firebreaks, and roads on a western Kentucky reclaimed coal mine during breeding (1 Apr-30 Sep 2010, $n = 53$; 2011, $n = 43$) and non-breeding (1 Oct-31 Mar 2010–2011; $n = 39$ coveys, 206 individuals) seasons.

	2010 Breeding season	2010–2011 Non-breeding season	2011 Breeding season
Mean ± SE distance to:			
Annual food plots	1,109 ± 24.29	1,110 ± 18.53	655 ± 13.48
Disk blocks	435 ± 16.26	578 ± 15.03	357 ± 13.69
Firebreaks	394 ± 15.19	512 ± 14.40	307 ± 11.79
Roads	106 ± 2.32	146 ± 2.81	145 ± 3.47
Mean daily movement	128 ± 4.63	163 ± 6.24	147 ± 6.36

16 ± 0.78 during the 2011 breeding season. We recorded 922 consecutive covey locations during the non-breeding season of 2010–2011 based on 39 coveys representing 206 individuals, which averaged (± SE) 24 ± 1.18 locations per covey. Only 34 birds (15 females, 19 males) survived from one season to another, and 1 individual (male) survived through all 3 seasons.

Telemetry error was estimated among 7 different observers over the course of the study period. The mean (± SE) difference between the estimated and true location was 12.31 ± 1.20 m. The mean (± SE) difference between the estimated azimuth and true azimuth was 14 ± 2.49°.

Movement

There were 43 km of roads, 45 ha of firebreaks, and 20 annual food plots totaling 32 ha during all seasons on the study area. There were 184 disk blocks totaling 131 ha (3% of study area) during the 2010 breeding season, which increased to 243 disk blocks and 129 ha (4% of study area) in the 2010–2011 non-breeding season, and totaled 299 disk blocks and 159 ha (5% of study area) by the 2011 breeding season. Disk block size ranged from 0.07 to 1.7 ha, but averaged 0.5 ha. Mean distances of northern bobwhites from annual food plots on the study area during the breeding and non-breeding seasons were: 655–1,110 m; firebreaks = 307–512 m; roads = 106–146 m; and disk blocks = 357–578 m (Table 2).

We detected a significant difference ($P = 0.015$) between mean (± SE) daily movements in the 2010 (128 ± 4.63 m) and 2011 breeding seasons (147 ± 6.36 m). Thus, the 2 years remained separate in the multiple regression analyses. Distance to annual food plots, precipitation, individual, hours to next location, distance to disk blocks, distance to firebreaks, and average temperature did not improve regression models ($P > 0.10$). The quadratic model with distance to roads was significant ($P = 0.005$, $R^2 = 0.011$) and explained more variation in movement than the linear model ($P = 0.05$, $R^2 = 0.004$). The parameter estimate for distance to roads (–0.0000018) suggests that as daily movement decreases, distance from a road increases.

Covey, hours to next location, distance to annual grain plots, precipitation, and firebreaks each explained < 1% of variation in the non-breeding season, and were successively dropped from the model based on low partial R^2 values and P values > 0.05. The resulting model of average temperature, distance to roads, and disk blocks was significant ($P < 0.0001$, $R^2 = 0.043$). Based on parameter estimates, as distance from roads (0.00123) and average temperature (0.00609) increased, movement increased. However, as distance from disk blocks (–0.00013) increased, movement decreased. Distance from roads explained most of the variation in movement ($R^2 = 0.024$).

Precipitation, distance from annual grain plots, individual, distance to roads, disk blocks, and firebreaks were dropped from the 2011 breeding season analysis based on low partial R^2 values and P values > 0.05. The remaining variables, distance from firebreaks, average temperature, and hours to next location explained 3% of the variation in movement ($P = 0.027$). Parameter estimates indicate that as hours to the next location (0.0313) and average temperature (0.01023) increased, daily movement increased. However, as distance from firebreaks (–0.00028) increased, movement decreased.

Survival

Our best approximating model included only season (breeding/non-breeding), and explained 81% of the variation in bobwhite survival (Table 3). The year and global models were less informative, explaining 13% ($\Delta AIC_c = 3.7277$) and 4% ($\Delta AIC_c = 6.052$) of the variation in survival. All other models had ΔAIC_c scores greater than the null model. Survival estimates (± SE) from model averaging were 48.0 ± 8.08% and 28.1 ± 4.81% during the breeding and non-breeding seasons, respectively.

DISCUSSION

Our breeding season mean daily movements of 128 and 147 m were similar to movements reported in other studies (128–171 m in Georgia, Terhune et al. 2006; 146 m in New Jersey, Lohr et al. 2011). Lui et al. (2002) reported monthly means for the breeding season in a graphical format, and all appear to be within 100–300 m for non-relocated birds. Non-breeding season mean daily movements of 163 m were low compared to covey movements reported by other researchers in Tennessee (390 m; Yoho and Dimmick 1972), Kansas (218–275 m; Madison et al. 2000, Williams et al. 2000), and New Jersey (158 m; Lohr et al. 2011). Our lower mean daily movement estimates are surprising because higher

Table 3. Mean daily movement (m), season (breeding/non-breeding), year, time, and distances (m) of northern bobwhite locations from annual food plots, disk blocks, firebreaks, and roads on a western Kentucky reclaimed coal mine as covariates of survival during breeding (1 Apr-30 Sep 2010, $n = 53$; 2011, $n = 43$) and non-breeding (1 Oct-31 Mar 2010–2011; $n = 39$ coveys, 206 individuals) seasons.

Model	AIC*c*	Delta AIC*c*	AIC*c* weights	Model likelihood	Parameters	Deviance
Season	1,485.2710	0	0.80863	1	2	1,481.2704
Year	1,488.9987	3.7277	0.12540	0.1551	2	1,484.9981
Global	1,491.3230	6.0520	0.03923	0.0485	8	1,475.3162
Null model	1,494.6825	9.4115	0.00731	0.0090	1	1,492.6823
Disk blocks	1,495.5246	10.2536	0.00480	0.0059	2	1,491.5240
Roads	1,495.7278	10.4568	0.00434	0.0054	2	1,491.7272
Firebreaks	1,495.8058	10.5348	0.00417	0.0052	2	1,491.8052
Annual food plots	1,496.2829	11.0119	0.00329	0.0041	2	1,492.2823
Distance to next location	1,496.5719	11.3009	0.00284	0.0035	2	1,492.5713
Time	2,020.9905	535.7195	0	0	366	1,276.1606

[a] Akaike's Information Criterion (Lebreton et al. 1992).

estimates are generally associated with fragmented and marginal habitat, such as a reclaimed coal mine (Kabat and Thompson 1963, Fies et al. 2002, Stauffer et al. 2011). Decreased movement could be attributed to high interspersion of woody vegetation (25% of study area) in drainage ditches, planted patches, and natural scattered succession. Williams et al. (2000) related increased use of woody vegetation during winter to decreased movement on cropland and rangeland containing only 3–4% woody cover.

Decreased movement could also be attributed to increased disturbance, including disk blocks (4% of study area in the breeding season, 5% in non-breeding), disking for firebreaks (1% both seasons), and annual food plots (< 1% in both seasons). Smith et al. (1982) reported little movement between years on Tall Timbers Research Station, which had at least a decade of intensive northern bobwhite management. He suggested movement was so minor that it be disregarded as having a significant effect on population dynamics. Food plots did not affect non-breeding season daily movement of northern bobwhite on Fort Riley, Kansas over a 3-year period (Madison et al. 2000). Our data suggest average proximity of a bird to food plots, disk blocks, or firebreaks did not explain variation within movement data during the breeding or non-breeding seasons. Mean distance to each management practice was a poor covariate of survival, as each explained less variation in the data than the null model.

Increased daily movements may be associated with lower survival rates during breeding and non-breeding seasons because of increased vulnerability to predators (Scott and Klimstra 1954, Roseberry 1964). Decreased northern bobwhite survival rates on Kansas rangelands during winter were influenced by greater covey movement rates (Williams et al. 2000). Vulnerability of bobwhite to predators in New Jersey increased during both breeding and non-breeding seasons as daily movement distances increased (Lohr et al. 2011). Our data do not support this phenomenon. Daily movement was a poor covariate of survival throughout the year and explained less variation than the null model.

MANAGEMENT IMPLICATIONS

Disking, whether in blocks or for firebreaks or food plots, did not influence daily movement distances or survival of northern bobwhites on Peabody WMA. However, this should not suggest disking be discontinued. Disking has a profound effect on vegetation composition and structure, which influences nest-site selection and brood habitat use (Taylor et al. 1999, Rader et al. 2007, Harper and Gruchy 2009). The increased bare ground also benefits other ground foraging and nesting avian species, such as grasshopper (*Ammodramus savannarum*) and field (*Spizella pusilla*) sparrows. Further research should address the potential influence of habitat metrics and landscape configuration on movement, dispersal, and survival of northern bobwhite on reclaimed mined lands.

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LITERATURE CITED

Barnes, T. G., L. A. Madison, J. D. Sole, and M. J. Lacki. 1995. An assessment of habitat quality for northern bobwhite in tall fescue-dominated fields. Wildlife Society Bulletin 23:231–237.

Brennan, L. A. 1991. How can we reverse the northern bobwhite decline? Wildlife Society Bulletin 19:544–555.

Burger Jr., L. W. 2002. Quail management: issues, concerns, and solutions for public and private lands-a southeastern perspective. Proceedings of the National Quail Symposium 5:20–34.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York, USA.

Church, K. E., and J. S. Taylor. 1992. Management and research of northern bobwhite (*Colinus virginianus*) in North America: an overview. Gibier Faune Sauvage 9:787–796.

Dimmick, R. W. 1971. The influence of controlled burning on nesting patterns of bobwhite in west Tennessee. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 25:149–155.

Eddy, T. A., and C. M. Moore. 1998. Effects of sericea lespedeza (*Lespedeza cuneata*) invasion on oak savannas in Kansas. Transactions of the Wisconsin Academy of Science, Arts and Letters 86:57–62.

Eddy, T. A., J. Davidson, and B. Obermeyer. 2003. Invasion dynamics and biological control prospects for sericea lespedeza in Kansas. Great Plains Research 13:217–230.

Fies, M. L., K. M. Puckett, and B. Larson-Brogdon. 2002. Breeding season movements and dispersal of northern bobwhites in fragmented habitats of Virginia. Proceedings of the National Quail Symposium 5:173–179.

Harper, C. A., and J. P. Gruchy. 2009. Conservation practices to promote quality early successional wildlife habitat. L. W. Burger Jr., and K. O. Evans, eds. Managing working lands for northern bobwhite: the USDA NRCS Bobwhite Restoration Project. USDA, Natural Resources Conservation Service, Washington, D.C., USA.

Kabat, C., and D. R. Thompson. 1963. Wisconsin quail, 1834–1962, population dynamics and habitat management. Technical Bulletin 30. Wisconsin Conservation Department, Madison, USA.

Lebreton, J. D., K. P. Burnham, J. Clobert, and D. R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecological Monographs 62:67–118.

Liu, X., R. M. Whiting Jr., D. S. Parsons, and D. R. Dietz. 2002. Movement patterns of resident and relocated northern bobwhites in east Texas. Proceedings of the National Quail Symposium 5:168–172.

Lohr, M., B. M. Collins, P. M. Castelli, and C. K. Williams. 2011. Life on the edge: northern bobwhite ecology at the northern periphery of their range. Journal of Wildlife Management 75:52–60.

Madison, L. A., R. J. Robel, and D. P. Jones. 2000. Influence of food plots on northern bobwhite movements, habitat use, and home range. Proceedings of the National Quail Symposium 4:36–41.

Newlon, C. F., T. S. Baskett, R. P. Breitenbach, and J. A. Stanford. 1964. Sustaining values of emergency foods for bobwhites. Journal of Wildlife Management 28:532–542.

Ohlenbusch, P. D., T. Bidwell, W. H. Fick, G. Kilgore, W. Scott, J. Davidson, S. Clubine, J. Mayo, and M. Coffin. 2007. Sericea lespedeza: history, characteristics, and identification. Cooperative Extension Service, Kansas State University Agricultural Experiment Station, Manhattan, USA.

Powell, L. A. 2007. Approximating variance of demographic parameters using the delta method: a reference for avian biologists. Condor 109:949–954.

Rader, M. J., L. A. Brennan, F. Hernández, N. J. Silvy, and B. Wu. 2007. Nest-site selection and nest survival of northern bobwhite in southern Texas. Wilson Journal of Ornithology 119:392–399.

Robel, R. J., and K. E. Kemp. 1997. Winter mortality of northern bobwhites: effects of food plots and winter. Southwestern Naturalist 42:59–67.

Roseberry, J. L. 1964. Some responses of bobwhites to snow cover in southern Illinois. Journal of Wildlife Management 28:244–249.

Rosene Jr., W. 1969. The bobwhite quail: its life and management. Rutgers University Press, New Brunswick, New Jersey, USA.

SAS Institute. 2009. SAS user's guide: statistics. SAS Institute Inc., Cary, North Carolina, USA.

Sauer, J. R., J. E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, results and analysis 1966–2007. Version 5.15. USDI, Geological Survey, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Scott, T. G., and W. D. Klimstra. 1954. Report on a visit to quail management areas in southeastern United States. Illinois Wildlife 9:5–9.

Smith, G. E., F. E. Kellogg, G. L. Doster, and E. E. Provost. 1982. A 10-year study of bobwhite quail movement patterns. National Bobwhite Quail Symposium 2:35–44.

Stauffer, D. F. 2011. Potential of reclaimed mine-land habitat to support northern bobwhite–a pilot study. Virginia Department of Game and Inland Fisheries, Richmond, USA. www.dgif.virginia.gov/quail/

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. Charles Scribner's Sons, New York, USA.

Taylor, J. S., K. E. Church, and D. H. Rusch. 1999. Microhabitat selection by nesting and brood- rearing northern bobwhite in Kansas. Journal of Wildlife Management 63:686–694.

Terhune, T. M., D. C. Sisson, H. L. Stribling, and J. P. Carroll. 2006. Home range, movement, and site fidelity of translocated northern bobwhite (*Colinus virginianus*) in southwest Georgia, USA. European Journal of Wildlife Research 52:119–124.

White, G. C., and K. P. Burnham. 1999. Program MARK-survival estimation from populations of marked animals. Bird Study 46 (Supplement):120–138.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radiotracking data. Academic Press, San Diego, California, USA.

Williams, C. K., R. S. Lutz, R. D. Applegate, and D. H. Rusch. 2000. Habitat use and survival of northern bobwhite (*Colinus virginianus*) in cropland and rangeland ecosystems during the hunting season. Canadian Journal of Zoology 78:1562–1566.

Yoho, N. S., and R. W. Dimmick. 1972. Influence of winter weather on daily movements of telemetered bobwhite quail coveys in Tennessee. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 26: 214–217.

AGE-SPECIFIC NESTING PERFORMANCE BY NORTHERN BOBWHITES

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ABSTRACT

Greater reproductive productivity of adult versus juvenile northern bobwhites (*Colinus virginianus*) has been hypothesized as a factor for rapid population growth. Research on bobwhites in the western portions of the species' range has not supported this hypothesis; however, no effort has been made to investigate age-specific reproduction on population dynamics in the southeast. We measured age-specific reproductive parameters between adult and juvenile bobwhites during 2000–2010. We radio-marked 1,069 females of which 308 were adults and 761 were juveniles. Nests per hens for adults (0.78 nests/hen) was slightly greater than that for juveniles (0.65 nests/hen) ($P = 0.09$). Adult productivity was 1.7 times greater than for juveniles in 4 of 10 years which corresponded to years of population growth. No differences were found in initial clutch sizes or nesting success. Adult hens began incubation earlier than juveniles in all but 1 year suggesting increased nesting may be due to early recrudescence in adults. The magnitude of age-specific reproductive differences in short-lived species like bobwhites is not as great as long-lived species, but has implications for understanding bobwhite population dynamics and harvest.

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Key words: age-specific reproduction, *Colinus virginianus*, Florida, northern bobwhite, population dynamics, reproductive ecology

INTRODUCTION

Northern bobwhite populations exhibit large fluctuations over time as a result of high annual mortality and variable reproductive productivity (Stoddard 1931, Rosene 1969, Guthery et al. 1988). Factors that influence reproductive productivity of bobwhites may help to explain population fluctuations. One potential factor is age and its affect on reproductive effort and success. Yearling birds have been found to recrudesce later in spring, begin incubation later in the breeding season, and produce smaller clutches and fewer nests than adults (Curio 1983, Sæther 1990, Martin 1995). Additionally, adults may have better chick-rearing skills than juveniles (Hepp and Kennamer 1993, Caizergues and Ellison 2000). Alternatively, older females in long-lived species may have reduced fertility rates due to senescence (Sæther 1990). Age-specific reproduction among galliforms has been shown to occur in some species of grouse (Caizergues and Ellison 2000) and eastern wild turkeys (*Meleagris gallopavo silvestris*) (Roberts et al. 1995, Norman et al. 2001). Improvement in parenting skills with age has been demonstrated in ring-necked pheasants (*Phasianus colchicus*) (Brittas et al. 1992). Other studies of galliforms, such as lesser prairie-chickens (*Tympanuchus pallidicinctus*), have not found age-specific differences in reproductive performance (e.g., Pitman et al. 2006).

Hernández et al. (2007) conducted the most comprehensive study on age-specific reproduction in bobwhites and found no differences in major reproductive variables used to explain productivity. However, they cited a study with a larger sample size of wild radio-marked bobwhites that had a greater nesting rate among adults than sub-adults during a stressful (e.g., drought) weather year (Brooks 2005) and suggested field studies with large sample sizes should consider the effects of age on reproduction. Other researchers have suggested earlier nesting and increased nest production among older bobwhites (Lehmann 1953, Rosene 1969). No field studies have been conducted to date to examine the effect of age on reproduction for bobwhites in the southeastern United States. Annual population fluctuations in this region are more stable than in arid portions of the bobwhites' range, although populations may fluctuate 50% or more annually (Palmer et al. 2002). Thus, the role that age-specific reproduction has on population fluctuation is important for southeastern populations as well. Age-specific information could be useful for modeling bobwhite populations and for examining harvest rates.

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The objective of our study was to examine differences in nesting productivity between adult and juvenile bobwhite hens in north Florida. We specifically were interested in differences in age-specific clutch size, nest initiation dates, nesting rate, and nesting success to learn if age-specific productivity of bobwhites may be influenced by these factors.

STUDY AREA

Tall Timbers Research Station (~1,570 ha in size) is in north Leon County, Florida. The property primarily consists of rolling hills with the majority (66%) being upland forests of loblolly pine (*Pinus taeda*), shortleaf pine (*P. echinata*), and a lesser amount of longleaf pine (*P. palustris*). Pine uplands are intermixed with hardwood drainages (21%) and annually-disked fallow fields (13%), 0.4 to 1.2 ha in size. The property is maintained as a frequently-burned pine savanna with approximately half of the upland area burned each year to maintain suitable groundstory for bobwhites. Other management practices include mowing and roller chopping to reduce hardwood and pine encroachment. Supplemental feeding occurred on a portion of the property during this study. Radio-marked bobwhites were equally distributed on areas with and without supplemental feed.

METHODS

Data Collection

We monitored reproduction of radio-marked bobwhites from 2000 to 2010. Too few adults ($n = 4$) were monitored in 2001 to include in this analyses. We captured bobwhites in walk-in funnel traps (Stoddard 1931) during January each year. We recorded gender, age, and mass of each bobwhite and banded them with uniquely-numbered aluminum leg bands (National Band and Tag Co., Newport, KY, USA); a sample of birds was equipped with a 6.5-g necklace-style radio transmitter (American Wildlife Enterprises, Monticello, FL, USA). We classified bobwhite age as juvenile or adult based on their primary coverts (Rosene 1969). Trapping, handling, and marking procedures were consistent with the guidelines of the Tall Timbers Research Inc. Institutional Animal Care and Use Committee Permit (#GB2001-01).

Radio-marked bobwhites were tracked during the breeding season (15 Apr–1 Oct) ≥ 5 times a week using a 3-element, directional, yagi antenna and hand-held receivers using homing techniques (White and Garrott 1990). We plotted bobwhite locations on detailed land cover maps created using ArcGIS 9.3 (ESRI 2007). Bobwhites were assumed nesting if we observed them at the same location over 2 consecutive days. We monitored the incubating hen each morning and afternoon to ascertain clutch size when the incubating bird was off the nest. We checked incubating bobwhites daily until the nest hatched or failed. We counted hatched egg shells to ascertain the number of fledged chicks.

Data Analysis

We considered a hen to be part of the breeding population if they were alive on 15 April each year. We calculated age-specific nests per hen by dividing the total number of nests produced by each age cohort during the entire nesting season by the respective number of hens in each age cohort. We used the ratio of nests per hen for adults and juveniles on a yearly basis, rather than summing over all years, because we were interested if the ratio was stable or varied from year to year in relation to population growth. We tested the prediction that adult hens produce more nests during a nesting season than juvenile hens by comparing the ratio of nests per hen for adults to juveniles to unity using a one sample *t*-test. We would reject the hypothesis that age had no effect on nest productivity of bobwhite hens if the ratio was greater than unity.

We tested the hypothesis that adults may have higher nesting success as a result of previous nesting experience by comparing the ratio of nesting success for adults to juveniles to unity using a one-sample *t*-test. Greater nesting success for adults than juveniles would suggest survival of nests during egg-laying may be greater for adults as well. Thus, any increase in incubated nests observed for adults could be a function of higher survival of nests during egg-laying than increased nesting rate of hens. We considered a nest successful if at least 1 chick fledged. Abandoned nests were censored from nest success calculations.

We considered that age-specific survival could influence our ratio of nests produced per hen for adults and juveniles. Increased nesting could be from longer opportunity to nest rather than from increased nesting tendency if adult hens survived at a greater rate during the nesting season than juvenile hens. We did not conduct inferential statistics on this data set due to small sample sizes (< 10) of radio-marked adult hens surviving the nesting season in most years which made the annual ratios unstable. We were interested, however, if the direction of the relationships was similar when survival rate was removed as a potential influence on nests per hen. We also compared the ratio of nests per hen for adults and juveniles for hens surviving the nesting season for all years combined. We computed age-specific clutch sizes and the date of first incubation and the proportion of hens that nested at least 1 time for each age class.

RESULTS

Overall, 1,069 females (308 adults, 761 juveniles) produced 689 nests of which 218 were incubated by adults and 471 by juveniles (Table 1). Adult hens on average produced 0.78 nests/hen whereas juvenile hens produced 0.65 nests/hen. The ratio (mean ± SE) of nests per hen for adults to juveniles averaged 1.25 ± 0.133 and was marginally greater than 1 ($t_9 = 1.9$; $P = 0.09$). Nests per hen for adults was greater than juveniles in 5 of 10 years; however, the magnitude was substantially greater in 2000, 2004, 2006, and 2008.

Table 1. Nesting rate and nest success of radio-marked adult and juvenile northern bobwhite hens alive at the beginning of the nesting season (15 Apr) and those that survived the entire nesting season, Tall Timbers Research Station, Leon County, Florida, USA, 2000–2010.

Year	Age	*n*	Nests	Nests/hen	Nest success	Number surviving season	Nests/hen per season
2000	Adult	22	25	1.14	0.44	10	1.8
	Juvenile	63	54	0.86	0.56	22	1.45
2002	Adult	48	31	0.65	0.63	18	1.17
	Juvenile	99	77	0.78	0.70	47	1.15
2003	Adult	32	13	0.41	0.54	6	1.17
	Juvenile	95	44	0.46	0.54	19	1.16
2004	Adult	25	22	0.88	0.71	5	1.20
	Juvenile	76	36	0.47	0.67	15	1.00
2005	Adult	29	14	0.48	0.86	7	1.14
	Juvenile	64	33	0.52	0.69	20	1.05
2006	Adult	29	35	1.21	0.59	16	1.63
	Juvenile	85	56	0.66	0.64	24	1.17
2007	Adult	33	17	0.52	0.47	10	0.50
	Juvenile	63	25	0.40	0.56	18	0.78
2008	Adult	49	23	0.84	0.70	14	1.21
	Juvenile	55	19	0.49	0.67	15	0.33
2009	Adult	17	13	0.76	0.62	4	1.00
	Juvenile	93	76	0.83	0.64	34	1.41
2010	Adult	24	25	0.91	0.48	11	0.91
	Juvenile	68	51	1.00	0.65	29	1.03
All	Adult	308	218	0.78	0.60	101	1.17
years	Juvenile	761	471	0.65	0.63	243	1.03

Overall 344 hens survived from 15 April to 1 October including 101 adults and 243 juveniles. The annual ratio (mean ± SE) of nests per hen for adults to juveniles was 1.28 ± 0.27, although sample sizes of adults were low in several years. Summing over all years, adult hens produced 122 nests (1.21 nests/hen) versus 269 nests for juveniles (1.11 nests/hen) ($P = 0.025$). The greatest differences in nests per hen for adults and juveniles occurred in 2000, 2006, 2007, and 2008.

Nesting success (± SE) was 0.60 ± 0.041 for adults, similar to nesting success of juveniles (0.63 ± 0.018) (Table 1). The ratio of adult to juvenile nesting success was 0.92 but was not statistically different from 1 ($t_9 = –1.53$; $P = 0.16$).

Adult hens that survived the entire nesting season began incubating nests earlier than juveniles in 6 of 7 years (Table 2). Differences in incubation dates for adults to juveniles ranged from 1 day later to 24 days earlier with adults on average beginning nesting 11 days earlier than juveniles over all years. The proportion of hens that survived the nesting season that incubated at least 1 nest was not different for adults (0.87) or juveniles (0.82) ($P = 0.37$). Clutch size averaged (± SE) 12.48 ± 0.79 eggs for adult hens and 12.93 ± 0.08 eggs for juvenile hens.

Table 2. Nesting rate, clutch size, and date of first incubation of nests for radio-marked adult and juvenile northern bobwhite hens that survived the nesting season (15 Apr to 1 Oct), Tall Timbers Research Station, Leon County, Florida, USA, 2000–2006.

Year	Age	*n*	Nesters	Proportion that nested	Clutch size Mean ± SE	Date of first incubation
2000	Adult	10	9	0.90	13.9 ± 0.79	8 Jun
	Juvenile	22	21	0.95	12.9 ± 0.55	18 Jun
2002	Adult	18	17	0.94	12.8 ± 0.72	4 Jun
	Juvenile	47	42	0.89	12.7 ± 0.86	17 Jun
2003	Adult	6	5	0.83	13.5 ± 0.68	3 Jul
	Juvenile	19	16	0.84	12.3 ± 0.94	2 Jul
2004	Adult	5	3	0.60	8.6 ± 1.09	23 Jun
	Juvenile	15	10	0.67	12.6 ± 1.29	4 Jul
2005	Adult	7	5	0.71	13.2 ± 0.66	17 Jun
	Juvenile	20	15	0.75	12.5 ± 0.72	11 Jul
2006	Adult	16	15	0.94	12.9 ± 1.11	8 Jun
	Juvenile	24	20	0.83	12.5 ± 1.04	17 Jun
All	Adult	62	54	0.87	12.5 ± 0.79	
	Juvenile	164	134	0.82	12.9 ± 0.08	

DISCUSSION

Adult bobwhite hens incubated more nests over the course of a nesting season but the magnitude of the difference varied significantly among years. Adults produced on average for all years ~ 25% more nests than juveniles in the breeding population. However, most of the difference in productivity occurred in 4 of 10 years, 2000, 2004, 2006, and 2008 during which the average nest per hen for adults (1.02) was 1.7 times greater than that of juveniles (0.62). Each of these years was followed by 1 to 3 years in which juvenile and adult nest production was approximately equal. The bobwhite population in each of these years increased significantly over the previous year, based on mark-recapture estimates, fall covey counts, and hunter success per unit of effort (W. E. Palmer, unpublished data), especially in 2000, 2006, and 2008; bobwhite populations peaked during 2002 and 2010.

Comparisons of nesting productivity for bobwhites that survived the nesting season also had the same directional relationship as that for our entire data set. However, ratios on an annual basis were unstable due to low sample sizes ($n < 10$) of adults in most years. Nesting productivity of adult hens, averaged across all years, was greater than juveniles. These results suggest adult bobwhites in some years nest more prolifically than juveniles and this may be part of how bobwhite populations increase substantially when conditions permit. There was no difference in the proportion of adult and juvenile hens that incubated 1 or more nests, suggesting greater renesting by adults was the cause of higher nest productivity. Total nest production has been found to be a major factor in percent summer gain in bobwhites (Dimmick 1974, Klimstra and Roseberry 1975). However, further research is needed regarding the causal mechanisms of age-specific nesting in bobwhites and its demographic impact on population dynamics. Adults typically compose ~10–30% of bobwhite populations (Rosene 1969). Demographically, an increase in productivity by a small proportion of the population would not likely impact population growth. However, we have observed juvenile to adult ratios closer to unity following periods of population decline suggesting higher productivity of adults during those years resulted in steeper increases in population size due to adult reproductive performance.

Greater survival of adults could explain increased nest productivity of adults; however, we do not believe this was the cause during our study. Annual survival of adult and juvenile bobwhites on Tall Timbers did not differ in 2 long-term studies (Pollock et al. 1989, Palmer and Wellendorf 2007). Terhune et al. (2007) found no difference in survival of adults and juveniles during a long-term study in Georgia. Thus, we do not believe differences in survival were causal to increased nesting of adults.

There was no difference in nesting success which suggests increased nesting was not likely a function of higher pre-incubation survival of nests of adults versus nests of juveniles. Other studies have found previous experience increases nesting success of birds (Hepp and Kennamer 1989, Martin 1995). There was no difference in success of nests, but adult hens began nesting earlier than juveniles, adding up to 3 weeks to the nesting season. Earlier recrudescence may provide increased nesting season length providing for more time for renesting and increased nest production over the nesting season. That adult bobwhites nested earlier than juveniles is a common finding among birds (Martin 1995).

Hernández et al. (2007) found minor differences in nesting parameters among adults and juveniles. Our study suggests large sample sizes of radio-marked bobwhites over many years is necessary to identify increased nesting productivity because it did not occur each year of study. Sample sizes for adults, even with > 1,000 radio-marked hens, were marginal in many years, especially for hens that survived the entire nesting season. Our results agree with those of Brooks (2005) who suggested, at least in some years, adult bobwhites have higher nesting rates.

MANAGEMENT IMPLICATIONS

This study suggests adult bobwhites have higher productivity in some years and we cautiously suggest this result may influence population growth in some years. This indicates the importance of maintaining high quality nesting and brood-rearing habitat to take advantage of high productivity of adults. Further, it suggests the increase in productivity of adults, if associated with population increases following declining years, may be an important density-dependent process and harvest of adult bobwhites following periods of poor productivity (i.e., few juveniles in the population) could have increased additive effects on population growth. This suggests conservative harvests are more important when juvenile to adult age ratios are skewed towards adults (Williams et al. 2004). Additional research and modeling are needed to verify these implications.

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LITERATURE CITED

Brittas R., V. Marcström, R. E. Kenward, and M. Karlbom. 1992. Survival and breeding success of reared and wild ring-necked pheasants in Sweden. Journal of Wildlife Management 56: 368–376.

Brooks, J. L. 2005.The role of covey demographics in northern bobwhite (*Colinus virginianus*) production. Thesis. Texas A&M University, College Station, USA.

Caizergues, A., and L. N. Ellison. 2000. Age-specific reproductive performance of black grouse *Tetrao tetrix* females. Bird Study 47:344–351.

Curio, E. 1983. Why do young birds produce less well? Ibis 125:400–404.

Dimmick, R. W. 1974. Populations and reproductive effort among bobwhite in western Tennessee. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 28:594–602.

ESRI. 2007. ArcGIS Desktop: Release 9.3. Environmental Systems Research Institute, Redlands, California, USA.

Guthery, F. S., N. E. Koerth, and D. S. Smith. 1988. Reproduction of northern bobwhites in emiarid environments. Journal of Wildlife Management 52:144–149.

Hepp, G. R., and R. A. Kennamer. 1993. Effects of age and experience on reproductive performance of wood ducks. Ecology 74:2027–2036.

Hernández, F., K. M. Kelley, A. J. Arredondo, F. Hernández, D. G. Hewitt, F. C. Bryant, and R. L. Bingham. 2007. Population irruptions of northern bobwhite: testing an age-specific reproduction hypothesis. Journal of Wildlife Management 71:895–901.

Klimstra, W. D., and J. L. Roseberry. 1975. Nesting ecology of the bobwhite in southern Illinois. Wildlife Monographs 41.

Lehmann, V. W. 1953. Bobwhite population fluctuations and vitamin A. Transactions of the North American Wildlife Conference 18:199–246.

Martin, K. 1995. Patterns and mechanisms of age dependent reproduction and survival in birds. American Zoologist 35:123–141.

Norman, G. W., J. C. Pack, C. I. Taylor, D. E. Steffen, and K. H. Pollock. 2001. Reproduction of eastern wild turkeys in Virginia and West Virginia. Journal of Wildlife Management 65:1–9.

Palmer, W. E., and S. D. Wellendorf. 2007. Effects of radio-transmitters on northern bobwhite survival. Journal of Wildlife Management 71:1281–1287.

Palmer, W. E., S. D. Wellendorf, L. A. Brennan, W. R. Davidson, and F. E. Kellogg. 2002. Hunting success and northern bobwhite density on Tall Timbers Research Station: 1970–2001. Proceedings of the National Quail Symposium 5:213–217.

Pitman, J. C., C. A. Hagen, B. E. Jamison, R. J. Robel, T. M. Loughin, and R. D. Applegate. 2006. Nesting ecology of lesser prairie-chickens in sand sagebrush prairie of southwestern Kansas. Wilson Journal of Ornithology 118: 23–35.

Pollock, K. H., C. T. Moore, W. R. Davidson, F. E. Kellogg, and G. L. Doster. 1989. Survival rates of bobwhite quail based on band recovery rates. Journal of Wildlife Management 53:1–6.

Roberts, S. D., J. M. Coffey, and W. F. Porter. 1995. Survival and reproduction of female wild turkeys in New York. Journal of Wildlife Management 59:437–447.

Rosene Jr., W. 1969. The bobwhite quail: its life and management. Rutgers University Press, New Brunswick, New Jersey, USA.

Sæther, B.-E. 1990. Age-specific variation in reproductive performance of birds. Current Ornithology **7:**251–283.

Stoddard, H. L. 1931. The bobwhite quail: its life history and management. Charles Scribner's Sons, New York, USA.

Terhune, T. M., D. C. Sission, J. B. Grand, and H. L. Stribling. 2007. Factors influencing survival of radiotagged and banded northern bobwhites in Georgia. Journal of Wildlife Management 71:1288–1297.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, Inc., San Diego, California, USA.

Williams, C. K., R. S. Lutz, and R. D. Applegate. 2004. Winter survival and additive harvest in northern bobwhite coveys in Kansas. Journal of Wildlife Management 68:94–100.

NORTHERN BOBWHITE AGE RATIOS AND PRODUCTIVITY AT THE INDIVIDUAL PROPERTY SCALE IN SOUTH TEXAS

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ABSTRACT

Annual adult survival rate ($\hat{S}$) and finite rate of population growth (λ) are critical parameters that must be considered when subjecting a species to annual harvest. We used a data set of 148 estimates of northern bobwhite (*Colinus virginianus*) juvenile: adult age ratios (R) derived from hunter-harvested wings in the South Texas Plains to estimate these parameters. Data were collected from 1940 to 1976 and from 1983 to 2008. We used adjusted estimates of R to account for higher harvest vulnerability of juveniles, and the regional estimate of $\hat{S}$ (30.6% based on a stable population) to calculate estimates of λ at the ranch (~800–2,000 ha) scale. Mean (± SE) adjusted R was 2.79 ± 0.13 juveniles: adult. Assuming a stable population (i.e., $\lambda = 1$), mean (± SE) regional $\hat{S}$ was 30.6 ± 0.1%. Given an annual $\hat{S}$ of 30.6%, mean regional λ was 1.16 ± 0.04, and single year λ estimates ranged from 0.40 to 3.03 among individual properties. These data have important implications for bobwhite harvest management because they identify the potential for highly variable population growth rates (λ) at a localized scale. There is an increased probability of overharvesting the population when local populations are declining. Our data indicate using only a regional estimate of λ may mask local population trends, which has the potential for mismanagement of harvest within a given property by making harvest recommendations that are too high (overharvest) or too conservative (loss of opportunity).

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Key words: *Colinus virginianus*, northern bobwhite, population growth, survival, Texas

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EFFICACY OF TARGETED MIST-NETTING TO CAPTURE NORTHERN BOBWHITES DURING THE NON-BREEDING SEASON IN OHIO

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ABSTRACT

Baited funnel traps and nightlighting are well established northern bobwhite (*Colinus virginianus*) capture techniques, but their use is not always appropriate, particularly on private land where cooperating landowners may place constraints on research activities. Alternative capture techniques may be more effective under conditions considered to be unfavorable for established techniques (e.g., periods with abundant natural food). Targeted mist-netting, where mist nets are erected near the known location of specific individuals, has been used to capture gallinaceous species and may be an effective alternative to established bobwhite capture techniques. We evaluated the effectiveness of using targeted mist-netting to capture bobwhites during the non-breeding season in Ohio. We tested for differences in survival and age and sex ratios of individuals captured with targeted netting and baited funnel traps. We captured 257 individuals with targeted netting during 1 October-28 February 2009–2011 and concurrently captured 253 individuals with baited funnel traps. There was a short-term influence of capture and handling, but there was no significant difference in post-capture survival of bobwhites captured with targeted netting or trapping. Capture rates of age and sex classes were similar ($P = 0.488$ and $P = 0.973$, respectively) between targeted netting and trapping. Body mass of bobwhites captured by targeted netting was less than that of bobwhites captured by trapping ($P = 0.009$) suggesting that netting may provide more accurate estimates of body mass. We used targeted netting to capture bobwhites in a variety of situations where use of funnel traps was ineffective or problematic. Targeted netting was effective and often more compatible with constraints of working on private land than established capture techniques.

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Key words: capture techniques, *Colinus virginianus*, mist netting, northern bobwhite, Ohio, private land, Program MARK, radiotelemetry, survival, trapping

INTRODUCTION

Northern bobwhites have been studied for > 80 years (Scott 1985, Brennan 1999), but capture techniques used during the non-breeding season are largely unchanged. The 2 most commonly used, baited funnel traps (Stoddard 1931: 422) and nightlighting (Labisky 1968), have been effective in a variety of habitat types and seasons making use of alternative capture techniques generally unnecessary (e.g., Hernández et al. 2006). However, their use is not always compatible with working on private land. Both techniques require frequent investigator presence that could disrupt alternative activities on private lands (e.g., hunting, farming) and cause landowners to deny or rescind permission for access to their properties (Hilty and Merenlender 2003). The effectiveness of traditional techniques can vary with environmental conditions (e.g., periods with abundant food). Capture techniques that minimize investigator presence and are effective in a variety of environmental conditions may be more compatible with working on private lands and provide researchers with an alternative to traditional capture techniques.

Mist nets have been used to capture gallinaceous species in conjunction with audio lures (Cink 1975, Lohr et al. 2011), pointing dogs (Skinner et al. 1998), radiotelemetry (Schladweiler and Mussehl 1969), and researchers directing the path of flushing birds (Silvy and Robel 1968, Campbell 1972, Browers and Connelly 1986). Schladweiler and Mussehl (1969) used a mist-netting technique to capture specific radio-marked individuals. Skinner et al. (1998) used a comparable technique to capture juvenile willow ptarmigan (*Lagopus lagopus*) over pointing dogs. Investigators knew the location of birds in both applications, and placed mist nets to intersect the predicted flushing direction, effec-

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tively targeting specific individuals for capture (i.e., targeted netting). Targeted netting for bobwhites is not new, but the relative convenience of mist nets has made it far more practical than early attempts with clap nets (Stoddard 1931: 441). Mist nets have been used to capture bobwhites, but investigators passively netted individuals attracted by an audio lure during the breeding season (Cink 1975, Lohr et al. 2011). Targeted mist-netting should be an effective way to capture bobwhites during the non-breeding season because of their gregarious behavior during this period and their relatively low and short flight trajectories (Kassinis and Guthery 1996). Coveys can be located and targeted for capture by following previously radio-marked individuals, using pointing dogs, or after incidental flushes.

We evaluated the effectiveness of targeted mist-netting to capture bobwhites during the non-breeding season on private lands in southwestern Ohio. Our objectives were to: (1) evaluate the efficacy of targeted netting to capture bobwhites; (2) compare body mass, age, and sex ratios of individuals captured with baited funnel traps and mist nets to test for potential capture-related biases; and (3) test for differences in post-capture survival of individuals captured with baited funnel traps and mist nets.

STUDY AREA

We worked on 4 private land sites in Highland and Brown counties in southwestern Ohio (centered at 39° 04′59”, 83° 39′10”). The sites were in the glaciated till plains physiographic region (Ohio Division of Geologic Survey 1998). The predominant land-use in the area was agriculture (39% row crops and 17% pasture/hay fields; Homer et al. 2004). Mean annual temperature was 11.1 °C and mean annual precipitation was 110.2 cm (NCDC 2011).

Habitat composition on the study sites was primarily row crop agriculture (55%) planted in soybeans and corn. Forests covered 13% of the study sites and were dominated by oak (*Quercus* spp.) and hickory (*Carya* spp.), although some bottomland forests were primarily ash (*Fraxinus* spp.) and black walnut (*Juglans nigra*). Early successional vegetation, including grasslands, old-fields, fencerows, and ditches covered 19% of the study area. Grasslands were generally dominated by fescue (*Festuca* spp.) or Indiangrass (*Sorghastrum nutans*). The most common shrub species used by bobwhites were blackberry (*Rubus allegheniensis*) and black raspberry (*R. occidentalis*).

METHODS

We captured bobwhites during 1 October-28 February 2009–2011 using baited funnel traps or targeted netting. Trapping, handling, and marking protocols were reviewed and approved by the Animal Care and Use Committee at Ohio State University (protocol # 2007A0228). We did not use nightlighting because of the proximity of study sites to areas where people unfamiliar with our research might have been alarmed by activity after sunset. Implementation of capture methods was non-random and opportunistic, dictated by expediency and necessity. We used both capture methods concurrently throughout the study period to maintain ≥ 1 radio-marked individuals in each known covey within the study sites.

Funnel traps were 30 × 40 x 45 cm and were baited with cracked corn. Traps were covered with burlap (Stoddard 1931: 443) to reduce trap-related injuries. We placed traps in areas where use by bobwhites was evident. We pre-baited trap sites with cracked corn for 1 week before traps were used. We positioned traps within cover and concealed them with vegetation to protect bobwhites from predators and weather. We checked traps ≥ 2 times per day after sunrise and at sunset. We documented trapping effort (i.e., trap-days) during the 2010–2011 field season.

We used 61-mm mesh 4-shelf mist nets for targeted netting (AFO Mist Nets, Manomet, MA, USA). Each net measured 2.6 by 12 m and was suspended between 2, 3.05-m aluminum conduit poles (1.9-cm diam). We used homing or triangulation from short distances to locate coveys with previously radio-marked individuals (White and Garrott 1990). We identified the apparent location for coveys that did not contain radio-marked individuals using cues from pointing dogs and by visually marking the location of bobwhites that were flushed incidental to other research activities. Nets were erected near the anticipated covey location and positioned to intersect the most likely flight path of flushing bobwhites. We identified the most likely flight path based on characteristics of nearby cover, position of pointing dogs, and direction of investigator approach. We typically used 1–2 nets during each attempt, although up to 4 nets were used within expansive homogenous cover (e.g., grass fields) where flight direction was less predictable. Investigators flushed bobwhites toward the standing nets and extracted entangled birds. We defined netting attempts as events where ≥ 1 bobwhite was flushed after ≥ 1 mist net was fully deployed. We documented all netting attempts including date, method of bobwhite location, habitat type, number of bobwhites captured, and reasons for failure. We defined successful attempts as those that resulted in capture of ≥ 1 bobwhite.

We recorded age and sex of each bobwhite (Rosene 1969: 44–54), and weighed birds to the nearest gram. We leg-banded all captured bobwhites and radiomarked a subset of individuals weighing ≥ 165 g with pendant-style mortality-sensing radio transmitters (6.6 g; Advanced Telemetry Systems, Isanti, MN, USA). We released bobwhites at the capture site immediately after processing and marking. We located each radio-marked individual ≥ 6 times/week by homing or triangulation (White and Garrott 1990). We immediately located the transmitter after detecting a mortality signal and inferred the cause of mortality based on field signs at recovery sites or condition of the transmitter.

We used a Chi-square test to examine differences in age and sex ratios of individuals captured. We used a *t*-test to examine differences in body mass potentially

Table 1. Total number of targeted netting attempts on bobwhites and capture success rates by covey location method during October-February 2009–2011 in southwestern Ohio.

Location method	No. of attempts	Success rate (%)
Radiotelemetry	155	67.7
Pointing dog	30	76.7
Incidental contact	16	81.3

caused by consumption of bait after capture in funnel traps. We excluded individuals < 150 days of age based on molt of primary flight feathers (Rosene 1969) in body mass comparisons. We assumed potential influences associated with handling and radiomarking were equal between capture methods and tested for differences in post-capture survival between the 2 techniques. We used funnel traps and targeted mist-netting concurrently and assume captured individuals were exposed to the same natural mortality factors. We used the nest survival model in Program MARK to compare post-capture survival over a 21-day interval starting at the day of the initial capture. We assumed mortalities after a 21-day interval were unrelated to the initial capture. Abbott et al. (2005) detected differences in survival between 45 and 62 days but we assumed that such differences would be difficult to detect in our data set, because of the low survival observed in the population (Janke and Gates 2012).

We compared 8 models with age and temporal (i.e., year and time) effects (Holt et al. 2009). We used the most parsimonious baseline model to examine the influence of capture technique (netting or trapping) and linearly decreasing effects representing days since capture (DSC). The DSC covariates represented a decreasing linear trend from day of capture through 3, 7, 14, or 21 days. Day values represented a range of traditional censoring periods used in radiotelemetry studies to control for short-term acute effects of capture and handling (Holt et al. 2009). We developed a candidate model set that included a model for each DSC covariate alone, each DSC covariate with a capture technique effect, and their interaction. Interaction terms were used to test for differences in DSC influences between capture techniques. We compared models with Akaike's Information Criteria corrected for small sample sizes (AIC_c), and considered all models with $\Delta AIC_c < 2.0$ as having equivalent support (Burnham and Anderson 2002). We interpreted the influence of each parameter in the top models based on model-averaged coefficients and 95% confidence intervals.

Table 2. Total number of targeted netting attempts on bobwhites and capture success rates by habitat type during October-February 2009–2011 in southwestern Ohio.

Habitat type	No. of attempts	Success rate (%)
Agricultural field	13	53.8
Grassland and old field	56	76.8
Woody ditch and fencerow	103	69.9
Woodlot	17	47.1
Unknown (not recorded)	12	91.7

Table 3. Sex and age distributions of bobwhites captured by targeted netting and baited funnel traps during October-February 2009–2011 in southwestern Ohio.

		Capture method	
		Targeted netting	Baited funnel traps
Sex	Male	132	136
	Female	104	106
	Unknown	21	11
Age	Adult	59	52
	Juvenile	191	200
	Unknown	7	1

RESULTS

We captured 257 individuals with targeted netting (137 in 2009-10 and 120 in 2010-11) and 253 individuals with baited funnel traps (105 in 2009-10 and 148 in 2010-11). A single successful netting attempt generally captured ≤ 4 birds, whereas a successful trap was capable of capturing as many as 18 in a single event. We captured 0.306 birds/trap-day in 484 trap-days during the 2010–2011 field season. We made 201 targeted-netting attempts of which 141 (70.1%) were successful. Success rates were similar among covey location methods (Table 1) and habitat types (Table 2). We incorrectly predicted flight path in 56.7% of all failed netting attempts for which reason for failure was recorded ($n = 30$). Flight in the predicted direction but over standing nets contributed to 36.7% of recorded failures. Other reasons for failure included bobwhites breaking through or striking the net without becoming entangled. There were no differences in age ($\chi^2 = 0.480$, df $= 1$, $P = 0.4884$) or sex ($\chi^2 = 0.001$, df $= 1$, $P = 0.973$) ratios of birds captured between the 2 techniques (Table 3). Mean body mass of bobwhites captured by targeted netting (mean $= 185.6$ g, 95% CI $=$ 183.5-187.6 g) was less than bobwhites caught in traps (mean $= 191.4$ g, 95% CI $= 188.7$-194.1 g; $P = 0.009$). Bobwhites or non-target passerines died in funnel traps in ≥ 8 events during the study period, all of which resulted from predation while in the trap. Trapped bobwhites occasionally sustained visible injuries (e.g., scalp lacerations) from striking the top of the trap. No bobwhites died during capture with mist nets although 2 (0.8%) were visibly injured by pointing dogs following entanglement in the net.

We included 259 individuals in the survival analysis (netting: $n = 153$, trapping: $n = 103$). The best fitting baseline model in the survival analysis represented an across year quadratic relationship with time (Table 4). The addition of DSC covariates improved the fit of the baseline model but models with a capture technique term were not competitive (Table 5). Model averaged coefficient for the technique term was $\beta_{net} = 0.002$ (95% CI $=$ –0.214, 0.219) and the odds ratio was 1.002 (95% CI $=$ 0.807, 1.244) indicating there was no difference in

Table 4. Baseline temporal models used to control for seasonal variation in survival of bobwhites captured with baited funnel traps and targeted mist-netting during October-February 2009–2011 in southwestern Ohio.

Model[a]	k^b	$AIC_c{}^b$	$\Delta AIC_c{}^b$	$w_i{}^b$
Across year quadratic time	3	624.28	0.000	0.385
Within year time	2	625.96	1.684	0.166
Null	1	626.39	2.111	0.134
Age	2	627.29	3.014	0.085
Across year time	2	627.43	3.148	0.080
Year + within year time	3	627.82	3.544	0.065
Year	2	628.28	4.005	0.052
Year + age	3	629.26	4.983	0.032

[a] Time = linear trend increasing from 1.

[b] k = number model parameters; AIC_c = Akaike's Information Criteria corrected for small sample sizes; ΔAIC_c = change in AIC_c from lowest model; w_i = Akaike's weight.

survival between the 2 techniques. The model with a 7-day acute influence had the most support ($w_i = 0.275$) and models including 14- and 21-day parameters had moderate support ($w_i = 0.183$ and $w_i = 0.108$ respectively; Table 5). The model averaged coefficient for the 7 DSC covariate was $\beta = -0.131$ (95% CI = –0.232, –0.029). The model averaged coefficient for the 14 DSC covariate was $\beta = -0.064$ (95% CI = –0.119, –0.001). The model averaged coefficient for the 21 DSC covariate was $\beta = -0.049$ (95% CI = –0.095, –0.002).

DISCUSSION

Targeted netting was a versatile technique that we used effectively in situations where traditional bobwhite capture techniques were ineffective or not feasible. The high ranking of the DSC covariate models and the negative coefficients illustrates there was a short-term effect of capture, handling, or radiomarking in this study but odds ratio near 1 showed there was no difference in post-capture survival among the 2 capture techniques. Low ranking of the models with a technique by days since capture (DSC) interaction term also demonstrated the influence of capture was consistent among the 2 techniques. There was a short-term influence of capture and handling, but there were no significant differences in post-capture survival of bobwhites captured by targeted netting or in baited funnel traps. Targeted netting was unbiased in capture rates of age or sex classes. Targeted netting may have advantages over trapping in some situations because it provides a more accurate estimate of individual body mass (not biased by bait consumption) and can be used to quickly target specific individuals.

Targeted netting exploits the flushing behavior and flight characteristics of bobwhites. The tendency for bobwhites to remain motionless within concealing cover when approached allowed time to place nets near their position. The average maximum height of bobwhite flight is fairly low (2.4 m; Kassinis and Guthery 1996); Schorger (1946) observed that bobwhites in flight are generally incapable of avoiding objects with unnatural dimensions. The flight path of a flushing covey was typically through pathways free of obstruction in the direction opposite the position of a pointing dog or approaching investigator. Flight was often toward patches of dense vegetation in areas with patchy or fragmented cover and parallel to nearby woody cover (e.g., fence-rows, woodlot edges). The generally predictable nature of bobwhite flushing directions coupled with their low and straight flight trajectories made targeting netting effective in areas with linear features. Flight path was generally less predictable within homogenous cover (e.g., grasslands).

The most common reason for failed net attempts, flight away or to the side of nets, was due in part to incorrect predictions of flight path or inability to place nets in the most likely flight path due to physical

Table 5. Ranking for candidate model set with factors affecting post-capture survival of northern bobwhites captured with baited funnel traps and targeted netting during October-February 2009–2011 in southwestern Ohio.

Model[a]	k^b	$AIC_c{}^b$	$\Delta AIC_c{}^b$	$w_i{}^b$
TT + 7 DSC	4	619.87	0.000	0.275
TT + 14 DSC	4	620.68	0.807	0.183
TT + 21 DSC	4	621.75	1.873	0.108
TT + Technique+ 7 DSC	5	621.86	1.989	0.102
TT + Technique + 14 DSC	5	622.67	2.796	0.068
TT + 3 DSC	4	622.70	2.826	0.067
TT + Technique + 21 DSC	5	623.73	3.860	0.040
TT + Technique+ 7 DSC + Technique x 7 DSC	6	623.86	3.992	0.037
TT	3	624.28	4.407	0.030
TT + Technique + 14 DSC + Technique x 14 DSC	6	624.39	4.520	0.029
TT + Technique + 3 DSC	5	624.68	4.808	0.025
TT + Technique + 21 DSC + Technique x 21 DSC	6	625.52	5.646	0.016
TT + Technique	4	626.25	6.378	0.011
TT + Technique + 3 DSC + Technique x 3 DSC	6	626.64	6.771	0.009

[a] TT = baseline temporal model; DSC = days since capture.

[b] k = number model parameters; AIC_c = Akaike's Information Criteria corrected for small sample sizes; ΔAIC_c = change in AIC_c from lowest model; w_i = Akaike's weight.

obstructions. Flight over nets generally occurred within relatively tall, homogenous cover (e.g., woodlots) that forced bobwhites to flush more vertically to avoid obstructions. We could have used additional nets or taller net poles to address these situations but these alterations may have resulted in decreased placement efficiency. Our success rates were fairly high for all covey location methods and across different habitat types. Success rates with pointing dogs and incidental contact were higher than for radiotelemetry. Our definition of a net attempt excluded some causes of failure that were more common with attempts with pointing dogs or incidental flushes, which likely artificially inflated success rates. We were more likely to flush bobwhites before nets were deployed during capture attempts with pointing dogs or after incidental flushes than when using radiotelemetry. We occasionally failed to locate and flush any bobwhites after net deployment for all methods except radiotelemetry.

One of the primary benefits of targeted netting was the ability to capture bobwhites immediately after their location was known. A single experienced investigator could deploy a net within 5-20 m of bobwhites with relative ease in 2–3 min. We typically kept nets in field vehicles, furled and rolled on net poles, during daily activities and carried rolled nets while actively searching for coveys. This allowed us to take advantage of opportunities when unmarked coveys were encountered (i.e., dog pointing, incidental contact). Additionally, we could attempt targeted netting at different locations on several sites throughout the day, effectively spreading out capture effort. The area in which a single investigator could actively use funnel traps was restricted to that which could be quickly covered during trap checks and limited to only 1 site/day because of the distance between sites in our study ($\geq$ 7 km). The time-window for a trap check at sunset was particularly narrow because traps needed to be checked sufficiently late in the evening that bobwhites were unlikely to be captured afterward, yet sufficiently early that exposure of trapped bobwhites to nocturnal predators was minimized. Releasing captured bobwhites after sunset may predispose them to predation (Palmer and Wellendorf 2007).

Use of baited funnel traps is a well-established and effective capture technique for bobwhites, but we found it incompatible with landowner concerns in certain situations. Landowner acceptance is an important consideration when planning and conducting research on private land (Hilty and Merenlender 2003). Studies of recreational access on private lands indicate negative experiences (i.e., disruptive behavior, property damage) and protectionist attitudes (i.e., exclusive hunting rights, anti-hunting beliefs) were primary reasons for access to be denied (Stoddard and Day 1969, Brown 1974, Brown et al. 1984). Parallel concerns were expressed by several cooperating landowners in our study regarding the frequency and duration of investigator presence on their properties. Specific concerns included possible negative effects of investigator presence during hunting seasons. Hilty and Merenlender (2003) suggested landowners may be more accepting of experimental designs requiring only infrequent or brief visits to their property. Frequent trap checks, particularly during the hunting season, increased the likelihood of disturbing hunting or other recreational activities. Netting however, was used effectively throughout the day, allowing for more flexibility in our presence on a particular property. Properties could be avoided when hunters were present and accessed when the chances of disturbing hunters were relatively low.

Bait provided for trapping may have biased body mass estimates and may also have lingering effects on behavior or survival. We observed that coveys with radio-marked birds concentrated activities around bait piles during pre-baiting and trapping periods, which may have temporarily biased movements or survival (Robel and Kemp 1997, Townsend et al. 1999, Haines et al. 2004). Targeted netting captured individuals *in situ* and resulted in a quick release into the cover in which quail were found immediately prior to capture.

We found targeted mist-netting has applications outside the non-breeding season, when traditional capture techniques are generally less efficient (Wellendorf et al. 2002). We used targeted netting during summer to capture calling males, individuals paired with radio-marked bobwhites, and fledged young associated with a brooding adult (M. R. Liberati, personal communication). Capturing post-fledging young before separation from brooding adults may merit additional research because of the challenges presented in studying bobwhite chick survival (Roseberry and Klimstra 1984). Smith et al. (2003) used a wire fence erected around roosting radio-marked adults tending a brood in which some or all chicks were captured in 87% of capture attempts. This technique can be effective, but it requires that chicks can not fly (1–12 days post hatch) whereas we used targeted netting to capture flying chicks $\geq$12 days of age with a radio-marked adult. This technique could potentially provide an additional recapture period for capture-mark-recapture studies that use both chick-capture techniques. We found the smaller chicks were more capable of passing through the 61-mm mesh nets, and recommend that future investigations experiment with smaller mesh to capture chicks.

MANAGEMENT IMPLICATIONS

Targeted mist-netting is an effective alternative to traditional capture techniques, particularly when landowners place constraints on research activities, specific individuals are to be targeted, accurate measurements of body mass are required, or when traditional techniques are otherwise not feasible. Mist nets are highly portable and can be effective in all seasons. Researchers can quickly capture individuals from multiple coveys within a relatively short period of time using targeted netting in conjunction with well-trained pointing dogs or radiotelemetry. Targeted netting may also provide an effective capture technique for bobwhite chicks after they are able to fly. Investigators could use targeted netting concurrently with baited funnel traps or other capture techniques to optimize capture, particularly if their objective is to quickly capture as many individuals as possible.

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LITERATURE CITED

Abbott, C. W., C. B. Dabbert, D. R. Lucia, and R. B. Mitchell. 2005. Does muscular damage during capture and handling handicap radiomarked northern bobwhites? Journal of Wildlife Management 69:664–670.

Brennan, L. A. 1999. Northern bobwhite (*Colinus virginianus*). The birds of North America. Number 397.

Browers, H. W., and J. W. Connelly. 1986. Capturing sage grouse with mist nets. Prairie Naturalist 18:185–188.

Brown, T. L. 1974. New York landowners' attitudes toward recreation activities. Transactions of the North American Wildlife and Natural Resources Conference 39:255–263.

Brown, T. L., D. J. Decker, and J. W. Kelley. 1984. Access to private lands for hunting in New York: 1963–1980. Wildlife Society Bulletin 12:344–349.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer-Verlag, New York, USA.

Campbell, H. 1972. A population study of lesser prairie chickens in New Mexico. Journal of Wildlife Management 36:689–699.

Cink, C. L. 1975. Capturing bobwhites with mist nets, recordings and decoys. Inland Bird Banding News 47:83–86.

Haines, A. M., F. Hernandez, S. E. Henke, and R. L. Bingham. 2004. Effects of road baiting on home range and survival of northern bobwhites in southern Texas. Wildlife Society Bulletin 32:401–411.

Hernandez, F., L. A. Harveson, and C. E. Brewer. 2006. A comparison of trapping techniques for Montezuma quail. Wildlife Society Bulletin 34:1212–1215.

Hilty, J., and A. M. Merenlender. 2003. Studying biodiversity on private lands. Conservation Biology 17:132–137.

Holt, R. D., L. W. Burger, S. J. Dinsmore, M. D. Smith, S. J. Szukaitis, and K. D. Godwin. 2009. Estimating duration of short-term acute effects of capture handling and radiomarking. Journal of Wildlife Management 73:989–995.

Homer, C., C. Huang, C. Yang, B. Wylie, and M. Coan. 2004. Development of a 2001 national land-cover database for the United States. Photogrammetric Engineering and Remote Sensing 70:829–840.

Janke, A. K., and R. J. Gates. 2012. Temporal variability in survival of non-breeding northern bobwhites in Ohio. Proceedings of the National Quail Symposium 7:194–201.

Kassinis, N. I., and F. S. Guthery. 1996. Flight behavior of northern bobwhites. Journal of Wildlife Management 60:581–585.

Labisky, R. F. 1968. Nightlighting: its use in capturing pheasants, prairie chickens, bobwhites, and cottontails. Illinois Natural History Survey Biological Notes 62.

Lohr, M., B. M. Collins, P. M. Castelli, and C. K. Williams. 2011. Life on the edge: northern bobwhite ecology at the northern periphery of their range. Journal of Wildlife Management 75:52–60.

National Climate Data Center (NCDC). 2011. Quality controlled local climatological data. U.S. Department of Commerce, Asheville, North Carolina, USA. www.ncdc.noaa.gov/oa/ncdc.html

Ohio Division of Geologic Survey. 1998. Physiographic regions of Ohio. Ohio Department of Natural Resources, Columbus, USA.

Palmer, W. E., and S. D. Wellendorf. 2007. Effect of radiotransmitters on northern bobwhite annual survival. Journal of Wildlife Management 71:1281–1287.

Robel, R. J., and K. E. Kemp. 1997. Winter mortality of northern bobwhites: effects of food plots and weather. Southwestern Naturalist 42:59–67.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, USA.

Rosene Jr., W. 1969. The bobwhite quail: its life and management. Sun Press, Hartwell, Georgia, USA.

Schladweiler, P., and T. W. Mussehl. 1969. Use of mist-nets for recapturing radio-equipped blue grouse. Journal of Wildlife Management 33:443–444.

Schorger, A. W. 1946. The quail in early Wisconsin. Transactions of the Wisconsin Academy of Sciences, Arts and Letters 36:77–103.

Scott, T. G. 1985. Bobwhite thesaurus. International Quail Foundation, Edgefield, South Carolina, USA.

Silvy, N. J., and R. J. Robel. 1968. Mist nets and cannon nets compared for capturing prairie chickens on booming grounds. Journal of Wildlife Management 32:175–178.

Skinner, W. R., D. P. Snow, and N. F. Payne. 1998. A capture technique for juvenile willow ptarmigan. Wildlife Society Bulletin 26:111–112.

Smith, M. D., A. D. Hammond, L. W. Burger, W. E. Palmer, A. V. Carver, and S. D. Wellendorf. 2003. A technique for capturing northern bobwhite chicks. Wildlife Society Bulletin 31:1054–1060.

Stoddard, C. H., and A. M. Day. 1969. Private lands for public recreation: is there a solution? Transactions of the North American Wildlife and Natural Resources Conference 34:186–196.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner's Sons, New York, USA.

Townsend II, D. E., R. L. Lochmiller, S. J. DeMaso, D. M. Leslie Jr., A. D. Peoples, S. A. Cox, and E. S. Parry. 1999. Using supplemental food and its influence on survival of northern bobwhite (*Colinus virginianus*). Wildlife Society Bulletin 27:1074–1081.

Wellendorf, S. D., A. V. Carver, and W. E. Palmer. 2002. Comparison of methods to capture bobwhites during summer. Proceedings of the National Quail Symposium 5:219.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radiotracking data. Academic Press, Inc., San Diego, California, USA.

PARASITIC EYEWORM (*OXYSPIRURA PETROWI*) IN NORTHERN BOBWHITES FROM THE ROLLING PLAINS OF TEXAS, 2007–2011

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ABSTRACT

The eyeworm *Oxyspirura petrowi* is an indirect life cycle nematode that occurs under the nictitating membrane on the eye surface of certain bird species. Previous studies from western or northwestern regions of Texas reported *O. petrowi* from northern bobwhites (*Colinus virginianus*), scaled quail (*Callipepla squamata*), and Montezuma quail (*Cyrtonyx montezumae*). We examined 173 bobwhites from the Rolling Plains of Texas collected during the 2007–2008 ($n = 33$), 2009–2010 ($n = 86$), and 2010–2011 ($n = 54$) hunting seasons, respectively. Overall, 99 (57%) bobwhites were infected with 596 individual *O. petrowi*; the mean (± SD) eyeworm intensity was 6.0 ± 6.4 (range = 1–40) and mean abundance was 3.4 ± 5.7. Thus, this eyeworm is a commonly occurring parasite of bobwhites in the Rolling Plains of Texas. Additional surveys are needed to learn more about the geographic distribution of *O. petrowi* and to assess the possible negative effects on individual bobwhites and their populations.

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Key words: *Colinus virginianus*, eyeworm, helminth, northern bobwhite, *Oxyspirura petrowi*, Texas

INTRODUCTION

There have been concerns about the decline in abundance of northern bobwhites throughout their range, including Texas. Thus, there is keen interest in understanding factors that negatively affect bobwhite populations. One factor needing more thorough examination is the influence of parasites on bobwhite life history (Peterson 2007).

One parasite that has generated concern about potential negative effects on quail is the eyeworm *Oxyspirura petrowi*. It is unclear what, if any, pathological effect *O. petrowi* has on host individuals due to the lack of detailed studies, but Ruff (1984) suggested pathological effects would likely be similar to that of the poultry eyeworm (*O. mansoni*). Additionally, non-pathological consequences of infection may be important. One potential consequence could be visual obstruction by the parasites that could obscure vision and make infected birds less aware of environmental hazards and predators, thereby reducing their fitness.

A review conducted by Peterson (2007) indicated *O. petrowi* has been found in northern bobwhites, scaled quail, and Montezuma quail in Texas. Only one published study has reported *O. petrowi* in bobwhites from Texas, specifically the Rolling Plains (Jackson 1969). This study reported eyeworms in 49.5% of bobwhites and to be relatively common in West Texas. Only the life cycle of *O. mansoni* of the 84 species of oxyspiruids has been sufficiently examined (Anderson 2000), and it is uncertain which species of intermediate hosts are used by *O. petrowi* (Pence 1972). Intermediate hosts of *Oxyspirura* spp. include cockroaches (*Pycnocelus surinamensis*) (Fielding 1926, Sanders 1928) and grasshoppers (*Melanoplus* spp.) (Cram et al. 1931). Experimental studies by Fielding (1926, 1927) using *O. mansoni* (= *O. parvovum*), demonstrated the larval eyeworm exits the intermediate host in the definitive host's crop within minutes, likely governed by the temperature difference between the host's crop and the insect. The larvae, upon exiting the insect, migrate up the esophagus into the mouth and through the infra-ocular sinus cavity or nasolachrymal duct to the eyes where they develop into adults (Ruff 1984).

Our objective was to document the prevalence, intensity of infection, and abundance of *O. petrowi* in northern bobwhites by hunting season, host age, and host

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Table 1. Prevalence, intensity, and abundance (± SD) of *Oxyspirura petrowi* in northern bobwhites by age, gender, and hunting season in the Rolling Plains of Texas during 2007–2008, 2009–2010, and 2010–2011.

	Overall	Adult	Juvenile	Male	Female	2007–2008	2009–2010	2010–2011
Number of hosts	173	85	88	94	79	33	86	54
Prevalence No. infected (%)	99 (57%)	57 (67%)	42 (48%)	53 (56%)	46 (58%)	19 (58%)	54 (63%)	26 (48%)
Intensity	6.0 ± 6.4	6.9 ± 7.3	4.8 ± 4.7	5.8 ± 5.2	6.3 ± 7.6	8.3 ± 10.1	5.0 ± 4.2	6.5 ± 6.6
Abundance	3.4 ± 5.7	4.6 ± 6.8	2.3 ± 4.0	3.3 ± 4.8	3.7 ± 6.6	4.8 ± 8.6	3.1 ± 4.1	3.1 ± 5.6

gender on a ranch within the Rolling Plains ecoregion of Texas.

STUDY AREA

Our study sites were the Rolling Plains Quail Research Ranch (RPQRR) and the Melton Ranch near Roby in Fisher County, Texas, USA. The RPQRR is ~ 1,902 ha in size, where the main research focus is to sustain Texas' wild quail hunting heritage for this and future generations. This area is mostly rangeland with ranching and farming the major land uses. Common plants are mesquite (*Prosopis glandulosa*), prickly pear (*Opuntia* spp.), lotebush (*Ziziphus obtusifolia*), and sand shinnery oak (*Quercus havardii*), all of which are important woody plants for quail (Rollins 2007).

METHODS

Bobwhites donated by hunters were obtained during the 2007–2008, 2009–2010, and 2010–2011 hunting seasons, respectively. Each bird was classified to age (juvenile or adult) based on presence or absence of buffy tips on the primary wing coverts; gender was assigned based on coloration of the feathers on the head (Dimmick and Pelton 1996). Bobwhites were placed in individually numbered plastic freezer bags within 5 min to retain any parasites that could exit the bird post-mortem. Bobwhites were placed in a cooler on ice to slow and stop movement of helminths still alive and limit decomposition of dead helminths. The bobwhites were placed in a freezer upon returning from the field until they were transported to the necropsy laboratory at the Caesar Kleberg Wildlife Research Institute in Kingsville, Texas, USA.

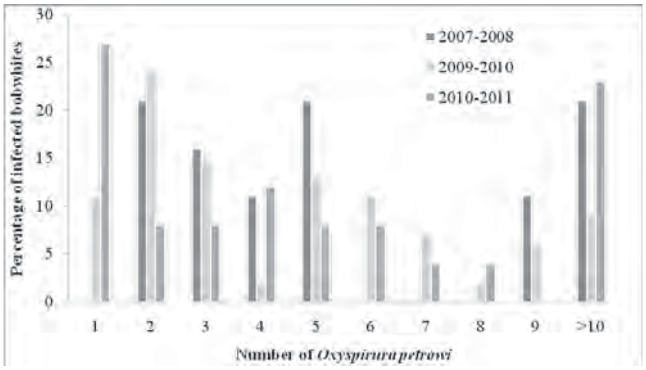

Fig. 1. *Oxyspirura petrowi* (%) in 99 infected northern bobwhites collected from the Rolling Plains of Texas during 2007–2008, 2009–2010, and 2010–2011.

Each bag containing a frozen carcass was placed in the refrigerator for thawing the night before necropsy. The head was removed once the carcass was thawed and examined for eyeworms on the eye surface, underneath the eyelids, and nictitating membrane; examinations were conducted using a variable power (1–40x) dissection microscope. Eyeworms were removed, fixed in glacial acetic acid for several minutes, and preserved in 70% alcohol and 8% glycerin in individually-marked vials corresponding to each bird.

We conducted Chi-square analyses to compare the prevalence of eyeworms for the main effects' variables of hunting season, host age, and host gender. We used analysis of variance (ANOVA) to examine whether mean abundance of eyeworms varied by the main and interaction effects' variables. Non-significant interaction effects' variables were eliminated from the model and the ANOVA rerun for final interpretation. Most parasite abundance data are not normally distributed, (i.e., over-dispersed or aggregated) and abundance data were rank transformed prior to ANOVA (Landgrebe et al. 2007).

RESULTS

Eyes of 173 northern bobwhites (85 adults, 88 juveniles; 94 males, and 79 females) were examined for *O. petrowi*. We found 99 (57%) infected with 596 worms. Intensity of infection averaged (± SD) 6.0 ± 6.4 (range = 1–40) and mean abundance was 3.4 ± 5.7 eyeworms.

Prevalence was 19% higher ($\chi^{2}{}_{1} = 5.82$, $P = 0.016$) in adults (67%) than in juveniles (48%) (Table 1). Prevalence was similar ($\chi^{2}{}_{1} = 0.06$, $P = 0.807$) in males (56%) and females (58%) (Table 1) as well as by hunting season 2007–2008, (58%), 2009–2010 (63%), and 2010–2011 (48%) ($\chi^{2}{}_{2}, = 2.91$, $P = 0.234$) (Table 1, Fig. 1). None of the ANOVA interaction effects variables was significant ($P > 0.087$). The ranked abundance model using the main effects variables was significant ($F_{4,166} = 2.77$, $P = 0.029$); only host age was significant ($F_{1,166} = 8.11$, $P = 0.005$) and adult bobwhites had 50% higher rank mean abundance of *O. petrowi* than juveniles (Table 1).

DISCUSSION

There have been 5 published articles on eyeworms in species of quail in Texas (Wallmo 1956, Jackson 1969, Pence 1975, Dancak et al. 1982, Landgrebe et al. 2007) and only Jackson (1969) examined bobwhites. Jackson's

(1969) findings on eyeworm prevalence (49.5%) were comparable to our results (57%) over 40 years later. However, we found the second highest recorded number (40) of *O. petrowi* in any wild galliform host individual reported in the literature. Robel et al. (2003) found a male lesser prairie-chicken (*Tympanuchus pallidicinctus*) with 81 *O. petrowi*. Jackson (1969) reported finding *O. sygmoidea* in bobwhites from the Rolling Plains; however, the parasite may have been misidentified and was likely *O. petrowi*, as *O. sygmoidea* is found primarily in Austria (Peterson 2007).

Oxyspirura mansoni is the eyeworm found most commonly in poultry (Ruff 1984, Anderson 2000). Based on Ruff (1984: 640–641), infected hosts may appear restless and continue to scratch their eyes; eyes may appear watery and inflamed with observation of swelling of the nictitating membrane; left untreated, eyelids can become stuck together, causing severe ophthalmia. However, descriptions of pathological effects caused by *O. petrowi* are lacking. Non-pathological consequences to infection may be important, such as difficulty in seeing caused by these large worms or distractions that could make infected birds less attentive to environmental hazards and predators. Jackson (1969) reported that erratic and peculiar (i.e., not flushing) behavior of some bobwhites lead to speculation that vision of bobwhites may have been impaired by eyeworms.

Prevalence and mean ranked abundance of *O. petrowi* were significantly higher in adult bobwhites than juveniles, suggesting infections increase through time, which is likely the result of adult bobwhites feeding on infected arthropods for longer periods (multiple seasons/ years) than juveniles (only several months). It also suggests the immune system of adult bobwhite is not effectively eliminating infections of *O. petrowi*. Prevalence and ranked abundance of eyeworms were not significant between males and females, suggesting similar exposure probabilities to infected intermediate hosts. This would be expected in host species where males and females regularly co-occur in social groups, feed together, and share similar dietary preferences.

More data on the life history of *O. petrowi* including their intermediate hosts in Texas and the geographic distribution of *O. petrowi* across the range of the northern bobwhite are needed. Future research should also assess the possible negative effects of *O. petrowi* on bobwhites including pathological responses and non-pathological consequences of infection in regard to host survival.

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LITERATURE CITED

Anderson, R. C. 2000. Nematode parasites of vertebrates, their development and transmission. Second edition. CABI Publishing, New York, USA.

Cram, E. B., M. F. Jones, and E. A. Allen. 1931. Internal parasites and parasitic diseases of the bobwhite. Pages 229–313 *in* H. L. Stoddard, ed. The bobwhite quail its habits, preservation, and increase. Charles Scribner's Sons, New York, USA.

Dancak, K., D. B. Pence, F. A. Stormer, and S. L. Beasom. 1982. Helminths of the scaled quail, *Callipepla squamata*, from northwest Texas. Proceedings of the Helminthological Society of Washington 49: 144–146.

Dimmick, R. W., and M. R. Pelton. 1996. Criteria for sex and age. Pages 169–214 *in* T. A. Bookhout, ed. Research and management techniques for wildlife and habitats. Fifth edition. The Wildlife Society, Bethesda, Maryland, USA.

Fielding, J. W. 1926. Additional observations on the development of the eye worm of poultry. Australian Journal of Experimental Biology and Medical Science 5: 1–8.

Fielding, J. W. 1927. Further observations on the life history of the eye worm of poultry. Australian Journal of Experimental Biology and Medical Science 4: 273–281.

Jackson, A. S. 1969. Quail management handbook for West Texas Rolling Plains. Bulletin Number 48. Texas Parks and Wildlife Department, Austin, USA.

Landgrebe, J. N., B. Vasquez, R. G. Bradley, A. M. Fedynich, S. P. Lerich, and J. M. Kinsella. 2007. Helminth community of scaled quail (*Callipepla squamata*) from western Texas. Journal of Parasitology 93: 204–208.

Pence, D. B. 1972. The genus *Oxyspirura* (Nematoda: Thelaziidae) from birds in Louisiana. Proceedings of the Helminthological Society of Washington 39: 23–28.

Pence, D. B. 1975. Eyeworms (Nematoda: Thelaziidae) from West Texas quail. Proceedings of the Helminthological Society of Washington 42: 181–183.

Peterson, M. J. 2007. Diseases and parasites of Texas quails. Pages 89–114 *in* L. A. Brennan, ed. Texas quails: ecology and management. Texas A&M University Press, College Station, USA.

Robel, R. J., T. L. Walker Jr., C. A. Hagen, R. K. Ridley, K. E. Kemp, and R. D. Applegate. 2003. Helminth parasites of lesser prairie-chicken *Tympanuchus pallidicinctus* in southwestern Kansas: incidence, burdens, and effects. Wildlife Biology 9: 341–349.

Rollins, D. 2007. Quails on the Rolling Plains. Pages 117–141 *in* L. A. Brennan, ed. Texas quails: ecology and management. Texas A&M University Press, College Station, USA.

Ruff, M. D. 1984. Nematodes and acanthocephalans. Pages 614–648 *in* M. S. Hofstad, B. W. Calnek, C. F. Helmboldt, W. M. Reid, and H. W. Yoder Jr., eds. Diseases of poultry. Eighth edition. Iowa State University Press, Ames, USA.

Sanders, D. A. 1928. Manson's eyeworm of poultry. Journal of the American Veterinary Association 25: 568–584.

Walmo, O. C. 1956. Ecology of scaled quail in West Texas. Texas Game and Fish Commission, Austin, USA.

GENETIC STRUCTURE OF NORTHERN BOBWHITES IN NORTHEAST MISSISSIPPI AND SOUTHWEST TENNESSEE

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ABSTRACT

Precipitous declines in northern bobwhite (*Colinus virginianus*) populations across most of the natural range may increase susceptibility to genetic isolation, restrict gene flow among subpopulations, and exacerbate vulnerability to catastrophic stochastic processes. We characterized the level of genetic variability of 223 individual bobwhites representing 4 disjunct populations in northeast Mississippi and southwest Tennessee in 2002. Analyses at 8 microsatellite loci suggested observed heterozygosity was lower than expected but showed no significant heterozygosity excess. Estimates of F_{IS} coefficients were positive in each subpopulation, but low overall, suggesting only minor loss in heterozygosity over the entire population. Gene diversity was high and genetic differentiation within and among subpopulations and isolation by distance effects were minimal, suggesting adequate levels of gene flow. We suggest, despite population losses, gene flow is maintained among subpopulations, which may reflect the bobwhite's ability to disperse successfully in the agricultural landscape in this region. Maintenance of gene flow across seemingly inhospitable landscapes suggests focal area management directives may enhance population sustainability. Greater understanding of the genetic structure of northern bobwhite populations on larger geographic scales and across the species' range is paramount to population recovery.

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Key words: *Colinus virginianus*, genetic structure, Mississippi, northern bobwhite, population genetics, Tennessee

INTRODUCTION

Northern bobwhites are distributed across a variety of habitat types in the eastern United States and northern Mexico (Brennan 1999). Bobwhites exhibit limited mobility compared to most avian species, which may increase susceptibility to population isolation from habitat loss (Roseberry 1993). Population isolation may simultaneously increase susceptibility to natural stochastic processes (Roseberry 1993) and genetic drift resulting from limited gene flow (Ellsworth et al. 1989). Bobwhite populations, as measured by the North American Breeding Bird Survey (BBS), have steadily declined by 3.8% annually in the United States and 5.0–5.3% annually in Mississippi and Tennessee since 1966 (Sauer et al. 2011). Declines in BBS counts presumptively reflect both a reduction in average number of birds detected per point and an increasing frequency of points where individuals were absent, which may indicate increasing population isolation.

The bobwhite decline has raised concern for the overall abundance and long-term viability of many local populations (Vance 1976, Roseberry et al. 1979, Exum et al. 1982, Brennan 1991, Fies et al. 1992). Consequently, a number of studies have been conducted on the dynamics and viability of bobwhite populations (Guthery et al. 2000, Fies et al. 2002, Thogmartin 2002, Sandercock et al. 2008). However, standard population viability analyses may not be applicable to fragmented populations because important parameters such as inbreeding levels within and gene flow among fragmented populations are not well understood (Roseberry 1993).

There is a paucity of studies characterizing patterns of genetic variability within and among subpopulations of bobwhite (Ellsworth et al. 1989, Wehland 2006). Precipitous population declines and potential for reduced gene flow as habitats become increasingly inhospitable suggest a critical need for a comprehensive understanding of genetic relationships among bobwhite subpopulations. We evaluated patterns of polymorphism at 8 microsatellite loci in bobwhite in 4 presumably disjunct locations in north and east Mississippi and southwest Tennessee to examine the extent of genetic differentiation, substructur-

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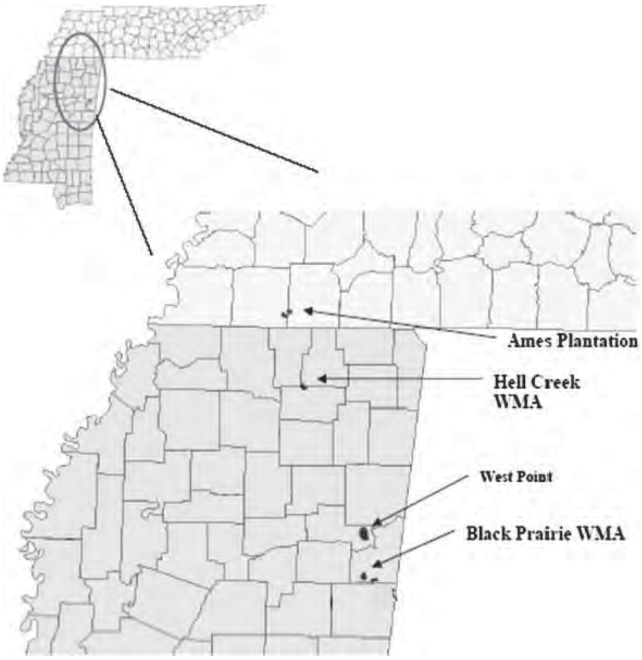

Fig. 1. Geographic locations of 4 northern bobwhite subpopulations in northeast Mississippi and southwest Tennessee sampled for analyses of population genetic structure in 2002.

ing, and variability within and among subpopulations in this region.

STUDY AREA

We sampled wild bobwhite populations at 3 locations in northern Mississippi (West Point Unit [WPU; 4,963.75 ha], Black Prairie Wildlife Management Area [BPWMA; 1,831.24 ha], Hell Creek Wildlife Management Area [HCWMA; 937.56 ha]) and one location in southwest Tennessee (Ames Plantation [AP; 5,478.09 ha]) from February to June 2002 (Fig. 1). Sampling area estimates were based on home range sizes from radio-marked bobwhites for WPU and BPWMA, and area under habitat management for HCWMA and AP. Distance among sites ranged from 32.27 km (WPU to BPWMA) to 202.63 km (BPWMA to AP). The region represents historic portions of the Black Belt Prairie range and is dominated by a mix of row-crop agriculture, exotic forage, interspersed with pine (*Pinus* spp.) plantations and other forest fragments with limited urban development.

METHODS

We obtained 223 samples of juvenile and adult body feathers from bobwhites captured in baited walk-in funnel traps at 4 locations (WPU, $n = 39$; BPWMA, $n = 65$; HCWMA, $n = 39$; AP, $n = 70$). All individuals were banded upon sampling, and recaptures were not resampled. We included samples from only a single individual where multiple individuals were captured in a single trap to diminish possible confounding effects of related individuals in genetic analysis. Bobwhite subpopulations at each study site were representative samples of the wild regional population, and study areas had not previously been the subject of captive bobwhite relocations as of 2002. Bird handling and tissue sampling followed procedures in the Mississippi State University Institutional Animal Care and Use Committee protocol (01–051).

Table 1. Locus identity, annealing temperatures (°C), and accession numbers for each locus used to examine population genetic structure of northern bobwhites in Mississippi and Tennessee, 2002.

Locus	Annealing temperature	Accession number
LEI 142	66	X83257
LEI 160	66	X85523
LEI 70	63	X82869
LEI 197	63	Z83776
LEI 31[b]	63	X83980
LLSD3	54	X99053
NBGP8[a]	57	AY522965
NBGP9	57	AY522966
NBGP10	57	AY522967
NBGP11	57	AY522968
NBGP12N[a]	57	AY522970
NBGP15[b]	57	AY522980

[a] Loci removed due to significant deviations from HW equilibrium.
[b] Loci removed due to excessive failed assays.

Genetic Analysis

Feather samples from each individual were stored on site in dry envelopes. The tips of each feather rachis were later transferred to 500 µl 70% ethanol. DNA was extracted from feather samples using a Qiagen DNeasy Tissue Extraction Kit (Qiagen Inc.,Valencia, CA, USA) combined with Dithiothreitol (DTT) to aid in breakdown of the keratinized feather shaft. Twelve di- and tetranucleotide microsatellite markers (LEI142, LEI160, LEI70, LEI197, LEI31, LLSD3 [Fok and Parkin 2001]; NBGP8, NBGP9, NBGP10, NBGP11, NBGP12N, NBGP15 [Schable et al. 2004]; Table 1) were amplified in 10 µl polymerase chain reactions (PCR) containing DNA template, Takara Ex-Taq DNA polymerase, 10X PCR buffer (containing 20 mM Mg^{+2}), 2.5 mM each dNTP (pH $7\sim9$), and 10 mM each fluorescent-labeled primer (Invitrogen Inc., Grand Island, NY, USA). PCR reactions were conducted with an initial denaturation of 5 min at 95 °C, followed by 40 cycles of 95 °C for 30 sec, 30 sec at the locus-specific optimized annealing temperature (Table 1), and 72 °C for 30 sec. Cycling was followed by a final extension period of 20 min at 72 °C. Products were identified and sized with 0.5 µl 400 bp standard following amplification by capillary electrophoresis on a Beckman-Coulter CEQ 8000XL DNA Sequencer (Beckman-Coulter Inc., Brea, CA, USA). Fragments representing pairs of alleles at each locus (i.e., genotypes) were generated for each individual in a subpopulation, which allowed for examination of detailed genetic structure within and among subpopulations.

Table 2. Size range (Bp), % failed assays (%), number of alleles (Na), average frequency of private alleles (F_p), observed heterozygosity (H), within population gene diversity (H_S), and overall gene diversity (H_T) per locus for northern bobwhite in Mississippi and Tennessee, 2002.

Locus	Bp	%	N_a	F_p	H	H_S	H_T
LEI 70	138–168	19.64	10	0.014	0.640	0.812	0.815
LLSD3	136–180	30.36	13	0	0.253	0.631	0.679
LEI 197	112–150	26.79	12	0.053	0.665	0.780	0.785
LEI 160	174–200	15.48	9	0.010	0.591	0.880	0.882
LEI 142	102–126	16.67	11	0.068	0.600	0.866	0.882
NBGP9	142–190	10.71	17	0.014	0.488	0.563	0.567
NBGP10	136–254	8.93	29	0.018	0.643	0.769	0.783
NBGP11	128–146	11.31	7	0.020	0.694	0.848	0.865

Statistical Analysis

Allele and genotype frequencies, and observed and expected numbers of heterozygotes in each subpopulation were calculated using Program GENEPOP Version 1.2 (Raymond and Rousset 1995). This program was also used to analyze genotypic deviations from Hardy-Weinberg (HW) equilibrium and linkage equilibrium. We estimated observed heterozygosity (H_O) for each locus over all subpopulations (Nei 1978), within subpopulation gene diversity (H_S), overall gene diversity (H_T), number of alleles, allele frequency, and allelic richness as implemented in Program FSTAT Version 2.9.3 (Goudet 2001). We used Weir and Cockerham's (1984) *F*-statistics, to estimate extent of population substructuring, and coefficients over the entire population (F_{IT}), within subpopulations (F_{IS}), and among subpopulations (F_{ST}) for each locus (Weir and Cockerham 1984) in FSTAT (Goudet 2001). We used sequential Bonferroni to adjust nominal significance levels for tests of HW and linkage disequilibrium, and genetic differentiation of pair-wise F_{ST} values (Rice 1989). We also conducted an analysis of molecular variance (AMOVA) (Excoffier et al. 1992), as implemented in Program ARLEQUIN Version 2.0 (Schneider et al. 2000) to test covariance components at a 2-level hierarchy: among subpopulations, and within subpopulations, and at a 3-level hierarchy: among groups (AP and HCWMA vs. BPWMA and WPU), among subpopulations within groups (AP vs. HCWMA, BPWMA vs. WPU), and within subpopulations. We based grouping on geographical distance between subpopulations with those < 60 km apart assumed to be more similar than those >115 km apart (Table 2). We used Program BOTTLENECK Version 1.2.02 (Cornuet and Luikart 1996, Luikart et al. 1998) to examine the potential for a reduction in genetic diversity using the 2-phase mutation (TPM) model with 20% variance with the Wilcoxon sign rank test (1,000 iterations). The TPM is a model that is intermediate between the SMM (step-wise mutation model) and the IAM (infinite alleles model), which fits more appropriately to microsatellite data and assumes mutation-drift equilibrium when calculating gene diversity and expected mean heterozygosity (DiRienzo et al. 1994). We expected to observe no significant difference, if the population had not undergone a recent bottleneck, between the calculated expected average heterozygosity (H_E) and the Hardy-Weinberg equilibrium heterozygosity (H_{EQ}).

RESULTS

We found no evidence of linkage disequilibrium among loci, indicating that loci were independent of one another, assuming they were not on the same macrochromosome. However, loci NBGP8 (13.9% failed assays) and NBGP12N (17.94% failed assays) were removed from further analysis due to significant deviations from HW equilibrium ($P < 0.001$) that were caused by significant heterozygote deficiencies ($P < 0.001$). Loci NBGP15 (48.88% failed assays) and LEI 31 (59.64% failed assays) were also removed due to a high proportion of missing alleles. An additional 45 individuals in the remaining subpopulations were removed due to a high frequency of missing alleles (at >3 loci). The resulting analysis was conducted using 26, 31, 54, and 57 individuals from HC, WPU, BPWMA, and AP, respectively.

Observed heterozygosity across all loci was on average 0.572 (range = 0.253-0.694), and the numbers of alleles at each locus ranged from 9 to 29 (Table 2). The mean observed number of heterozygotes was lower than the expected number of heterozygotes in each population (Table 3), which coincides with positive estimates of F_{IS} coefficients within each subpopulation (Table 4). However, overall F_{IT} was minimal (0.277 ± 0.047 [SE]), which suggests only minor loss of heterozygosity over the entire population. Gene diversity per locus over all populations (H_S) was fairly large (mean = 0.769, range = 0.563-0.880), as was overall gene diversity (H_T) (mean = 0.782, range 0.567-0.882) (Table 2). The mean per population gene diversity estimates were similar for the 4 subpopulations (BPWMA = 0.752, HCWMA = 0.772, WPU = 0.754, AP = 0.797). There was a significant difference between mean allelic richness of the 4 bobwhite populations ($P < 0.001$). The mean allelic richness over all populations and loci was 7.888 (Table 5).

The analyses were suggestive that genetic variability was high within the study subpopulations. Therefore, we conducted further analyses to examine for signs of bottleneck effects not apparent in analyses of heterozygosity. No population showed significant heterozygosity excess ($H_E > H_{EQ}$) when assuming the TPM (2-phased model) with the Wilcoxon test (Table 6). Our results suggest bobwhite populations at HCWMA, BPWMA, WP, and AP have not undergone a genetic bottleneck. These results, although not comprehensive (i.e., due to a reduced loci set), suggest subpopulations exhibited no

Table 3. Expected (H_E), and observed (H_O) number of heterozygotes per locus per population estimated using GENEPOP for northern bobwhite in Mississippi and Tennessee, 2002.

WPU			AP		
Locus	H_E	H_O	Locus	H_E	H_O
17	10.766	8.000	17	31.588	26.000
12	14.767	15.000	12	31.273	26.000
114	12.586	11.000	114	34.025	25.000
105	20.373	15.000	105	38.270	30.000
96	15.865	15.000	96	40.614	34.000
9	24.860	19.000	9	43.424	26.000
10	26.339	18.000	10	47.276	36.000
11	17.863	4.000	11	34.371	19.000
Mean	17.927	13.125	Mean	37.605	27.750

BPWMA			HCWMA		
Locus	H_E	H_O	Locus	H_E	H_O
17	18.887	17.000	17	16.294	16.000
12	28.107	19.000	12	15.400	13.000
114	35.259	30.000	114	21.755	18.000
105	38.421	36.000	105	18.444	13.000
96	34.103	24.000	96	16.512	15.000
9	39.747	25.000	9	21.510	17.000
10	40.582	25.000	10	20.404	13.000
11	32.200	13.000	11	10.814	5.000
Mean	33.413	23.625	Mean	17.642	13.750

significant heterozygosity excess and were not subject to bottleneck effects on genetic variability, assuming potential population isolation events occurred recently. Similarly, when allele frequency distributions were plotted for each locus, all populations had a solid L-shaped distribution indicating the lack of bottleneck effects on allelic diversity (Fig. 2).

We also applied 2 different methods (F_{ST}, AMOVA) to examine potential substructuring and differentiation within and among subpopulations. Pair-wise F_{ST} values ranged from 0.012 to 0.043 (mean $= 0.020 \pm 0.008$ [SE]) with BPWMA and HCWMA indicating genetic differentiation following Bonferonni correction ($P < 0.008$; Table 2). Results from AMOVA indicated there was no genetic differentiation among subpopulations. Covariance components at 2- and 3-level hierarchies indicated 97.5% and 97.1% of variance resulted from variation within subpopulations. An isolation by distance effect was also not detected among the 4 bobwhite subpopulations ($r = 0.197$, $P = 0.346$; Mantel test).

Table 4. Within population F_{IS} coefficients per population of northern bobwhite in Mississippi and Tennessee, 2002.

Locus	WPU	AP	BPWMA	HCWMA
LEI 70	0.261	0.178	0.101	0.018
LLSD3	−0.016	0.170	0.327	0.160
LEI 197	0.130	0.268	0.151	0.176
LEI 160	0.268	0.218	0.064	0.300
LEI 142	0.056	0.164	0.298	0.094
NBGP9	0.239	0.404	0.374	0.213
NBGP10	0.320	0.240	0.387	0.368
NBGP11	0.779	0.450	0.599	0.543
Overall	0.250	0.260	0.291	0.225

Table 5. Allelic richness per locus per subpopulation of northern bobwhite in Mississippi and Tennessee, 2002.

Locus	WPU	AP	BPWMA	HCWMA	Overall
17	4.234	5.786	2.966	4.523	4.738
12	6.461	9.687	9.212	8.756	9.210
114	7.000	8.252	6.073	9.500	8.544
105	6.427	7.427	7.451	6.634	7.312
96	8.628	7.110	6.055	7.776	7.410
9	9.448	8.927	9.744	10.098	9.840
10	10.986	11.940	10.915	8.879	11.441
11	5.329	4.377	4.059	4.862	4.606
Mean	7.314	7.938	7.059	7.629	7.888

DISCUSSION

Previous studies suggest avian populations exhibit low genetic differentiation due to high dispersal rates and enhanced ability to disperse long distances (Smith and Zimmerman 1976, Corbin 1977, Crochet 2000, Rocha and Del Lama 2004). However, sedentary avian populations may exhibit reduced gene flow compared to migratory populations (Arguedas and Parker 2000). Limited dispersal ability decreased gene flow among populations of several galliform species in fragmented habitats (Piertney et al. 1998, Oyler-McCance et al. 1999, Caizergues and Ellison 2002, Caizergues et al. 2003, Oyler-McCance et al. 2005), including evidence of genetic drift among isolated greater prairie-chicken (*Tympanuchus cupido*) populations in North America (Johnsgard 2002, Bellinger et al. 2003, Johnson et al. 2003).

Evidence from related taxa suggests genetic differentiation of disjunct bobwhite subpopulations may also occur; however, our findings indicate presumed isolation of bobwhite subpopulations in Mississippi and Tennessee has, to this point, exhibited negligible effects on gene flow. Extant gene flow among the 4 subpopulations examined here appears to have been sufficient to ameliorate effects of genetic differentiation. The few previous studies evaluating genetic structure of bobwhite subpopulations have revealed conflicting results, which are likely related to issue of scale or limitations in sample size and loci. Ellsworth et al. (1989) revealed adequate gene flow in continuous populations of bobwhite in

Table 6. *P*-values for 1-tailed Wilcoxon sign rank test for heterozygote excess ($H_E > H_{EQ}$) estimated under TPM (two-phased model) for northern bobwhite in Mississippi and Tennessee, 2002.

Population	TPM (Heterozygote excess)
WPU	0.87500
AP	0.67969
BPWMA	0.57813
HCWMA	0.62891

* Significant at $P < 0.05$.

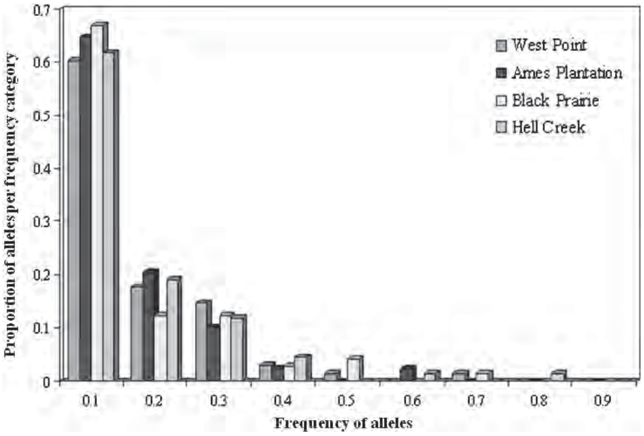

Fig. 2. Distribution of allele frequencies across all loci for populations of northern bobwhite in Mississippi and Tennessee, 2002. An L-shaped distribution of allele frequencies indicates the absence of a genetic bottleneck (Luikart et al. 1998).

Illinois, and Wehland (2006) suggested gene flow was substantial among South Texas subpopulations. However, Eo et al. (2010) suggested the possibility of restricted gene flow over large spatial scales (i.e., the eastern U.S.).

We presumed intensified agricultural practices and associated habitat losses in Mississippi and Tennessee impeded bobwhite dispersal and gene flow. However, open habitats (e.g., row-crop fields, pastures, fallow areas) remain abundant in the landscape and may support bobwhite dispersal. Conversion of the landscape into managed agricultural units may have resulted in a real loss of habitat, but failed to impact gene flow among the observed subpopulations because agricultural landscapes are relatively permeable to dispersing individuals. This is exemplified by a complementary habitat suitability model [HSM] constructed for the Southeastern Coastal Plain Bird Conservation Region in which our study sites occur (R. G. Hamrick, personal communication; Fig. 3). An overlay of suitable bobwhite habitat over our study sites

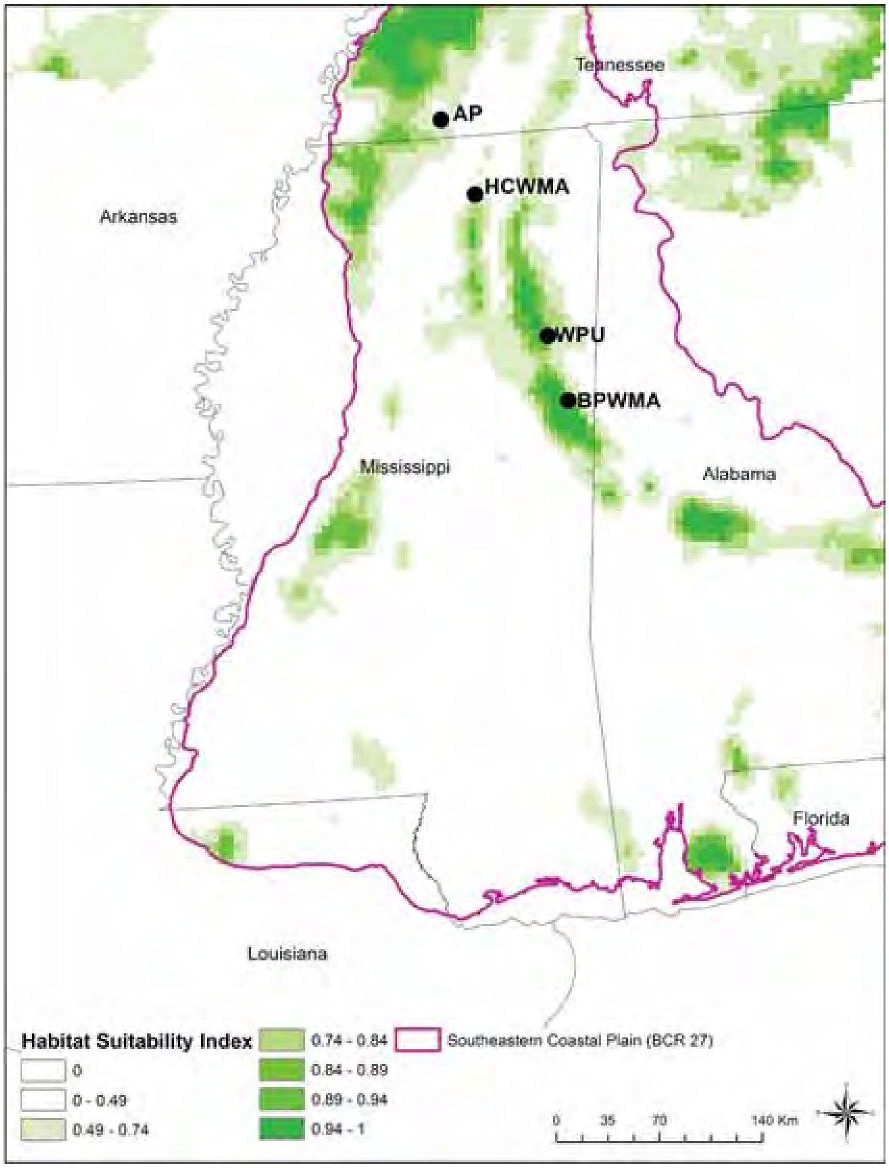

Fig. 3. Predicted bobwhite habitat suitability surface for the Southeastern Coastal Plain Bird Conservation Region (BCR 27) with superimposed geographic locations of sampled bobwhite subpopulations in Mississippi and Tennessee, 2002.

Table 7. Pair-wise F_{ST} values (upper diagonal) for each population of northern bobwhite, and approximated geographical distance (km) between study sites (lower diagonal) in Mississippi and Tennessee, 2002.

	WPU	AP	BPWMA	HCWMA
WPU		0.015	0.012	0.041
AP	173		0.014	0.012[a]
BPWMA	32	203		0.043[b]
HCWMA	118	57	147	

[a] $0.008 < P < 0.05$.
[b] $P < 0.008$.

reveals a distinct crescent of usable space in the Blackland Prairie region of northeast Mississippi whereby gene flow may be promoted (Fig. 3).

Large-scale habitat loss and fragmentation, coupled with low population densities may impede dispersal and gene flow to a significant extent on larger regional scales and across time (e.g., Eo et al. 2010). However, we must approach inference from this and existing bobwhite genetic studies with caution. Most studies are limited in spatial context and sample size and may present limited inference. Relatively small sample sizes and numbers of loci in this study may blur interpretation of results as differentiating effects of sample size and number of loci versus population processes may be difficult. Applicability of short-term genetic data to greater population processes across time is also uncertain, as these processes are expected to encompass decades and even centuries (Eo et al. 2010).

MANAGEMENT IMPLICATIONS

Bobwhite conservation geneticists now have a suite of 23 advanced genetic markers from which they can optimize regional or range-wide analyses and increase precision of parameter estimates beyond the scope presented here (Schable et al. 2004, Faircloth et al. 2009). There is a need for comprehensive studies of genetic structure of bobwhite populations at a larger regional scale in the southeastern United States and, preferably, over the species' range. There is also a need to understand effects of landscape permeability and dispersal efficacy on genetic structure. Knowledge of the extent of genetic differentiation across the species' range will allow researchers to make informed decisions regarding the relative importance of gene flow in bobwhite management. This information will be valuable in formulating a comprehensive management strategy for this species that incorporates information from population dynamics and demography as well as genetics.

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LITERATURE CITED

Arguedas, N., and P. G. Parker. 2000. Seasonal migration and genetic population structure in house wrens. Condor 102:517–528.

Bellinger, M. R., J. A. Johnson, J. E. Toepfer, and P. O. Dunn. 2003. Loss of genetic variation in greater prairie-chickens following a population bottleneck in Wisconsin, USA. Conservation Biology 17:717–724.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

Brennan, L. A. 1999. Northern bobwhite (*Colinus virginianus*). The birds of North America. Number 397.

Caizergues, A., and L. N. Ellison. 2002. Natal dispersal and its consequences in black grouse. Ibis 144:478–487.

Caizergues, A., O. Ratti, P. Helle, L. Rotelli, L. Ellison, and J. Y. Rasplus. 2003. Population genetic structure of male black grouse (*Tetrao tetrix l.*) in fragmented vs. continuous landscapes. Molecular Ecology 12:2297–2305.

Corbin, K. W. 1977. Genetic diversity in avian populations. Pages 291–302 *in* S. A. Temple, ed. Endangered birds: management techniques for preserving threatened species. University of Wisconsin Press, Madison, USA.

Cornuet, J. M., and G. Luikart. 1996. Description and power analysis of two tests for detecting recent population bottlenecks from allele frequency data. Genetics 144:2001–2014.

Crochet, P. A. 2000. Genetic structure of avian populations-allozymes revisited. Molecular Ecology 9:1463–1469.

DiRienzo, A., A. C. Peterson, J. C. Garza, A. M. Valdes, M. Slatkin, and N. B. Freimer. 1994. Mutational processes of simple-sequence repeat loci in human populations. Proceedings of the National Academy of Science of the USA 91:3166–3170.

Ellsworth, D. L., J. L. Roseberry, and W. D. Klimstra. 1989. Genetic structure and gene flow in the northern bobwhite. Auk 106:492–495.

Eo, S. H., J. P. Wares, and J. P. Carroll. 2010. Subspecies and units for conservation and management of the northern bobwhite in the eastern United States. Conservation Genetics 11:867–875.

Excoffier, L., P. E. Smouse, and J. M. Quattro. 1992. Analysis of molecular variance inferred from metric distances among DNA haplotypes: application to human mitochondrial DNA restriction data. Genetics 131:479–491.

Exum, J. H., R. W. Dimmick, and B. L. Deardon. 1982. Land use and bobwhite populations in an agricultural system in west Tennessee. Proceedings of the National Quail Symposium 2: 6–12.

Faircloth, B. C., T. M. Terhune, N. A. Schable, T. C. Glenn, W. E. Palmer, and J. P. Carroll. 2009. Ten microsatellite loci from northern bobwhite (*Colinus virginianus*). Conservation Genetics 10:535–538.

Fies, M. L., I. L. Kenyon, and J. V. Gwynn. 1992. Effects of changing land use patterns on bobwhite quail habitat in Virginia. Virginia Journal of Science 23:143–155.

Fies, M. L., K. M. Puckett, and B. Larson-Brogdon. 2002. Breeding season movements and dispersal of northern bobwhites in fragmented habitats of Virginia. Proceedings of the National Quail Symposium 5:173–179.

Fok, K. W., and D. Parkin. 2001. The cross species utility of domestic fowl *Gallus domesticus* microsatellites in other Galliformes and a population genetic study of ring-necked pheasants *Phasianus colchicus* in the UK. Pages 216–223 *in* M. I. A. H. Woodburn, P. J. K. McGowan, P. A. J. Garson, and J. P. Carroll, eds. Seventh International Galliformes Symposium. King Mahendra Trust, Katmandu, Nepal.

Goudet, J. 2001. FSTAT, a program to estimate and test gene diversities and fixation indices. Version 2.9.3. Department of Ecology and Evolution, University of Lausanne, Switzerland. www.unil.ch/izea/softwares/fstat

Guthery, F. S., M. J. Peterson, and R. R. George. 2000. Viability of northern bobwhite populations. Journal of Wildlife Management 64:646–662.

Johnsgard, P. A. 2002. Grassland grouse and their conservation. Smithsonian Institute Press, Washington, D.C., USA.

Johnson, J. A., J. E. Toepfer, and P. O. Dunn. 2003. Contrasting patterns of mitochondrial and microsatellite population structure in fragmented populations of greater prairie-chickens. Molecular Ecology 12:3335–3347.

Luikart, G., F. W. Allendorf, J. M. Cornuet, and W. B. Sherwin. 1998. Distortion of allele frequency distributions provides a test for recent population bottlenecks. Journal of Heredity 89:238–247.

Nei, M. 1978. Estimation of average heterozygosity and genetic distance from a small number of individuals. Genetics 89:583–590.

Oyler-McCance, S. J., N. W. Kahn, K. P. Burnham, C. E. Braun, and T. W. Quinn. 1999. A population genetic comparison of large- and small-bodied sage grouse in Colorado using microsatellite and mitochondrial DNA markers. Molecular Ecology 8:1457–1465.

Oyler-McCance, S. J., J. St. John, S. E. Taylor, A. D. Apa, and T. W. Quinn. 2005. Population genetics of Gunnison sage-grouse: implications for management. Journal of Wildlife Management 69:630–637.

Piertney, S. B., A. D. C. Maccoll, P. J. Bacon, and J. F. Dallas. 1998. Local genetic structure in red grouse (*Lagopus lagopus scoticus*): evidence from microsatellite DNA markers. Molecular Ecology 7:1645–1654.

Raymond, M., and F. Rousset. 1995. GENEPOP (Version 1.2): population genetics software for exact tests and ecumenism. Journal of Heredity 86:248–249.

Rice, W. R. 1989. Analyzing tables of statistical tests. Evolution 43:223–225.

Rocha, C. D., and S. N. Del Lama. 2004. Lack of genetic structuring among tropical Brazilian wood stork populations and low genetic differentiation from North American populations. Biotropica 36:248–258.

Roseberry, J. L. 1993. Bobwhite and the 'new' biology. Proceedings of the National Quail Symposium 3:16–20.

Roseberry, J. L., B. G. Peterjohn, and W. D. Klimstra. 1979. Dynamics of an unexploited bobwhite population in deteriorating habitat. Journal of Wildlife Management 43:306–315.

Sandercock, B. K., W. E. Jensen, C. K. Williams, and R. D. Applegate. 2008. Demographic sensitivity of population change in northern bobwhite. Journal of Wildlife Management 72:970–982.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski Jr., and W. A. Link. 2011. The North American Breeding Bird Survey, results and analysis 1966–2009. Version 3.23.2011. USGS, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Schable, N. A., B. C. Faircloth, J. P. Carroll, W. E. Palmer, L. W. Burger Jr., L. A. Brennan, C. Hagen, and T. C. Glenn. 2004. Tetranucleotide and dinucleotide microsatellite loci from the northern bobwhite (*Colinus virginianus*). Molecular Ecology Notes 4:415–419.

Schneider, S., D. Roessli, and L. Excoffier. 2000. Arlequin Version 2.00: a software for population genetics data analysis. Genetics and Biometry Laboratory, University of Geneva, Switzerland.

Smith, J. K., and E. G. Zimmerman. 1976. Biochemical genetics and evolution of North American blackbirds, Family Icteridae. Computational Biochemical Physiology 53:3319–3324.

Thogmartin, W. E. 2002. Spatio-temporal dynamics of northern bobwhite (*Colinus virginianus*) in Illinois. Dissertation. Southern Illinois University, Carbondale, USA.

Vance, D. R. 1976. Changes in land-use and wildlife populations in southeastern Illinois. Wildlife Society Bulletin 4:11–15.

Wehland, E. M. 2006. Genetic variation among South Texas populations of northern bobwhite. Thesis. Texas A&M University-Kingsville, USA.

Weir, B. S., and C. C. Cockerham. 1984. Estimating *F*-statistics for the analysis of population structure. Evolution 38:1358–1370.

NORTHERN BOBWHITE POPULATION STRUCTURE AND DIVERSITY IN TEXAS AND THE GREAT PLAINS

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ABSTRACT

Many northern bobwhite (*Colinus virginianus*) populations have been experiencing severe declines. This decline is of concern to wildlife biologists, landowners, and legislators due to the popularity of this species as a game bird. Previous molecular genetic analyses for populations inhabiting intact habitats in South Texas indicate the northern bobwhite population in this region is genetically diverse with low population structure. W assessed whether landscape affects the population structure and diversity for northern bobwhite in Texas and the Great Plains. We extracted DNA from hunter-harvested northern bobwhites from 19 sites in South Texas from 2004 to 2010. We analyzed 7 microsatellites (Quail 5, 8, 9, 10, 11, 12, and 15). We used F_{ST} to measure genetic structure and AMOVA for genetic variation. We built 3 matrices to compare the genetic structure with the landscape. Geographic distances (km) between sample locations were ascertained using Google Earth. A matrix of barriers incorporated large water bodies and highways. We used the Biologist Ranking Information from the National Bobwhite Conservation Initiative for the third matrix to identify the number of different habitat patches a quail would need to cross from ranch to ranch. These matrices were compared to the genetic structure (pairwise F_{ST}), using Mantel tests with 10,000 permutations. We used partial Mantel tests to test the correlation of pairwise F_{ST} to combinations of distance and barriers, distance and habitat, and barriers and habitat. Overall F_{ST} was < 0.01, suggesting low levels of population differentiation and AMOVA revealed most variation was within individuals. All Mantel tests had a positive correlation with genetic differentiation; however, barriers appear to be important factors for the observed genetic patterns.

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Key words: *Colinus virginianus*, genetics, northern bobwhite, population structure, South Texas

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GENETIC STRUCTURE AND DIVERSITY IN SOUTH TEXAS BOBWHITES: IMPLICATIONS FOR CONSERVATION

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ABSTRACT

The northern bobwhite (*Colinus virginianus*) has experienced range-wide declines in population size and reductions in geographic range during the last century. Declines in northern bobwhite population size and geographic distribution continue to occur despite vigorous conservation and research efforts directed at sustaining and enhancing populations. Viable populations of northern bobwhite have persisted only in areas with large expanses of relatively contiguous habitat, such as southern Texas, parts of Oklahoma, Kansas, and areas in southern Georgia and northern Florida. The decline of northern bobwhite populations is often associated with changes in land-use practices, including proliferation of intensive agriculture and fire suppression, which have altered, removed, or fragmented northern bobwhite habitat. Typically, the effects of changes in land use on northern bobwhites are regional in scale, given the large geographic extent which current agricultural land-use practices, such as farming and timber production, occur. It is clear that precipitation and land use affect regional population trends, but consideration of northern bobwhite population dynamics has remained confined to the local scale. Thus, the specific manner in which land-use changes have affected populations of northern bobwhites is unknown. We investigated the genetics and population structure of northern bobwhites at the landscape scale to learn if bobwhites function as

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metapopulations. Dispersal and exchange in a metapopulation system are critical to the long-term maintenance of populations; if interrupted, the entire network of populations might collapse. We sampled hunter-harvested northern bobwhites during 2004 to 2007 from 24 sites in South Texas, a region containing large areas of contiguous habitat where populations of northern bobwhites have been relatively stable. We extracted DNA and used bi-parentally and maternally inherited genetic markers to compare genetic structure and diversity among populations. We genotyped 567 individuals at 7 DNA microsatellite loci and sequenced 353 bp of the mtDNA control region for 190 individuals. Genetic diversity was high for microsatellite loci and mtDNA haplotypes ($H_O = 0.58$; $H = 0.88$, respectively), and did not differ among populations. We observed little population structure across the geographic region (microsatellite $F_{ST} = 0.01$; mtDNA theta $= 0.037$), and Fisher exact tests of population differentiation were not statistically significant. Spatial autocorrelation analysis of the microsatellite data set revealed a positive correlation between Moran's I and geographic distance out to $>$50 km. Our genetic data are surprising for an avian species that is considered relatively sedentary and a short-distance disperser. South Texas populations of northern bobwhites had high levels of genetic variation and were genetically similar across a broad region. Population genetics theory predicts that genetic diversity and similarity among local populations in a metapopulation are influenced by the rate of dispersal (gene flow). Life history theory predicts species with high turnover rates, such as northern bobwhite, should be good dispersers. The region-wide genetic similarity among populations of northern bobwhites implies dispersal may be more important in the population dynamics of the species than previous studies have indicated. We hypothesize that disruption of dispersal by habitat fragmentation may explain the overall decline of northern bobwhite populations in some regions. This may explain why patches of suitable habitat in fragmented landscapes go unoccupied by northern bobwhites. Our results lend additional support to recent calls for regional-scale management of this declining species.

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Key words: *Colinus virginianus*, dispersal, genetics, northern bobwhite, population structure

PHYLOGEOGRAPHY OF BOBWHITES

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ABSTRACT

Bobwhites (*Colinus* spp.) are a widely distributed genus of New World quails. Four species are recognized with a geographic range spanning the eastern United States to northern South America. The northern bobwhite (*C. virginianus*) historically occurred throughout much of the eastern United States and eastern Mexico with disjunct populations in Sonora and Cuba. The Yucatán bobwhite (*C. nigrogularis*) occurs in allopatric populations in Nicaragua and Honduras, and on the Yucatán Peninsula. The spot-bellied and crested bobwhites (*C. leucopogon* and *C. cristatus*) constitute a species complex with the spot-bellied bobwhite distributed from Guatemala to Costa Rica, and the crested bobwhite from Panama to northern Brazil. The 4 species exhibit substantial intraspecific variation, and up to 56 subspecies are recognized among *Colinus* largely on the basis of geographic distribution and male plumage coloration. However, relationships within and among species have not been studied in detail. We sampled museum study skins and obtained DNA sequences from mitochondrial control region and ND2 genes. We used concatenated sequences of control region and ND2 to investigate relationships among the bobwhite species, and the control region to assess the geographic distribution of genetic variation within each species. Maximum likelihood analysis of bobwhite phylogeny revealed *Colinus* is composed of two deeply divergent lineages, one clade of northern and Yucatán bobwhites and another of spot-bellied and crested bobwhites. The Yucatán bobwhite was genetically distinct from the northern bobwhite. The Yucatán bobwhite was composed of 2 distinct subclades, one confined to the Yucatán Peninsula and another occurring in Nicaragua. The genetic data showed the spot-bellied bobwhite is closely related to the crested bobwhite, but did not reveal clear support for 2 distinct species. The crested bobwhite was composed of 3 distinct lineages: a western clade that occurs in Panama and west of the northern Andes in Venezuela and Colombia, an eastern clade concentrated in Venezuela (east of the Andes), and a clade restricted to northern Brazil. We found 58 control region haplotypes, of which 29 were shared among $\geq$ 2 northern bobwhite subspecies and 5 haplotypes were especially geographically widespread. We found 16 haplotypes in the Yucatán bobwhite with 4 restricted to the Yucatán Peninsula and shared among the 3 subspecies found there, and 3 other haplotypes restricted to the Nicaraguan subspecies. The spot-bellied bobwhite did not share haplotypes with any of the 3 crested bobwhite subclades. We found little phylogeographic structure within the spot-bellied bobwhite, and 2 of the 5 haplotypes occurred across much of the species' range and were shared among the 6 subspecies. The crested bobwhite exhibited strong phylogeographic structure and a lack of shared haplotypes among subspecies. The 20 haplotypes of the crested bobwhite were distributed unevenly among its 3 clades: 2 haplotypes in the Brazilian clade, 6 in the eastern clade, and 12 in the western clade. The weak phylogeographic structure and geographically widespread haplotypes of the northern bobwhite suggests large effective population size and gene flow among subspecies. The deep phylogeographic breaks within the Yucatán bobwhite and the spot-bellied bobwhite-crested bobwhite complex may be due to changes in the availability of suitable habitat and geological events during the Pleistocene. The lack of geographically distinct groups within the northern bobwhite implies that many subspecies may not provide good management units. Our data support the continued recognition of the Yucatán bobwhite as a distinct species. The 2 intraspecific groups identified in the Yucatán and the 4 groups within the spot-bellied/crested bobwhite complex may each represent discrete management units. Further assessment of the phylogenetic relationships and the phylogeography of the bobwhite species is warranted to clarify the phylogeny of *Colinus*.

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Key words: bobwhites, Central and South America, *Colinus* spp., genetics, Mexico, New World quail

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THE SEXUAL PROCLIVITIES OF NORTHERN BOBWHITES

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ABSTRACT

Mating systems and mating behavior are historically viewed as static characteristics of populations. 'Monogamy', 'polygamy', 'multiple clutch polygamy', 'polyandry', etc. imply most individuals express similar social and genetic mating patterns and characterize the behavior of most or all individuals in a given population. Mating systems of different populations of northern bobwhites (*Colinus virginianus*) have been described as monogamous, polygamous, multi-clutch polygamous, ambisexually polygamous, and polyandrous in contrast to the expectation that behavior, at the species level, fits defined categories. Prior studies of bobwhite breeding behavior, to arrive at these classifications, were based on observations of social interactions and did not incorporate genetic outcomes. Thus, it is challenging to discern whether social behaviors predict genetic outcomes and whether bobwhite mating behavior varies among populations or if behavior is flexible within populations. We used 3 years of field observations and variation at 14 microsatellite loci of 601 adult and 841 neonatal bobwhites to estimate rates of extra-pair paternity in bobwhite broods, evaluate the utility of social behavior as an indicator of genetic outcomes, and evaluate the fit of bobwhite social and genetic behavior to classic mating system theories. Extra-pair paternity occurred in >50% of bobwhite broods, whereas extra-pair matings resulted in few ($\bar{x} = 1.1$) extra-pair offspring per nest. Social interactions between female and male bobwhites generally predicted the father of most offspring in a brood, but social interactions did not predict extra-pair matings better than chance. The mating behavior of individual females changed within and between breeding seasons, suggesting individual reproductive decisions of females were flexible. The mating 'system' of bobwhites meets neither the predictions nor the assumptions of classic mating theories.

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Key words: *Colinus virginianus*, mating systems, northern bobwhite, paternity

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DEPREDATION PATTERNS AND NORTHERN BOBWHITE NEST SUCCESS IN FIELD BORDERS

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ABSTRACT

Northern bobwhite (*Colinus virginianus*) populations have declined because of habitat loss and fragmentation. Field borders provide additional habitat for northern bobwhites and other wildlife that depend on early-succession habitat. However, their proximity to woods as well as other edge types may result in increased bobwhite nest depredation. We examined if northern bobwhite nest survival in field borders decreased with increasing proximity to edges such as woods, crop fields, ditches, and roads; effects of year, camera presence, and field border width also were considered. We examined if snakes are the primary nest predator with 24-hr video camera surveillance. We searched for and monitored northern bobwhite nests on ~ 77 ha of field borders in southeast North Carolina during summers 2010 and 2011. We found 26 nests and monitored them every 3–4 days. Fourteen nests were monitored with cameras. We built nest survival models using the covariates of distance to nearest woody edge, crop field, ditch, and road as well as year, camera effect, and field border width. The most explanatory model was constant northern bobwhite nest survival with an estimated daily nest survival ± SE of 0.9512 ± 0.0119 (AIC*c* weight = 0.23). Models with covariates suggested similar daily nest survival rates. Four snake and two mammalian predation events were recorded on camera. Distance to edge types and field border width did not appear to influence the outcome of nests in an agriculture-dominated landscape. Thus, landowners and managers in an agriculture-dominated landscape may have flexibility with field border placement and distance to edge type as they relate to nest success.

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Key words: *Colinus virginianus*, field borders, nest predators, nest survival, North Carolina

INTRODUCTION

Northern bobwhites have been declining over the past few decades and these declines are primarily attributed to habitat loss and fragmentation (Vance 1976, Brennan 1991, Hunter et al. 2001, Brennan and Kuvlesky 2005). Field borders, a strip of planted native or volunteer vegetation on the edge of a crop field, have been proposed as a conservation tool to aid in reversing this declining trend. Numerous studies have shown field borders have been beneficial in providing suitable habitat for bobwhites. For example, summer and fall bobwhite abundance increased with establishment of field borders (Bromley et al. 2002, Palmer et al. 2005, Riddle et al. 2008). Additionally, more bobwhite nests were found on farms with field borders than farms without field borders (Puckett et al. 1995).

The effectiveness of field borders as a successful management tool can vary due to characteristics including field border shape, width, or the surrounding landscape context. For example, Riddle et al. (2008) found that northern bobwhite populations increased on farms with both linear and non-linear borders in agriculture-dominated landscapes and only on farms with non-linear field borders in forest-dominated landscapes. Greater avian abundance and richness of overwintering birds were found in wide field borders compared to narrow field borders (Conover et al. 2007), and nearly twice the density of breeding birds was found in wide field borders as opposed to narrow field borders (Conover et al. 2009). Distance to differing edge types is another factor that could impact the effectiveness of a field border in providing adequate habitat, and especially nesting habitat, for northern bobwhites.

Field borders, by definition, are along edges that are adjacent to other features such as woods, roads, and ditches. Many studies have investigated the relationship between edge effects and breeding songbirds but few studies have examined the relationship between edge and breeding northern bobwhites. Increased depredation rates of songbird nests have been observed along field edges (Gates and Gysel 1978, Andren and Anglestam 1988, Marini et al. 1995), potentially making field borders unsuitable for producing high nest success. This could be due to predators using edges for foraging or as travel lanes between different habitats (Bider 1968, Pedlar et al. 1997, Dijak and Thompson 2000). Nest depredation already is a significant source of nest failure for bobwhite populations (Stoddard 1931, DeVos and Mueller 1993, Puckett et al. 1995, Conover 2005), and field borders could increase this risk through negative edge effects.

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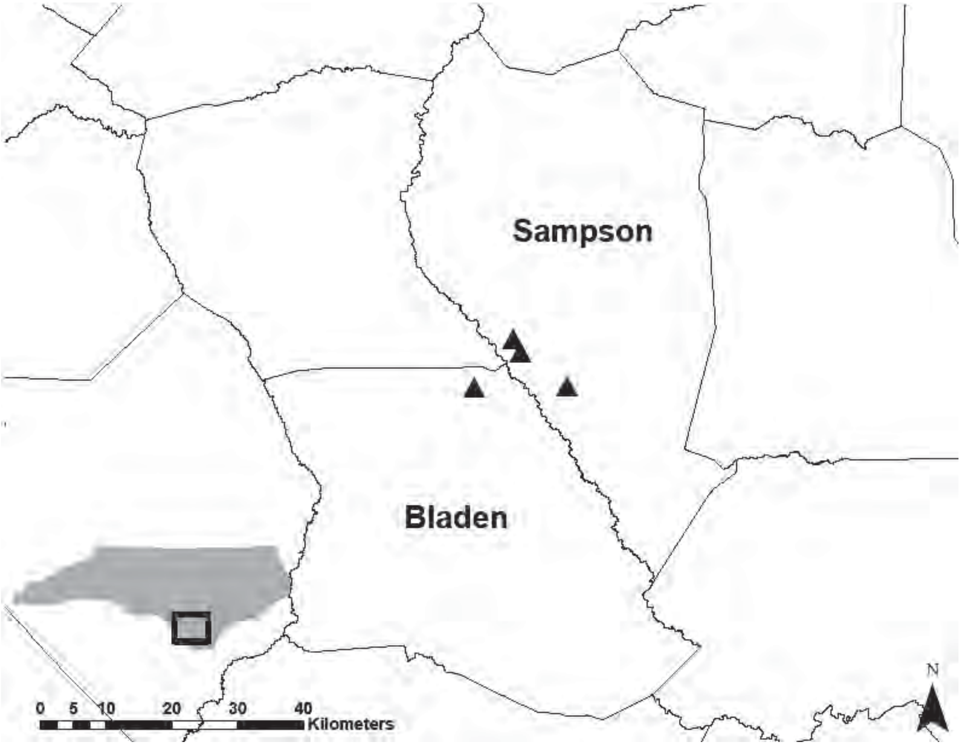

Fig. 1. Locations of farms studied in Bladen and Sampson counties, North Carolina, USA.

The composition of the predator community depends upon the region and habitat. Studies including real and artificial nests have shown that mammals are major nest predators of northern bobwhites (Klimstra and Roseberry 1975, DeVos and Mueller 1993, Hernández et al. 1997, Fies and Puckett 2000, Staller et al. 2005, Rader et al. 2007b). However, Puckett et al. (1995) reported snakes were the primary nest predators on their study farms. Other studies also have found snakes to be important predators of bobwhite nests (Stoddard 1931, Burger et al. 1995, Staller et al. 2005). This could be due to selective snake use of edges as opposed to other landscape features (Weatherhead and Charland 1985, Blouin-Demers and Weatherhead 2001, Sperry et al. 2009). Riddle and Moorman (2010) speculated that black rat snakes (*Elaphe obsoleta*) may be a main predator of songbird nests in southeastern North Carolina based on signs of predation. However, this could not be confirmed because they did not monitor nests with cameras.

The relationship between predators, landscape context, and edge effects needs to be studied further to better manage bobwhite populations (Rollins and Carroll 2001, Burger 2002, Riddle et al. 2008). This is particularly true for managing northern bobwhites in field border habitats as there is a lack of research linking northern bobwhite nest success in field borders to proximity to woody edges and other edge types.

Our objectives were to ascertain: (1) if nests of northern bobwhites in field borders were more likely to fail if they were closer to woody, crop, ditch, and road edges, and (2) if snakes were the primary nest predators of northern bobwhites in field borders. We hypothesized the closer nests were to edge types, the more likely they were to fail. We also hypothesized that snakes were the main nest predator.

STUDY AREA

Our study sites consisted of ~ 77 ha of field borders on four commercial hog farms in Bladen and Sampson counties in southeast North Carolina (Fig. 1). The agricultural land on the farms mainly was used to grow soybeans, corn, and winter wheat. Three of the farms were smaller in size totaling ~ 312 ha and the fourth farm was ~ 1,619 ha.

Field borders were maintained in an early-successional state which distinguishes them from other areas bordering crop fields. Specifically they were disked, mowed, and treated with herbicide when needed to keep them in an early-successional state. About 5 ha of field borders were used for this study on the three smaller farms and ~ 72 ha of field borders on the larger farm. We used only those field borders adjacent to crop fields on at least 1 side and selected 141 linear and 24 non-linear field borders for this study. Linear field borders were spatially arranged around the crop fields, often being on 1 or more sides of a crop field at varying lengths. Linear borders were ~ 0.41 ± 0.34 ha (mean ± SD) in size and varied in length (509.08 ± 305.25 m) and width (9.02 ± 6.40 m). A non-linear field border was an irregularly-shaped field border and averaged 0.80 ± 0.72 ha in size. Most field borders contained marestail (*Conyza canadensis*), dog fennel (*Eupatorium capillifolium*), little bluestem (*Schizachyrium scoparium*), blackberry (*Rubus* spp.), salt myrtle (*Baccharis halimifolia*), and other herbaceous or grassy vegetation. A few non-linear field borders were composed of mostly planted native warm season grasses including big bluestem (*Andropogon gerardii)*, little bluestem, and switchgrass (*Panicum virgatum*).

METHODS

Nest Searching

We separated individual field borders into 2 groups at the beginning of each field season: one comprised of field borders on the larger farm and one of field borders on the 3 smaller farms. Separating the larger farm and the smaller farms into 2 different groups allowed the area of field borders searched on the 3 small farms to be proportional with those searched on the larger farm. This reduced the chance of searching one field border in a farm group more than another. We searched the field borders in each group in a random order. We paired field borders separated by a ditch for searching purposes. We searched each field border at least twice in 2010 and at least 4 times in 2011.

We searched for nests in each field border systematically, using behavioral cues from birds, and opportunistically. We systematically searched each field border thoroughly by walking transects through the entire field border and looking for nests. We also used behavioral cues such as vocalizations and flushes while we were systematically searching or performing other duties. We found nests opportunistically when one was encountered while we were performing activities such as monitoring an active nest or setting up a camera.

We simultaneously searched paired field borders that were separated by a ditch (if applicable). Two people either searched linear borders parallel to the ditch on the same side or on opposite sides of the ditch until each field border was completely searched. Searches in non-linear borders depended on shape of the border. Each person either started on opposite ends of the non-linear field border and walked parallel lines toward each other or both people walked side by side. We recorded the stage of the nest and the number of eggs present for all nests located.

Nest Monitoring

We monitored nests every 3 to 4 days and tried not to destroy vegetation or leave a trail (Martin and Geupel 1993). We recorded the stage of progress at each nest check as well as how many eggs were present, and any other comments relevant to parental behavior and the eggs. This information helped us identify when the young fledged if it was successful.

Camera Set-up

We randomly selected half of all nests found for cameras. We placed a camera at the nest once it was selected during the next designated nest check for that particular farm. The camera setup included a small bullet camera (PC506-IR Color weatherproof infrared camera Supercircuits; Austin, TX, USA), a digital video recorder (DVR, SVAT CVP800 Mini Portable DVR Digital Video Recorder with MPEG4 Compression; SVAT Electronics, Niagara Falls, ON, Canada), and batteries. We attached the camera to a PVC pipe ~ 1.5 m from the nest at the appropriate height based on the amount of surrounding vegetation. We chose the best angle to ensure the camera had a clear view of the nest without destroying vegetation which could make the nest more visible to predators.

We connected a closed-circuit television (CCTV) video/power cable from the camera to the DVR and 2, 12-volt 33-amp hr batteries contained in a sealed bucket. The bucket also contained a voltage regulator and harness which attached the batteries to the DVR and camera. We used 16 gigabyte secure digital (SD) cards throughout the entire season to store the video data collected from each nest. We changed the SD cards and batteries every 3–4 days during routine nest monitoring activities. We placed 2 humidity sponges in the bucket to prevent moisture buildup. We placed the bucket ~ 8 m from the camera and under as much vegetation as possible for concealment and to reduce exposure to the weather. We placed a sheet of burlap over the bucket to provide camouflage and prevent overheating of the bucket contents. We encased the cable in heavy duty piping to prevent exposure from the weather and from being chewed by animals. Nests were recorded continuously at 8 frames/sec on high mega pixel quality with no audio.

Edge Sampling

We recorded the width of the border and distance from each nest to the closest woody, ditch, and crop edge once the outcome of the nest was known. We measured field border width for both linear and non-linear field borders by walking from the nest to both the crop side of the field border and the other side of the field border which was usually a woody, ditch, or road edge. We measured distance to the closest woody edge using a range finder at the nests. We used the measuring tool in ArcGIS to measure the distance to the closest road for every nest.

Data Analysis

We used Program MARK (White and Burnham 1999) to analyze the collected nest data via the daily nest survival option. Specifically, Program MARK uses the number of exposure days, number of nest failures, and the last day a nest was known to be active to estimate daily nest survival. However, unlike traditional methods that use exposure days (e.g., the Mayfield method; Mayfield 1961, 1975), Program MARK allows covariates on individual nests (model development in Dinsmore et al. 2002). We built nest survival models using 7 covariates to test our hypotheses: distance to closest woody, crop, ditch, and road edge as well as field border width, camera effect, and year effect. Each model included one of the covariates. We also included a null model (i.e., one with

Table 1. AIC model results from Program MARK including AIC*c* statistics, point estimates of survival ($\hat{S}$), and standard error. S(.) represents constant nest survival. The other covariates are year effect (S(Year)), camera effect (S(Camera)), distance to closest crop (S(Distance to crop)), distance to closest ditch (S(Distance to ditch)), distance to closest woody edge (S(Distance to woody edge)), distance to closest road (S(Distance to road)), and field border width (S(Field border width)). All data were collected from nests in field borders on farms in Bladen and Sampson counties, North Carolina, USA.

Model description	AIC*c*	AIC*c* Weight	No. Parameters	Deviance	$\hat{S}$	SE
S(.)	89.79	0.23	1	87.77	0.9512	0.0119
S(Year)	90.27	0.18	2	86.23	0.9516	0.0120
S(Camera)	91.08	0.12	2	87.04	0.9508	0.0120
S(Distance to crop)	91.23	0.11	2	87.19	0.9493	0.0125
S(Distance to ditch)	91.31	0.11	2	87.27	0.9540	0.0127
S(Distance to woody edge)	91.53	0.10	2	87.49	0.9521	0.0120
S(Distance to road)	91.81	0.08	2	87.77	0.9511	0.0120
S(Field border width)	91.81	0.08	2	87.77	0.9513	0.0123

constant nest survival) for a total of 8 models. Program MARK uses an information-theoretic approach to facilitate model selection. Daily survival rates and distance summaries are presented as mean ± SE.

We used a Chi-square goodness of fit test ($\alpha > 0.05$) to examine if snakes were the main nest predators. This was done by placing predators caught on camera into three main predator groups (snake, mammalian, and avian) for comparison.

RESULTS

Twenty-six nests were found in 2010 and 2011 for a total of 297 exposure days. Seventeen nests failed during the study. The top 2 models in Program MARK were constant nest survival and year effect, (AIC*c* weight = 0.23 and 0.18, respectively; Table 1). All covariates had betas with 95% confidence intervals that overlapped zero, resulting in little contribution to the slope. Daily nest survival for the constant nest survival model was 0.9512 ± 0.0119, 95% CI = 0.9218-0.9699). The model averaged estimate for daily nest survival was 0.9514 ± 0.0121, 95% CI 0.9211–0.9704).

Average distance to woody edge in relation to nest location was 403.6 ± 271.3 m while average distance to closest crop, ditch, and road was 35.2 ± 4.8, 8.8 ± 18, and 168.5 ± 142.8 m, respectively (Table 2). The average field border width at each nest location was 13.4 ± 16.9 m.

Cameras were placed at 14 nests between 2010 and 2011 (Table 3). Four snake (3 king snake [*Lampropelitis getula getula*] and one unidentifiable snake) and two Virginia opossum (*Didelphis virginiana*) were captured on cameras in predation events ($\chi_2^{\,2} = 4.0$, $P = 0.14$). Eggs in 6 nests monitored with cameras successfully hatched and 2 nests were abandoned.

Table 2. Average, minimum, and maximum distances (m) from nests to closest woody, crop, ditch, and road edges. All data were collected from nests in field borders on farms in Bladen and Sampson counties, North Carolina, USA.

Edge type	Average	Minimum	Maximum
Woody	403.6	13.0	942.0
Ditch	8.8	0.8	87.0
Crop	5.2	0.4	16.0
Road	168.5	8.1	525.0

DISCUSSION

Constant daily nest survival was the most competitive model. There appeared to be considerable model uncertainty because the 7 covariates had little effect on estimation of daily nest survival. Daily nest survival estimates had small SEs and were similar across all models indicating our estimates were stable and that proximity to edges as well as field border width, year effect, and camera effect did not influence the outcome of nests in field borders. We had similar results with indigo bunting (*Passerina cyanea*) and blue grosbeak (*P. caerulea*) on these farms, which suggests a trend among both ground and shrub nesting birds (unpublished data). Our model-averaged daily nest survival estimate for bobwhites (0.9514, 95% CI = 0.9211–0.9704) was similar to mean daily nest survival rates from Burger et al. (1995) and Rader et al. (2007a) which ranged from 0.9458 to 0.9692.

Woody edges, on average, were farther from nests than any of the other 4 edge types, and only 7 of our nests were < 200 m from a woody edge. Therefore, nests tended to be far from woody edges, and predators that come from the woods would have to travel substantial

Table 3. Camera identification of nest outcome from 2010 and 2011 field seasons. All data were collected from nests in field borders on farms in Bladen and Sampson counties, North Carolina, USA.

Outcome	2010	2011	Totals
Predator			
Virginia opossum	1	1	2
King snake	1	2	3
Unidentifiable snake	0	1	1
Abandoned	1	1	2
Successful	2	4	6

distances to depredate a nest. Landscape context may have influenced this distance pattern.

All northern bobwhite nests located during our study were in field borders on the large farm which was in an agriculture-dominated landscape as opposed to field borders on the 3 smaller farms which were in a forest-dominated landscape. Field borders in an agriculture-dominated landscape could be providing more preferable nesting habitat or simply nesting habitat in a more favorable landscape context. This may help explain why Riddle et al. (2008) found that breeding season bobwhite abundance almost doubled on farms in agriculture-dominated landscapes as opposed to forest-dominated landscapes after establishment of field borders.

Nest predation was a more common cause of nest failure than abandonment (56 vs. 44%, respectively). Snakes depredated twice as many nests as other taxa, but this was not statistically significant, likely due to our small sample size with cameras.

Studies have shown different primary predators of northern bobwhite nests and those without cameras have speculated snakes were the main nest predators due to evidence left after depredation (Burger et al. 1995, Puckett et al. 1995). Previous camera studies involving bobwhite nests have shown a variety of primary predators. Staller et al. (2005) found common raccoons (*Procyon lotor*) were the primary nest predator in Florida and Georgia while Rader et al. (2007b) found coyotes (*Canis latrans*) were the primary nest predators in Texas. Fies and Puckett (2000) found striped skunks (*Mephitis mephitis*) most frequently depredated artificial bobwhite nests in Virginia. Hernández et al. (1997) found raccoons were the most frequent predator of artificial nests in Texas. King snakes depredated bobwhite nests 3 times in our study. King snakes were also a frequent predator of songbird nests in a field setting (Thompson et al. 1999), but have not previously been shown to be an important predator of northern bobwhite nests to our knowledge.

Our findings should be viewed with caution as we only had 26 nests in our study and only 14 nests with cameras. Future studies should focus on acquiring a larger sample size to gain a more accurate representation of the predator community in particular areas and to more thoroughly examine distances to difference edge types. The predator community needs to be compared between forest and agriculture-dominated landscapes to examine for differences.

MANAGEMENT IMPLICATIONS

Distance to edges did not appear to influence bobwhite nest success in our study. Thus, landowners and managers appear to have flexibility with field border placement relative to the edge types we considered in an agriculture-dominated landscape. This could allow more field borders to be established without having the concern of whether edge will negatively affect nest success for bobwhites. Establishing more field borders should benefit bobwhite populations and also other wildlife. We found no bobwhite nests on farms in a forest-dominated landscape and recognize our recommendations for field border placement may not apply to that type of landscape.

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LITERATURE CITED

Andren, H., and P. Anglestam. 1988. Elevated predation rates as an edge effect in habitat islands: experimental evidence. Ecology 69:544–547.

Bider, J. R. 1968. Animal activity in uncontrolled terrestrial communities as determined by a sand transect technique. Ecological Monographs 38:269–308.

Blouin-Demers, G., and P. J. Weatherhead. 2001. Habitat use by black rat snakes (*Elaphe obsoleta obsoleta*) in fragmented forests. Ecology 82:2882–2896.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

Brennan, L. A., and W. P. Kuvlesky Jr. 2005. North American grassland birds: an unfolding conservation crisis? Journal of Wildlife Management 69:1–13.

Bromley, P. T., S. D. Wellendorf, W. E. Palmer, and J. F. Marcus. 2002. Effects of field borders and mesomammal reduction on northern bobwhite and songbird abundance on three farms in North Carolina. Proceedings of the National Quail Symposium 5:71.

Burger, L. W. 2002. Quail management: issues, concerns, and solutions for public and private lands–a southeastern perspective. Proceedings of the National Quail Symposium 5:20–34.

Burger, L. W., M. R. Ryan, T. V. Dailey, and E. W. Kurzejeski. 1995. Reproductive strategies, success, and mating systems of northern bobwhite in Missouri. Journal of Wildlife Management 59:417–426.

Conover, R. R. 2005. Avian response to field borders in the Mississippi Alluvial Valley. Thesis. Mississippi State University, Mississippi State, USA.

Conover, R. R., L. W. Burger, and E. T. Linder. 2007. Winter avian community and sparrow response to field border width. Journal of Wildlife Management 71:1917–1923.

Conover, R. R., L. W. Burger Jr., and E. T. Linder. 2009. Breeding bird response to field border presence and width. Wilson Journal of Ornithology 121:548–555.

DeVos, T., and B. S. Mueller. 1993. Reproductive ecology of northern bobwhite in north Florida. Proceedings of the National Quail Symposium 3:83–90.

Dijak, W. D., and F. R. Thompson III. 2000. Landscape and edge effects on the distribution of mammalian predators in Missouri. Journal of Wildlife Management 64:209–216.

Dinsmore, S. J., G. C. White, and F. L. Knopf. 2002. Advanced techniques for modeling avian nest survival. Ecology 83:3476–3488.

Fies, M. L., and K. M. Puckett. 2000. Depredation patterns of northern bobwhite nest predators in Virginia. Proceedings of the National Quail Symposium 4:96–102.

Gates, J. E., and L. W. Gysel. 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology 59:871–883.

Hernández, F., D. Rollins, and R. Cantu. 1997. Evaluating evidence to identify ground-nest predators in west Texas. Wildlife Society Bulletin 25:826–831.

Hunter, W. C., D. A. Buehler, R. A. Canterbury, J. L. Confer, and P. B. Hamel. 2001. Conservation of disturbance-dependent birds in eastern North America. Wildlife Society Bulletin 29:440–455.

Klimstra, W. D., and J. L. Roseberry. 1975. Nesting ecology of the bobwhite in southern Illinois. Wildlife Monographs 41.

Marini, M. A., S. K. Robinson, and E. J. Heske. 1995. Edge effects on nest predation in the Shawnee National Forest, southern Illinois. Biological Conservation 74:203–213.

Martin, T. E., and G. R. Geupel. 1993. Nest-monitoring plots: methods for locating nests and monitoring success. Journal of Field Ornithology 64:507–519.

Mayfield, H. F. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255–261.

Mayfield, H. F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456–466.

Palmer, W. E., S. D. Wellendorf, J. R. Gillis, and P. T. Bromley. 2005. Effect of field borders and nest-predator reduction on abundance of northern bobwhites. Wildlife Society Bulletin 33:1398–1405.

Pedlar, J. H., L. Fahrig, and H. G. Merriam. 1997. Raccoon habitat use at 2 spatial scales. Journal of Wildlife Management 61:102–112.

Puckett, K. M., W. E. Palmer, P. T. Bromley, J. R. Anderson, and T. L. Sharpe. 1995. Bobwhite nesting ecology and modern agriculture: a management experiment. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:505–515.

Rader, M. J., L. A. Brennan, F. Hernández, N. J. Silvy, and X. B. Wu. 2007a. Nest-site selection and nest survival of northern bobwhite in southern Texas. Wilson Journal of Ornithology 119:392–399.

Rader, M. J., T. W. Teinert, L. A. Brennan, F. Hernández, N. J. Silvy, and X. B. Wu. 2007b. Identifying predators and nest fates of bobwhites in southern Texas. Journal of Wildlife Management 71:1626–1630.

Riddle, J. D., and C. E. Moorman. 2010. The importance of agriculture-dominated landscapes and lack of field border effect for early succession songbird nest success. Avian Conservation and Ecology 5:9.

Riddle, J. D., C. E. Moorman, and K. H. Pollock. 2008. The importance of habitat shape and landscape context to northern bobwhite populations. Journal of Wildlife Management 72:1376–1382.

Rollins, D., and J. P. Carroll. 2001. Impacts of predation on northern bobwhite and scaled quail. Wildlife Society Bulletin 29:39–51.

Sperry, J. H., D. A. Cimprich, R. G. Peak, and P. J. Weatherhead. 2009. Is nest predation on two endangered bird species higher in habitats preferred by snakes? Ecoscience 16:111–118.

Staller, E. L., W. E. Palmer, J. P. Carroll, R. P. Thornton, and D. C. Sisson. 2005. Identifying predators at northern bobwhite nests. Journal of Wildlife Management 69:124–132.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner and Sons, New York, USA.

Thompson III, F. R., W. Dijak, and D. E. Burhans. 1999. Video identification of predators at songbird nests in old fields. Auk 116:259–264.

Vance, D. R. 1976. Changes in land use and wildlife populations in southeastern Illinois. Wildlife Society Bulletin 4:11–15.

Weatherhead, P. J., and M. B. Charland. 1985. Habitat selection in an Ontario population of the snake, *Elaphe obsoleta*. Journal of Herpetology 19:12–19.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 (Supplement):120–139.

EXCLOSURES: AN EXPERIMENTAL TECHNIQUE FOR PROTECTION OF NORTHERN BOBWHITE NESTS

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ABSTRACT

Nest predation has been implicated as a factor affecting northern bobwhite (*Colinus virginianus*) recruitment rates. Public stakeholders are increasingly questioning use of lethal methods to manage predation. We evaluated a nonlethal method consisting of single nest treatments using an exclosure to protect nests from potential predators. The exclosure treatment also included use of Amdro® (hydramethylnon) and Snake-a-way® repellents to deter red-imported fire ants (*Solenopsis invicta*) and snakes, respectively. We compared nest success of treated ($n = 8$) to untreated nests ($n = 18$). Treated nests were 88% successful which was a 2-fold increase over unprotected nests. We did not observe any difference in hen behavior between treatment and controls. This technique may be useful to study nest success of wild quail and is not intended to be a management technique to influence overall population growth.

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Key words: Amdro®, *Colinus virginianus,* exclosure, fire ants, nest success, non-lethal control, northern bobwhite, predation, Snake-a-way®, snakes

INTRODUCTION

Lethal and nonlethal predation management has been used by researchers and managers for decades in efforts to increase populations of ground-nesting birds (Chessness et al. 1968). However, removal of predators, primarily furbearers, has produced mixed results, especially for bird species other than waterfowl (Sargeant et al. 1995, Garretson et al. 1996). Concomitantly, public stakeholders are increasingly questioning use of lethal methods to manage predation (Messmer et al. 1999).

Data concerning efficacy of predator control for increasing northern bobwhite populations are limited and contradictory (Rollins and Carroll 2001). Beasom (1974) reported increased northern bobwhite population densities after 2 years of mesomammal control, but Guthery and Beasom (1977) did not. Lehmann (1984) reported slight annual increases in bobwhite numbers but no long-term trends, even though large numbers of coyotes (*Canis latrans*) were removed from the King Ranch. Frost (2000) suggested the effects of predator control were difficult to quantify. These mixed results may have occurred because lethal removal of species can change the importance of different predators rather than increasing nest success (Dion et al. 1999).

Public support for predator removal as a means of increasing nest success has been uncertain and use of taste aversion, screens, fences, or exclosures to reduce predation has been evaluated for several species. Electric fences and exclosures have been successfully used to protect duck (*Anas* spp.) nests from predation by mammals (Cowardin et al. 1998). Exclosures also have been useful in protecting nests of the endangered piping plover (*Charadrius melodus*) (Melvin et al. 1992). Plover nest success increased from 17 to 90% by excluding mammalian predators. Controlled taste aversion, lethal removal, and nest screens were compared as techniques to reduce northern raccoon (*Procyon lotor*) predation of loggerhead sea turtle (*Caretta caretta*) nests (Ratnaswamy et al. 1997). Only nest screens were effective at reducing the effect of raccoons and increasing nest success. Protected nests had predation rates of 7.6%, which was 20–50% of the rates of other treatments (Ratnaswamy et al. 1997).

Screens of sufficient size to allow passage of northern bobwhites likely will not restrict most reptilian and arthropod nest predators. Red-imported fire ants in some areas, including much of Texas, can depredate northern bobwhite nests causing chick mortality (Mueller et al.

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1999). These authors demonstrated the effectiveness of Amdro® (Ambrands, Atlanta, GA, USA) for protecting northern bobwhite nests from red-imported fire ants. Amdro® treatment eliminated the presence of red-imported fire ants in the nest area on the day of hatch and increased survival of chicks from nests treated by 38% compared to non-treated controls.

No studies of the effects of chemical treatments for prevention of reptilian nest predators are available. Snake-a-way® (Dr. T's Nature Product Inc., Pelham, GA, USA) is a commercially available snake repellent that contains naphthalene and sulfur, active ingredients that are registered as snake repellents by the Environmental Protection Agency (EPA Reg. No. 58630-1). We are not aware of any studies that used exclosures or Snake-a-way® to protect northern bobwhite nests.

The objectives of our research were to: (1) develop, and (2) evaluate a non-invasive nest exclosure technique designed to exclude mammalian predators from northern bobwhite nests. We also (3) evaluated if exclosures and snake repellent affected hen and chick movements and nest abandonment rates.

STUDY AREA

The project was conducted in Refugio County, Texas in the Texas Coastal Prairie (Gould 1975). The site (28° 28′ N, 97° 11′ W; elevation = 25 m) is a 10,040-ha working cattle ranch with oil wells and limited agricultural production. Grasslands were interspersed with live oak (*Quercus virginiana*) motts, honey mesquite (*Prosopis glandulosa*), and huisache (*Acacia smallii*). This area provides prime quail habitat with relatively dense populations. Potential nest predators included feral hogs (*Sus scrofa*), long-tailed weasels (*Mustela frenata*), coyotes, hispid cotton rats (*Sigmodon hispidus*), northern raccoons, bobcats (*Lynx rufus*), striped skunks (*Mephitis mephitis*), eastern spotted skunks (*Spilogale putorius*) (Davis and Schimdly 1994), and various snakes. No predator control was occurring on the ranch with the exception of periodic feral hog control.

METHODS

We followed guidelines of the Texas Tech University Institutional Animal Care and Use Committee (IACUC #99885) during this study. Northern bobwhite hens were trapped from February until May 2000 ($n = 35$) and 2001 ($n = 24$) using walk-in funnel traps (Smith et al. 1981) baited with milo, corn, or a mixture of both. Hens were fitted with a 6-g necklace style radio transmitter (American Wildlife Enterprises, Monticello, FL, USA) and released. Radiotelemetry was used to monitor hens and locate their nests following Mueller et al. (1999). We randomly assigned each nest located to be a treatment or control by flipping a coin. This sampling scheme resulted in nests being scattered across the 10,040-ha landscape with all nests at least 75 m apart. We assumed that all were subject to similar pressure from vertebrate predators. Nests of hens that renested were also randomly assigned as a treatment or control. This approach ensured that both treatment and control nests would be exposed from the beginning to end of the nesting season.

The treatment consisted of exclosures that were $1.22 \times 1.22 \times 0.4$ m in size constructed of welded wire with 5×10 cm openings. Each exclosure had 4 sides, a wire mesh top, and an open bottom. Exclosures were centered on the nest and staked to the ground with 1.27-cm diameter rebar. Two pieces of rebar were threaded through the top of the exclosure to prevent any impact from an aerial attack or from large birds using it as a roost site. We attempted to build the exclosures when the hen was off the nest, but 4 of the 8 exclosures were installed while the hen was on the nest. Exclosures were installed within the first week a hen was incubating. The exclosure treatment also included Amdro® and Snake-a-way® to deter red-imported fire ants and snakes, respectively. Amdro® was spread at the rate of 1.7 kg/ha over 60-m^2 centered on the nest to reduce red-imported fire ants in the immediate area and to negate the impacts of individuals foraging outside the treated area (Mueller et al. 1999). Eighty-five grams of Snake-a-way® were applied in a 10 to 12-cm band encircling the exclosure.

Radio-marked hens were checked every 2 to 3 days early in the nesting cycle and daily as the expected hatch date approached. Nests were classified after hatch as either successful or not. A nest was considered successful if at least 1 egg hatched. Nest predators were differentiated as red-imported fire ants or other. We used the adjusted-Wald normal test for small sample sizes to examine differences in nest success between treatments (Agresti and Coull 1998).

RESULTS

Only 14 and 11 hens were alive at the onset of nesting season during 2000 and 2001, respectively. Success was arithmetically greater for exclosure nests (75%, $n = 4$ during 2000; 100%, $n = 4$ during 2001) than for control nests (25%, $n = 12$ during 2000; 67%, $n = 6$ during 2001) within years. We pooled the data by year for analysis because small sample sizes (< 5 per treatment) precluded analysis between years. Exclosure nest success (88%, $n = 8$) was greater ($Z = 2.07$, $P = 0.019$) than control nest success (39%, $n = 18$) when data were pooled for both years. Only 1 control nest and no exclosure nests were predated by red-imported fire ants. We did not identify individual vertebrate nest predators and do not have an evaluation of the effectiveness of Snake-a-way® alone for repelling snakes from nests.

DISCUSSION

Naphthalene and sulfur, the active ingredients in Snake-a-way®, are registered as snake repellents by the Environmental Protection Agency, but the effectiveness of Snake-a-way® in the field is unclear (Marsh 1993, Ferraro 1995). Our sample size did not allow examination of the individual components of the exclosure study, but the exclosure treatment as a whole.

Our results were similar to those of Melvin et al. (1992) and Ratnaswamy et al. (1997), who used nest exclosures to achieve nest success rates of 90 and 92% for piping plover and sea turtle nests, respectively. Nest success for northern bobwhites typically varies from 28 to 46% (Rosene 1969) and averages 45% in South Texas counties (Lehmann 1984). A 38% nest success rate for northern bobwhites has been previously reported for our study area; thus, the success rate for control nests in our study is typical for the area (Mueller et al. 1999).

Only 1 of the exclosure nests was destroyed during either year, by an unidentified predator. Long-tailed weasels, hispid cotton rats, and eastern spotted skunks occur in the area and are known predators of quail eggs (Davis and Schimdly 1994). These species are the most likely suspects because of their size and the fact the exclosure was left intact; only the nest and eggs were destroyed. We ruled out other mesomammals and anything larger, such as coyotes, because the exclosure itself was completely intact. Larger animals could not enter through the 5 × 10-cm opening, and could not enter from underneath without digging. No sign of digging under the exclosure was present and the predator had to have entered through the welded wire mesh. We do not believe the nest was predated by a snake because egg fragments were present in the nest and snakes typically consume the eggs whole (Hernández et al. 1997).

Installation of the exclosures did not cause nest abandonment even when the hen was present while we drove stakes to secure the enclosure. Occasionally, the hen when present during exclosure installation, would run or fly through the mesh openings but usually remained close to the nest. We monitored hen movements later the same day or early the next day to make sure hens were still incubating and they returned in every case.

We do not believe brood movements were affected. Chicks moved freely with their parent upon hatch as expected. Use of exclosures did not appear to have any negative effects on hen or chick behavior. Many studies have not achieved an increase in nest success through predator control, whereas we increased nest success by reducing the impacts of predation rather than predators themselves. Thus, exclosures may be a non-lethal technique that could be used to protect ground-nesting birds from mammalian predators. This technique warrants further investigation regarding its potential for contributing to increased nest success.

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LITERATURE CITED

Agresti, A., and B. A. Coull. 1998. Approximate is better than "exact" for interval estimation of binomial proportions. American Statistician 52:119–126.

Beasom, S. L. 1974. Intensive, short-term predator removal as a game management tool. Transactions of the North American Wildlife and Natural Resources Conference 39: 230–240.

Chessness, A. A., M. M. Nelson, and W. H. Longley. 1968. The effect of predator removal on pheasant reproductive success. Journal of Wildlife Management 32: 683–697.

Cowardin, L. M., P. J. Pietz, J. T. Lokemon, H. T. Sklebar, and G. A. Sargeant. 1998. Response of nesting ducks to predator exclosures and water conditions during drought. Journal of Wildlife Management 62: 152–163.

Davis, W. B., and D. J. Schmidly. 1994. The mammals of Texas. Texas Parks and Wildlife Press, Austin, USA.

Dion, N., K. A. Hobson, and S. Lariviere. 1999. Effects of removing duck-nest predators on nesting success of grassland songbirds. Canadian Journal of Zoology 77: 1801–1806.

Ferraro, D. M. 1995. The efficacy of naphthalene and sulfur repellents to cause avoidance behavior in the Plains Garter Snake, *Thamnophis radix*. Great Plains Wildlife Damage Control Workshop Proceedings 12: 116–120.

Frost, J. B. 2000. Evaluation of short-term mesomammal control to improve nesting success and survival of northern bobwhites in west central Texas. Thesis. San Angelo State University, San Angelo, Texas, USA.

Garretson, P. R., F. C. Rohwer, J. M. Zimmer, B. J. Mense, and N. Dion. 1996. Effects of mammalian predator removal on waterfowl and non-game birds in North Dakota. Transactions of the North American Wildlife and Natural Resources Conference 61: 94–101.

Gould, F. W. 1975. The grasses of Texas. Texas A & M University Press, College Station, USA.

Guthery, F., and S. L. Beasom. 1977. Responses of game and nongame wildlife to predator control in South Texas. Journal of Range Management 30: 404–409.

Hernández, F., D. Rollins, and R. Cantu. 1997. Evaluating evidence to identify ground-nest predators in West Texas. Wildlife Society Bulletin 25: 826–831.

Lehmann, V. W. 1984. Bobwhites in the Rio Grande Plain of Texas. Texas A&M University Press, College Station, USA.

Marsh, R. E. 1993. Test results of a new snake repellent. Great Plains Wildlife Damage Control Workshop Proceedings 11: 166.

Melvin, S., L. H. MacIvor, and C. R. Griffin. 1992. Predator exclosures: a technique to reduce predation at piping plover nests. Wildlife Society Bulletin 20: 143–148.

Messmer, T. A., M. W. Brunson, D. Reiter, and D. G. Hewitt. 1999. United States public attitudes regarding predators and their management to enhance avian recruitment. Wildlife Society Bulletin 27:75–85.

Mueller, J. M., C. B. Dabbert, S. Demarais, and A. R. Forbes. 1999. Northern bobwhite chick mortality caused by red-imported fire ants. Journal of Wildlife Management 63: 1291–1298.

Ratnaswamy, M. J., R. J. Warren, M. T. Kramer, and M. D. Adam. 1997. Comparisons of lethal and nonlethal techniques to reduce raccoon depredation of sea turtle nests. Journal of Wildlife Management 61: 368–376.

Rollins, D., and J. P. Carroll. 2001. Impacts of predation on northern bobwhite and scaled quail. Wildlife Society Bulletin 29: 39–51.

Rosene Jr., W. 1969. The bobwhite quail: its life and management. Rutgers University Press, New Brunswick, New Jersey, USA.

Sargeant, A. B., M. A. Sovada, and T. L. Shaffer. 1995. Seasonal predator removal relative to hatch rate of duck nests in waterfowl production areas. Wildlife Society Bulletin 23: 507–513.

Smith, H. D., F. A. Stormer, and R. D. Godfrey Jr. 1981. A collapsible quail trap. USDA, Forest Service Research Note RM-400. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.

ANNUAL VARIATION IN NORTHERN BOBWHITE SURVIVAL AND RAPTOR MIGRATION

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ABSTRACT

We estimated survival of radio-marked northern bobwhite (*Colinus virginianus*) on a managed prairie site in northeast Mississippi during 2 disparate winters (15 Sep-14 Apr 2000–2002). We retrospectively examined factors that may influence bobwhite survival. Pooled survival rates differed substantially between years ($S = 0.03 \pm 0.02$ in 2000–2001 and $S = 0.36 \pm 0.16$ in 2001–2002). Regional relative abundance of 3 species of raptors thought to be important predators of bobwhite was greater during 2000 compared to 2001 based on kriging of Christmas Bird Count (CBC) data. We demonstrate an approach for characterizing annual variation in spatial distribution of migratory raptors and suggest that annual variation in local winter predator context may be useful for explaining annual variation in winter survival of local bobwhite populations.

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Key words: *Colinus virginianus*, Mississippi, northern bobwhite, predation, raptors, Survival

INTRODUCTION

Northern bobwhites experienced range-wide population declines during the last 3 decades of the twentieth century (Droege and Sauer 1990, Brennan 1991, Church et al. 1993). Bobwhite populations declined at a rate of 3.8% per year in the southeastern United States between 1966 and 1999 (Sauer et al. 2000). The most likely cause of bobwhite population declines is the reduction of suitable habitat (Klimstra 1982) associated with changes in farming practices (Roseberry and Klimstra 1984), changes in silvicultural practices (Brennan 1991), advancing stages of plant succession (Roseberry et al. 1979), and reduction in the intensity and frequency of natural disturbance (Stoddard 1931).

Bobwhites are associated with early successional ground cover for nesting, brood-rearing, and foraging. Bobwhite populations respond positively to habitat management and may be locally abundant in managed landscapes (Burger and Linduska 1967, Ellis et al. 1969, Webb and Guthery 1982). Populations in intensively managed areas have remained stable in contrast to regionally declining population trends (Brennan et al. 2000). Habitat management is generally designed to create and maintain native herbaceous ground cover. Commonly implemented management practices include disking, rotational agriculture, and prescribed fire. Specific management objectives of these practices include provision of seasonal resources (i.e., annual seed producing plants, appropriate nesting structure, invertebrates, etc.) and maximizing usable space through time. The latter objective is clearly a desirable goal for increasing or stabilizing local bobwhite populations, as there are other factors beyond the control of land managers that may influence bobwhite population demographics. Spatial and temporal variation in weather (Guthery 1997, 2002), landscape context (Thompson et al. 2002), landscape composition (Staller et al. 2002), predator space use (Chalfoun et al. 2002), and predator context (Burger 2002) may influence predation processes and demographics.

Numerous important bobwhite predators are migratory raptors and include sharp-shinned hawks (*Accipiter striatus*), Cooper's hawks (*A. cooperii*), northern harriers (*Circus cyaneus*), and red-tailed hawks (*Buteo jamaicen-*

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sis). It is likely that none of these raptors prey exclusively, or even primarily, on bobwhites (Rosene 1969), but individual species and their collective impact may substantially influence local bobwhite survival. Bobwhites may not constitute an important food source for avian predators, but avian predators may contribute substantially to bobwhite mortality (Burger et al. 1995, 1998). Previous research has suggested that composition of the raptor community and abundance of specific species of predators rather than the overall raptor density influences bobwhite survival (Holschneider et al. 2002). A local bobwhite population decline in Texas was attributed to an unusual seasonal influx of avian predators (Jackson 1947). Migration patterns of raptors likely vary from year to year and influence local predator community composition.

The objective of our study was to retrospectively examine annual variation in raptor migration that may account for variation in bobwhite survival estimates. A retrospective analysis does not constitute a rigorous test of cause and effect, nor even correlative evidence given the short duration of the study. Thus, we demonstrate an approach for using large-scale regional abundance information such as Christmas Bird Counts (CBC) to characterize annual variation in local abundance of migratory predators as a covariate for use in studies designed to explore annual variation in bobwhite demographics.

METHODS

We conducted research on the Black Prairie Wildlife Management Area (BPWMA) in southern Lowndes County, Mississippi in the Blackland Prairie physiographic region. The mean annual temperature was 16.5 °C with a range from 4.4 °C in January to 27.0 °C in July (NOAA 2000). The study area was ~ 2,300 ha and is managed by the Mississippi Department of Wildlife, Fisheries and Parks (MDWFP). The purpose of BPWMA is to demonstrate wildlife friendly management practices in an agricultural landscape. The overwinter period defined for our study was from 15 September until 14 April.

Bobwhites were captured during fall and spring of each year, 2000–2002. Fall capture occurred during 2 weeks in September and 2 weeks in November of each year using walk-in style wire traps (Stoddard 1931) baited with cracked corn. We classified sex and age of each bird captured and weighed, and banded all birds on the right leg with a #7 numbered aluminum band. Each bird was fitted with a 5-6-g necklace style radio transmitter (American Wildlife Enterprises, Monticello, FL, USA) and released at the capture site. Radio transmitters had a 12-hr mortality sensor. Additional bobwhites were captured by night netting throughout the study (Truitt and Dailey 2000).

Radio-marked bobwhites were located at least 5 days each week using a programmable scanning receiver and a handheld 3-element Yagi antenna (Advanced Telemetry Systems Inc., Isanti, MN, USA). Remains of bobwhite were recovered upon receiving a mortality signal with the telemetry receiver. An approximate cause of mortality was assigned at the site of the radio transmitter when possible (Dumke and Pils 1973). Mortality factors were classified as avian, mammalian, unknown, or other. Seasonal cause-specific mortality rates were calculated using Program MICROMORT (Heisey and Fuller 1985).

Seasonal survival rates were estimated for the 2000–2001 and 2001–2002 over-winter periods using the Kaplan-Meier approach modified for staggered entry (Pollock et al. 1989). Birds with unknown fates (radio failure, emigration from study area, mortality attributed to research, or survival past 14 Apr of each year) were right censored. We assumed that right censoring mechanisms were independent of the bird's fate and left censored bobwhite had similar survival distributions to birds that were previously included in the risk set. We also assumed the sample of bobwhites used was random, survival times were independent for all individuals, and capture, handling, and marking did not affect survival. Radio-marked bobwhites were entered into the risk set on the first day following capture with no adjustment period to account for acute effects of time since capture, handling, and marking on survival (Holt et al. 2009).

Christmas Bird Count (CBC) data indexing year-specific relative abundance and spatial distribution of migratory raptors during December were downloaded from the National Audubon Society Christmas Bird Counts for 1985–2001 (National Audubon Society 2002). We were interested in mean relative raptor abundances over a longer period in addition to between years of our study. The CBC data were collected for chosen count circles in a 14 state area including Alabama, Arkansas, Florida, Georgia, Illinois, Indiana, Kentucky, Louisiana, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, and Kentucky. All CBC circles chosen were south of latitude 40.54, north of latitude 29.21, east of longitude –95.33, and west of longitude –81.27. The CBC circles used were chosen from available CBC circles based on continuity of data over time and even distribution over the region.

We used data from 181 CBC circles. Data were used from 176 CBC circles in 2000 and 173 circles in 1999. The number of CBC circles used in this analysis during the 17 years from 1985 to 2001 ranged from 120 in 1985 to 177 in 1998. Locations of CBC circles were georeferenced in ArcView 3.2. Attribute information for each circle included the number of birds per hour counted for sharp-shinned hawks, Cooper's hawks, northern harriers, and red-tailed hawks. We used kriging to generate a year-specific surface of regional relative abundance of each raptor species during December. We used universal kriging, because it allows for a trend to be present in the spatial data (Isaaks and Srivastava 1989). The kriged surface of relative raptor abundance was developed with a cell size of 0.1^2 decimal degrees, which equaled ~ 10,424 ha within the latitudes of interest.

We defined 6 latitudinal bands to describe year-specific spatial patterns in relative raptor abundance. Latitude bands were 1° wide from north to south and 11° wide from east to west. The northernmost latitude used was 37° and the southernmost latitude was 31°. Each band was ~ 111 km wide from north to south. There were

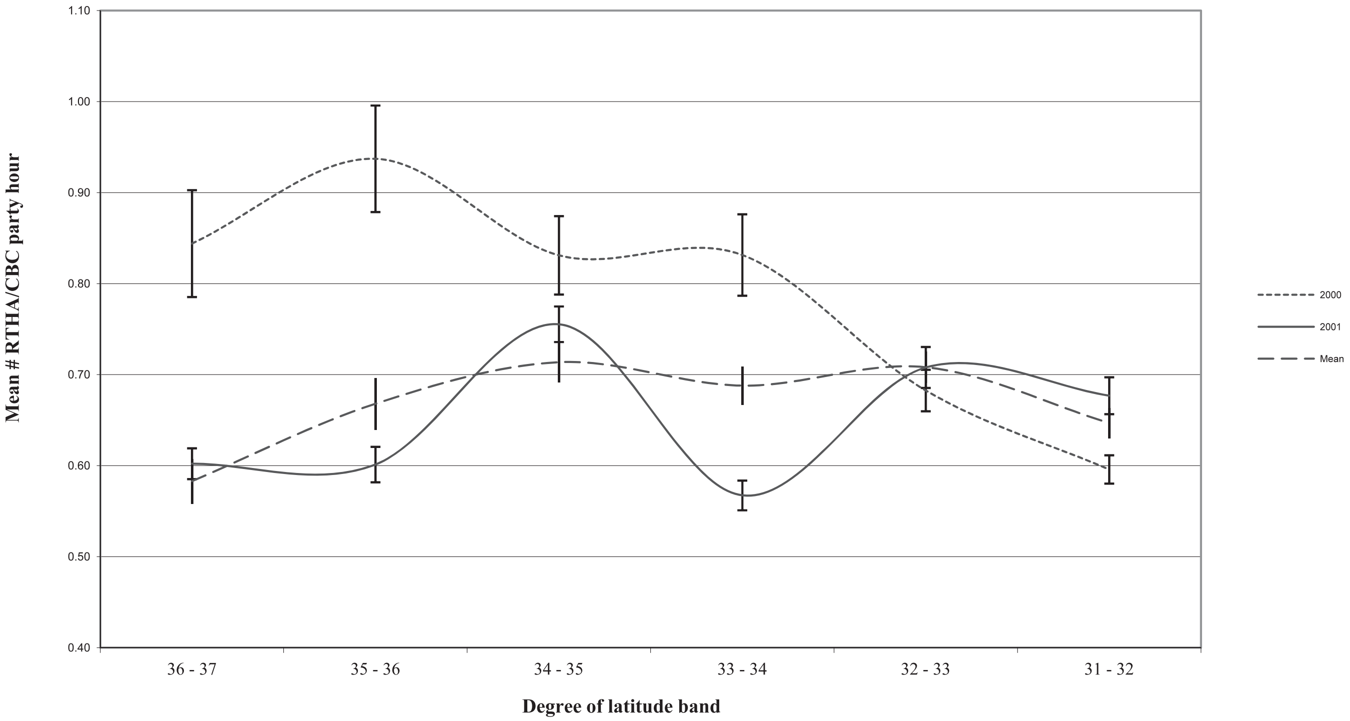

Fig. 1. Mean relative abundance of red-tailed hawks (RTHA) within 1° latitude bands based on surface kriged from Audubon Society Christmas Bird Counts during 2000, 2001, and averaged from 1985 to 2001.

1,100 cell grids in each band. We calculated means and standard errors of relative abundance of selected raptor species as estimated from the kriged surface of CBC data for each latitude band.

RESULTS

Seasonal Survival and Cause-specific Mortality

We captured and marked 173 bobwhites during the 2000–2001 season and 71 during the 2001–2002 season. Over-winter survival estimates were 0.03 ± 0.02 for the 2000–2001 season and 0.36 ± 0.16 for the 2001–2002 season. Avian predators were the primary mortality factor during both seasons with cause-specific mortality rates of 0.50 ± 0.78 during the 2000–2001 season and 0.28 ± 0.13 during the 2001–2002 season. This was followed in each year by mammalian cause-specific mortality rates of 0.37 ± 0.08 during the 2000–2001 season and 0.23 ± 0.14 during the 2001–2002 season; unknown cause-specific mortality rates were 0.09 ± 0.04 during the 2000–2001 season and 0.13 ± 0.10 during the 2001–2002 season. Cause-specific mortality rates for other causes were 0.01 ± 0.02 during the 2000–2001 seasons. There were no mortalities due to other mortality factors during the 2001–2002 season.

Raptor Migration Phenology

There were greater relative abundances of red-tailed hawks (Fig. 1) and Cooper's hawks (Fig. 2) in 2000 compared to 2001 and to the 17-year mean (1985–2001) in the latitude band that contains BPWMA (33°-34°) based on the estimated index of regional raptor relative abundance from CBC data. There was greater relative abundance of northern harriers (Fig. 3) in 2000 compared to 2001 and during both years of our study compared to the 17-year mean (1985–2001) in latitude band 33°-34°. Estimated relative abundance of sharp-shinned hawks (Fig. 4) from the same data showed greater relative abundance in 2001 than in 2000 and for the 17-year mean (1985–2001) in latitude band 33°-34°. Estimated relative abundance of sharp-shinned hawks (Fig. 4) was about equal between 2000 and the 17-year mean (1985–2001) in latitude band 33°-34°.

DISCUSSION

Annual studies of bobwhite have reported greater mortality rates during the overwinter period (Roseberry and Klimstra 1984; Curtis et al. 1988; Burger et al. 1995, 1998) than during other times of the year. Overwinter survival (0.03) observed on BPWMA during the 2000–2001 season was less than any previously reported study (Burger et al. 1995, Townsend et al. 1999) and clearly would not allow the population to be self-sustaining.

We observed greater regional relative abundance of migratory raptors in the latitude band containing BPWMA concurrent with high winter avian mortality in 2000. Cooper's hawks, sharp-shinned hawks, red-tailed hawks, red-shouldered hawks (*Buteo lineatus*), and great horned owls (*Bubo virginianus*) contribute to bobwhite mortality during the breeding season. However, mortality of bobwhite due to mammalian predators is generally greater

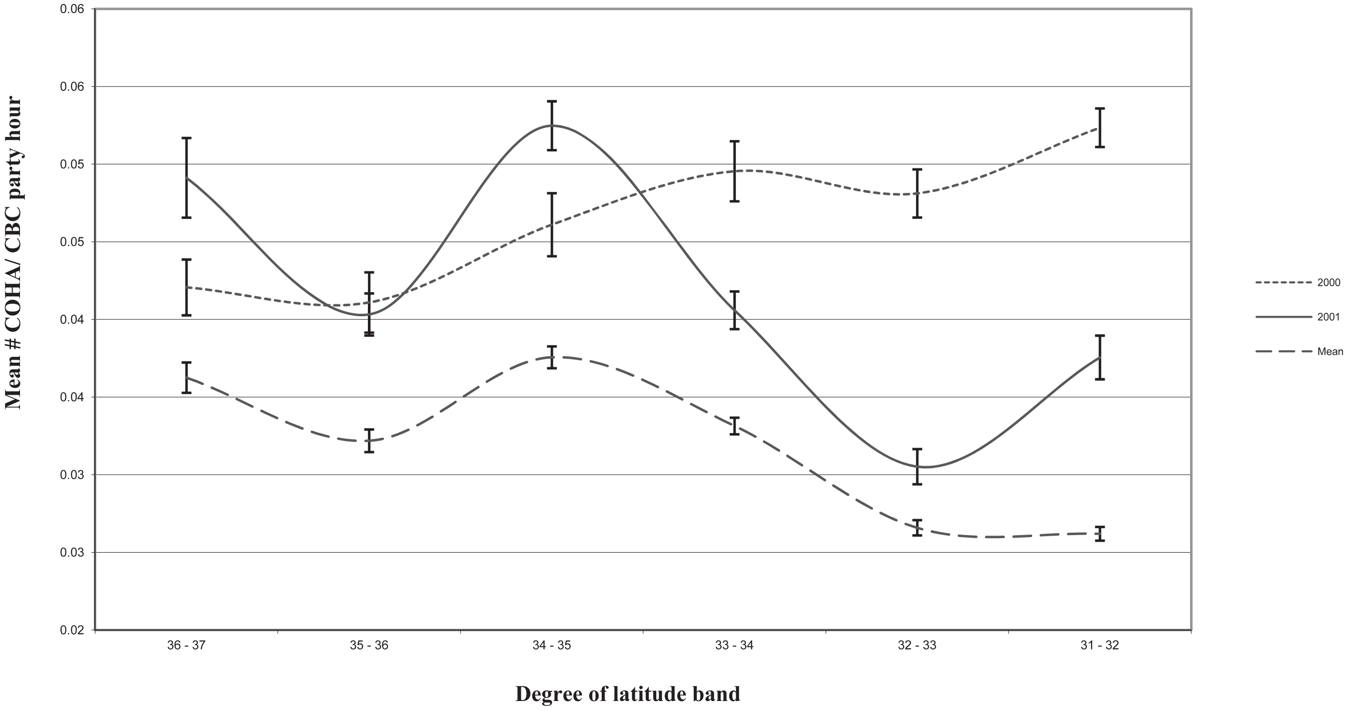

Fig. 2. Mean relative abundance of Cooper's hawks (COHA) within 1° latitude bands based on surface kriged from Audubon Society Christmas Bird Counts during 2000, 2001, and averaged from 1985 to 2001.

than that due to avian predators during the bobwhite nesting season (Burger et al. 1995, 1998). Previous studies have suggested that seasonal variation in relative abundance of specific raptors might affect bobwhite overwinter survival (Jackson 1947, Holschneider 2002). Specifically, Jackson (1947) reported that an unusually high wintering population of migratory northern harriers reduced a high density local bobwhite population.

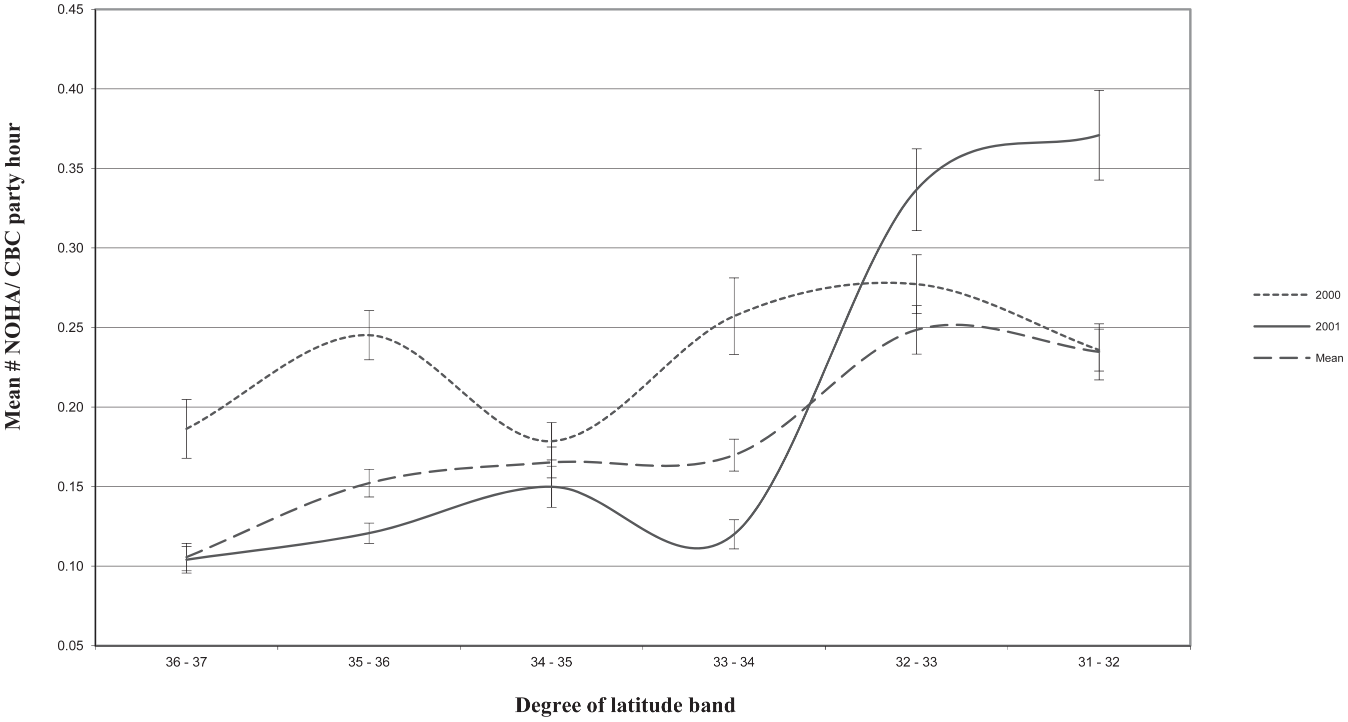

Fig. 3. Mean relative abundance of northern harriers (NOHA) within 1° latitude bands based on surface kriged from Audubon Society Christmas Bird Counts during 2000, 2001, and averaged from 1985 to 2001.

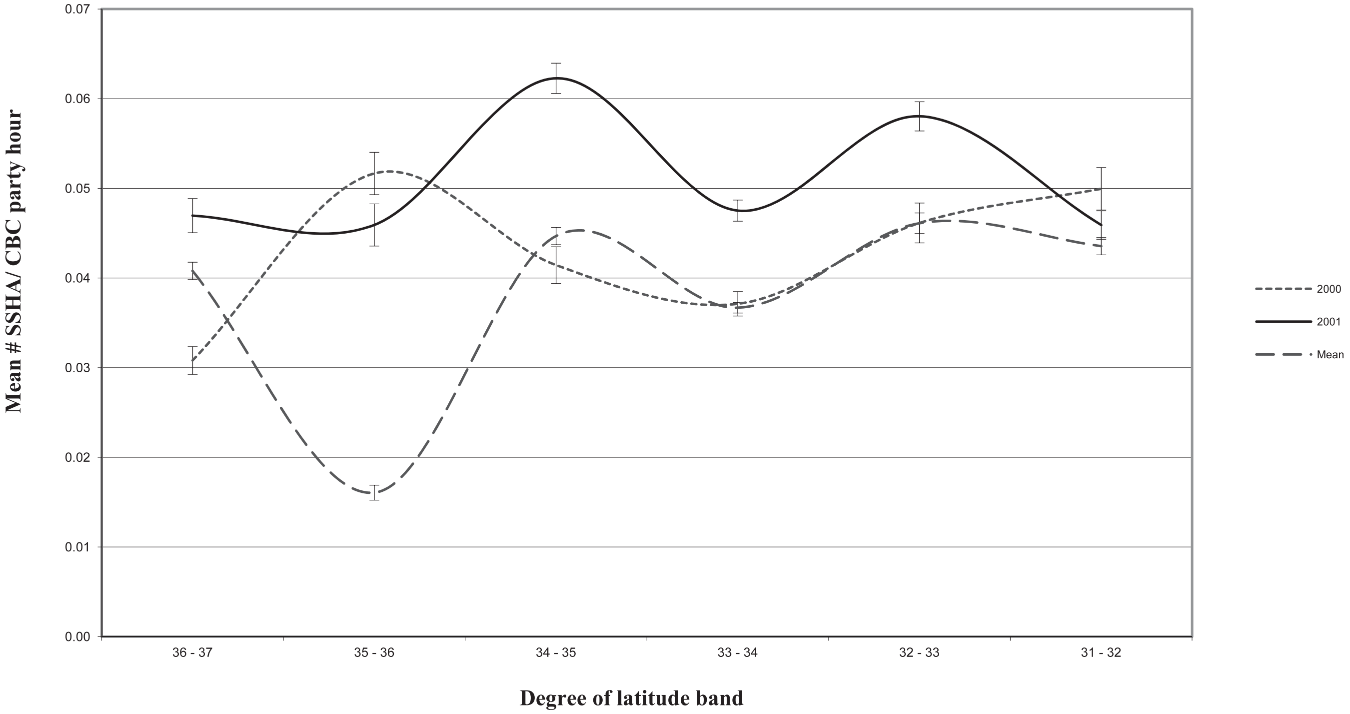

Fig. 4. Mean relative abundance of sharp-shinned hawks (SSHA) within 1° latitude bands based on surface kriged from Audubon Society Christmas Bird Counts during 2000, 2001, and averaged from 1985 to 2001.

Holscheider (2002) reported a weak correlation between abundance of all raptor species and total bobwhite mortality, but a stronger correlation between predation of bobwhite from raptors and *Accipiter* spp. abundance.

Migratory birds may appear in southerly latitudes in different densities and at different times annually (Saunders 1959, Wedemeyer 1973, Welty 1982). Abundance of wintering raptors at a given location may be expected to vary annually in relation to prevailing climatic conditions. A major migration may occur, but influxes of avian predators may happen throughout the season as cold fronts move into an area (Mueller and Berger 1961).

Our data suggests that for at least 3 species (red-tailed hawks, Cooper's hawks, and northern harriers), there were greater relative abundances present during the season of poor over-winter survival (2000–2001) at the latitude band that included BPWMA. The poor over-winter survival experienced by bobwhites during the first year could be the result of the culmination of a number of factors working together. We cannot attribute cause and effect, and hypothesize that independent of local habitat composition and landscape context; annual variation in local abundance of migratory raptors interacts with year-specific herbaceous ground cover conditions to influence annual variation in winter survival of bobwhite.

We demonstrated a technique to model annual change in relative abundance of migratory raptors. We made the assumption that annual differences in relative abundances at a regional scale translate to corresponding differences at the local or study site scale. This method has limitations as it does not provide *post-hoc* estimates of raptor abundance or density at either the local or regional scale. The method provides an index of relative abundance of raptors compared to other years or long-term means over a regional scale. We believe this method has utility to re-examine one factor that could influence annual variation in survival of bobwhites when more data are available.

This method allows for validation where local raptor survey data are available. We suggest spatial modeling of large-scale relative abundance information, such as from CBCs, when coupled with long-term local demographic studies, could provide insight into annual variation in winter survival.

ACKNOWLEDGMENTS

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LITERATURE CITED

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

Brennan, L. A., J. M. Lee, and R. S. Fuller. 2000. Long term trends of northern bobwhite populations and hunting success on private shooting plantations in northern Florida and southern Georgia. Proceedings of the National Quail Symposium 4:75–77.

Burger, G. V., and J. P. Linduska. 1967. Habitat management related to bobwhite populations at Remington Farms. Journal of Wildlife Management 31:1–12.

Burger, L. W. 2002. Quail management: issues, concerns, and solutions for public and private lands-a southeastern perspective. Proceedings of the National Quail Symposium 5:20–34.

Burger, L. W., T. V. Dailey, E. W. Kurzejeski, and M. R. Ryan. 1995. Survival and cause-specific mortality rates of northern bobwhite in Missouri. Journal of Wildlife Management 59:401–410.

Burger, L. W., C. D. Sisson, H. L. Stribling, and D. W. Speake. 1998. Northern bobwhite survival and cause-specific mortality on an intensively managed plantation in Georgia. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 52:174–190.

Chalfoun, A. D., F. R. Thompson III, and M. J. Ratnaswamy. 2002. Nest predators and fragmentation: a review and meta-analysis. Conservation Biology 16:305–318.

Church, K. E., J. R. Sauer, and S. Droege. 1993. Population trends of quails in North America. Proceedings of the National Quail Symposium 3:44–54.

Curtis, P. D., B. S. Mueller, P. D. Doerr, and C. F. Robinette. 1988. Seasonal survival of radio-marked northern bobwhite quail from hunted and non-hunted populations. Proceedings of the Symposium on Biotelemetry 10:263–275.

Droege, S., and J. R. Sauer. 1990. Northern bobwhite, gray partridge, and ring-necked pheasant population trends (1966–1988) from the North American Breeding Bird Survey. Pages 2–20 *in* K. E. Church, R. E. Warner, and S. J. Brady, eds. Perdix V: Gray Partridge and Ringed-necked Pheasant Workshop.

Dumke, R. T., and C. M. Pils. 1973. Mortality of radio-tagged pheasants on the Waterloo Wildlife Area. Technical Bulletin 72. Wisconsin Department of Natural Resources, Madison, USA.

Ellis, J. A., W. R. Edwards, and K. P. Thomas. 1969. Responses of bobwhites to management in Illinois. Journal of Wildlife Management 33:749–762.

Guthrey, F. S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 61:291–301.

Guthrey, F. S. 2002. The technology of bobwhite management: the theory behind the practice. Iowa State Press, Ames, USA.

Heisey, D. M., and T. K. Fuller. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. Journal of Wildlife Management 49:668–674.

Holschneider, F. R., F. Hernández, D. Rios, and J. D. Vasquez. 2002. Understanding the relationship between northern bobwhite mortality and raptor migration in south Texas. Proceedings of the National Quail Symposium 5:72.

Holt, R. D., L. W. Burger Jr., S. J. Dinsmore, M. D. Smith, S. J. Szukaitis, and K. D. Godwin. 2009. Estimating duration of short-term acute effects of capture, handling, and radio-marking. Journal of Wildlife Management 73:989–995.

Isaaks, E. H., and R. M. Srivastava. 1989. An introduction to applied geostatistics. Oxford University Press, New York, USA.

Jackson, A. S. 1947. A bobwhite quail irruption in northwest Texas lower plains terminated by predation. Proceedings of the North American Wildlife Conference 12:511–519.

Klimstra, W. D. 1982. Bobwhite quail and changing land use. Proceedings of the National Bobwhite Quail Symposium 2:1–5.

Mueller, H. C., and D. D. Berger. 1961. Weather and fall migration of hawks at Cedar Grove, Wisconsin. Wilson Bulletin 73:171–192.

National Audubon Society. 2002. The Christmas Bird Count historical results, National Audubon Society, New York, USA. www.audubon.org/bird/cbc

National Oceanic and Atmospheric Administration (NOAA). 2000. National Climatic Data Center, Ashville, North Carolina, USA. http://www.ncdc.noaa.gov

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry approach. Journal of Wildlife Management 53:7–14.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, USA.

Roseberry, J. L., B. J. Peterjohn, and W. D. Klimstra. 1979. Dynamics of an unexploited bobwhite population in deteriorating habitat. Journal of Wildlife Management 43:306–315.

Rosene Jr., W. 1969. The bobwhite quail: its life and management. Rutgers University Press, New Brunswick, New Jersey, USA.

Sauer, J. R., J. E. Hines, I. Thomas, J. Fallon, and G. Gough. 2000. The North American Breeding Bird Survey, results and analysis 1966–1999. Version 98.1. USDI, Geological Survey, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Saunders, A. A. 1959. Forty years of spring migration in southern Connecticut. Wilson Bulletin 71:208–219.

Staller, E. L., W. E. Palmer, and J. D. Carroll. 2002. Macrohabitat composition surrounding successful and depredated northern bobwhite nests. Proceedings of the National Quail Symposium 5:61–64.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. Charles Scribner's Sons, New York, USA.

Thompson III, F. R., T. M. Donovan, R. M. DeGraaf, J. Faaborg, and S. K. Robinson. 2002. A multiscale perspective of the effects of forest fragmentation on birds in eastern forests. Studies in Avian Biology 25:8–19.

Townsend II, D. E., R. L. Lochmiller, S. J. DeMaso, D. M. Leslie Jr., A. D. Peoples, S. A. Cox, and E. S. Parry. 1999. Using supplemental food and its influence on survival of northern bobwhite (*Colinus virginanus*). Wildlife Society Bulletin 27:1074–1081.

Truitt, V. L., and T. V. Dailey. 2000. Efficiency of bait trapping and night lighting for capturing northern bobwhite in Missouri. Proceedings of the National Quail Symposium 4:207–210.

Webb, W. M., and F. S. Guthrey. 1982. Response of bobwhite to habitat management in northwest Texas. Wildlife Society Bulletin 10:142–146.

Wedemeyer, W. 1973. The spring migration pattern at Fortine, Montana. Condor 75:400–413.

Welty, J. C. 1982. The life of birds. Saunders College Publishing, New York, USA.

SPATIAL ANALYSIS OF PREDATOR ABUNDANCE AND NORTHERN BOBWHITE NEST SUCCESS IN SOUTHERN TEXAS

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ABSTRACT

Northern bobwhites (*Colinus virginianus*) have low nest success across their geographic range, and predation is the primary cause of failure. We evaluated the influence of relative abundance of predators on northern bobwhite nest success. We used data from a long-term radiotelemetry study conducted on 3 sites (800 ha each) in Brooks County, Texas during 2000–2007. We located bobwhite nests ($n = 456$) using radiotelemetry and estimated Mayfield nest success each year. We also estimated relative abundance of nest predators using scent stations (400 × 400 m grid/site) during the nesting season (May–Aug). We developed a gradient map of predator relative abundance and correlated this variable with location-specific bobwhite nest success. Mayfield nest success during the incubation period (23 days) varied between 0.43 and 0.60 during the study. Scent-station visitation rates (% stations visited/night) ranged from 0 to 67%.

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Key words: *Colinus virginianus*, nest success, northern bobwhites, predation, south Texas

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THREAT AVOIDANCE BEHAVIOR AND LAND USE OF THE NORTHERN BOBWHITE IN THE ROLLING PLAINS OF TEXAS

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ABSTRACT

Northern bobwhites (*Colinus virginianus*) are an economically important species for several regions within the state of Texas. Bobwhites, along with their fiscal importance, fill a key role within the ecosystem as an *r*-selected common prey species. However, throughout the past few decades, bobwhite populations have plummeted to record lows. Currently many studies are investigating possible causes behind this precipitous decline, but efforts to discover better land management practices that provide preferred habitat for bobwhites should not be abandoned. Current landscape recommendations related to bobwhite escape cover stem from data collected on anthropogenic threats to bobwhites (i.e., coveys flushed by human disturbance). Bobwhites have a multitude of non-anthropogenic threats in the wild, and the existing data may lack important information regarding threat-specific avoidance behavior. Predation is a primary cause of bobwhite mortality, and we focused on bobwhite anti-predatory behavior and resulting land-use strategies with an ultimate goal of providing management recommendations to increase bobwhite survival. We designed and conducted an experiment to investigate not only bobwhite responses to anthropogenic threats, but also their responses to common natural predators. We investigated bobwhite behavioral and use of cover actions in response to 4 threat types: researchers, hunters, raptors, and nocturnal mammals. We collected data from January through March in 2010 and from November 2010 through March 2011. We measured characteristics of bobwhite flushing behavior, flight speed, and land and vegetative use when presented with specific threats. We located radio-marked coveys and conducted a walk-through for the researcher threat, if necessary, to cause the birds to flush. The hunter and raptor threats were conducted similarly with introduction of pointing dogs and shotgun blasts for the hunting scenario, and introduction of a trained northern goshawk (*Accipiter gentilis*) to give chase to bobwhites in the raptor scenario. We followed the same methods as the researcher treatment when creating the nocturnal mammal treatment, but conducted the test at night and followed the birds' flight with a thermal imaging scope. There was a significant difference in landing cover among threat types with bobwhites selecting shrubs for landing cover when pursued by a raptor ($P < 0.0001$), whereas they showed no selection for shrubs when flushed by the other threat types. Bobwhites landed in live oak (*Quercus virginianus*) mottes and hackberry (*Celtis reticulata*) shrubs with the highest frequency, followed closely by wolfberry (*Lycium barbarum*), lote bush (*Ziziphyus obtusifolia*), and Englemann's pricklypear (*Opuntia engelmannii*) when escaping the raptorial threat, These 5 species accounted for 49% of all shrubs used (19 total species) as escape cover in the raptor treatment. Obstructive vegetative height was higher at landing sites when bobwhites were presented with a raptor ($P < 0.0001$) or hunter ($P = 0.033$) threat; however, bobwhites displayed no selection for obstructive vegetative height when presented with a researcher or nocturnal mammal threat. Further analyses will include modeling environmental and experimental parameters to find likely predictors of bobwhite threat avoidance behaviors, such as flushing speed, flight speed, and flight distance; behaviors that arguably affect energy expenditure and may interact with bobwhite health and predator avoidance capabilities. Our results suggest that land management recommendations based solely on anthropogenic threats may be insufficient to enable successful bobwhite escape strategies from raptors. Considering the availability and 'integrity' of shrubs as escape cover from raptors when contemplating brush management plans may enhance bobwhite management. We expect to provide threat-specific land management recommendations for bobwhites related to shrub species and density as well as grass density with continued analysis of these data.

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Key words: behavior, *Colinus virginianus,* land use, northern bobwhite, predators, Texas

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DISTRIBUTION OF COMMON RACCOONS AND COYOTES DURING QUAIL NESTING SEASON

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ABSTRACT

Mammalian predation of quail and their eggs is a problem to many producers of quail particularly considering that abundance of common meso-predators, such as coyotes (*Canis latrans*) and common raccoons (*Procyon lotor*), is increasing. Predator removal programs are often not cost effective in increasing quail numbers but habitat management may be appropriate. There is a need for detailed knowledge of the habitat preferences and foraging patterns of these predators so producers of quail may limit predation of quail through management decisions and habitat manipulation. We placed GPS collars on 5 coyotes and 11 raccoons at Rolling Plains Quail Research Ranch, Fisher County, Texas during the nesting season of northern bobwhites (*Colinus virginianus*). The location of each animal was recorded at 5-min intervals for 35–42 consecutive nights. Habitat use and selectivity was calculated by Chi-square test of proportional use and availability of ecological sites both within the minimum convex polygon area used by each animal and throughout the ranch and adjacent 3-km buffer zone. Distribution of marked animals relative to roads, water, and quail feeders was compared to an equal number of randomly generated locations. Coyotes preferentially hunted in grassland which is prime nesting habitat for northern bobwhites. Coyotes were not deterred from accessing grassland with high concentrations of low growing plains prickly pear (*Opuntia polyacantha*). The nocturnal paths taken by coyotes over 1 month effectively covered virtually all the grassland habitat within their home range which increases the probability of locating nesting quail. Coyotes used ranch roads for travel but had little attraction to quail feeders and water sources. Raccoons favored areas of heavy cover such as riparian woodland and boulder strewn hillsides. Female raccoons had small home ranges and remained within thick cover. They rarely entered the more open habitats where quail nest and did not use ranch roads or seek out quail feeders which were mainly in grassland areas, nor did they encounter cactus-dominated grassland areas. Male raccoons had more expansive home ranges than females; they favored riparian strips and rocky hills as travel corridors but also ventured into more open habitats. They strongly avoided cactus-dominated areas but used grassland where scattered shrubs provided additional cover. Male raccoons within these areas used ranch roads for ease of travel and certain individuals frequently visited quail feeding stations. The tortuous nocturnal foraging path followed by raccoons provided efficient search patterns for locating scattered resources such as quail nests. Raccoons are generally considered to be more problematic predators of quail nests than coyotes. Where coyotes are less of a threat to quail than raccoons, tolerating the presence of coyotes may protect quail through competitive exclusion of raccoons from grasslands by the larger predator. Similarly, cactus in grasslands is seen as a problem for grazing livestock and a hindrance to quail hunters, but leaving some areas dominated by cactus may provide quail with valuable nesting refugia inaccessible to raccoons. The success of supplemental feed programs for quail should be balanced against the problem of altering the distribution of raccoons so they spend more time in quail nesting habitat and are more likely to discover quail nests. Placing feeders in areas where cover for predators is limited is advisable, as is targeted predator removal at quail feeding stations.

Citation: Cooper, S. M., D. Rollins, and S. Jhala. 2012. Distribution of common raccoons and coyotes during quail nesting season. Proceedings of the National Quail Symposium 7:273.

Key words: *Colinus virginianus,* common raccoon, coyote, nesting, northern bobwhite, Texas

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COYOTE DIETS ON THE ROLLING PLAINS QUAIL RESEARCH RANCH, TEXAS

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ABSTRACT

Predation is a major cause of mortality and nest failure for the northern bobwhite (*Colinus virginianus*) across its range. Coyotes (*Canis latrans*) are a potential predator of bobwhites and typically the most common mesocarnivore on bobwhite range in Texas. Few data exist regarding the importance of bobwhites in the coyote's diet in the Rolling Plains of Texas. We describe the seasonal and annual diets of coyotes on the Rolling Plains Quail Research Ranch (RPQRR), Fisher County, Texas. The RPQRR encompasses 1,902 ha of rolling terrain consisting of ridges and mesquite (*Prosopis glandulosa*) dominated rangeland; other common shrubs include netleaf hackberry (*Celtis laevigata*), littleleaf sumac (*Rhus microphylla*), lotebush (*Ziziphus obtusifolia*), wolfberry (*Lycium berlandieri*), chittam (*Bumrlia lanuginosa*), catclaws (*Acacia* spp., *Mimosa* spp.), and agarito (*Mahonia trifoliolata*). Prickly pear (*Opuntia* spp.) is abundant on most sites. The study area received 58 and 64 cm of rainfall, respectively during 2009 and 2010, below the 30-year average of 76 cm for Fisher County, Texas. We collected, and examined 720 coyote scats from December 2008 to December 2010. Each scat was prepared for analysis by placing it inside a nylon mesh bag and washing it for 2 cycles in an automatic washing machine. We analyzed scat contents macroscopically and any guard hairs were analyzed microscopically to identify prey to genus. We also collected estimates of abundance for a range of potential food sources including bobwhites, small mammals, and insects. Preliminary analyses suggest coyotes were minor predators of quail and their diets mainly consisted of seasonally-available mast (e.g., tunas of prickly pear) and rodents. Variation in timing and amount of rainfall during our study allowed us to document how coyotes adjusted their diets to the resulting fluctuations in food availability (especially mast).

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APPLICATION OF METAPOPULATION THEORY TO NORTHERN BOBWHITE CONSERVATION

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ABSTRACT

Northern bobwhite (*Colinus virginianus*) populations have declined throughout the majority of the species' range, and have experienced the largest declines in fragmented habitats, suggesting landscape scale processes may be responsible for this decline. We used the results from a stochastic population dynamics model of South Texas bobwhites as conceptual justification for use of metapopulation theory in bobwhite management. Annual quasi-extinction probabilities for isolated bobwhite populations were 0.003 (95% CI: 0.001–0.006), 0.105 (95% CI: 0.083–0.126), and 0.773 (95% CI: 0.750–0.796) for simulated populations harvested at 20, 30, and 40% annually. The probability of regional persistence at 30% harvest increased to $\sim$ 100% in scenarios where we modeled 5 occupied hypothetical 800-ha habitat patches; however, at 40% harvest rates, probability of regional metapopulation persistence did not reach 95% until 12 habitat patches were occupied. This suggests bobwhites probably require somewhere from 800 to 9,600 ha of available habitat space to maintain 95% probability of regional metapopulation persistence as harvest varies from 0 to 40% annually. Our results have strong implications for bobwhite harvest management given the high probability of quasi-extinction of isolated populations at rates of harvest $\geq$ 25%. Multiple patches of habitat (where individual patch size is $\geq$ 800 ha) must be available to ensure bobwhite metapopulation persistence.

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INTRODUCTION

The long-term range-wide decline in northern bobwhite populations has been occurring since the late 19th Century, and has been a concern of research scientists and quail managers since at least the 1930s (Stoddard 1931, Brennan 1991). This decline is primarily associated with landscape-scale fragmentation and range-wide loss of usable habitat space (Brady et al. 1998). Habitat fragmentation has broad scale implications for impacting ecosystem processes, and maintaining native biodiversity (Saunders et al. 1991, Walters 1998, Fahrig 2003), of which northern bobwhites and their habitat are clearly a part.

Metapopulation theory is based on the concept of individuals dispersing from one population to another and these movements have an impact on the probability of persistence of the entire metapopulation (Hanski 2001). Bobwhites have generally been considered a sedentary species; however, observations from banded and radio-marked bobwhites (Lehmann 1984:119, Fies et al. 2002, Townsend et al. 2003, Cook et al. 2009) and genetic analysis from Texas (R. W. DeYoung, unpublished data) indicate bobwhite dispersal among habitat patches may occur more frequently than previously thought.

Bobwhites have been subject to intense research efforts since the 1920s, but little is known about the potential applicability of metapopulation theory in northern bobwhite conservation. Our objectives were to: (1) use the results from a stochastic bobwhite population dynamics model developed for the South Texas Plains as the basis for a classical (Levins 1970) metapopulation modeling exercise using 5 simulated harvest scenarios; (2) apply these results as conceptual justification for application of metapopulation theory in bobwhite management; and (3) discuss how the metapopulation concept is consistent with habitat objectives necessary for successful bobwhite conservation outcomes at local, state, and national scales.

METHODS

Field Methods

We collected field data (DeMaso 2008, Sands 2010) in the South Texas Plains ecoregion (Gould 1975). The South Texas Plains experiences high annual and seasonal variability in rainfall amount, and quail populations exhibit irruptive population behavior (Lehmann 1984). The study area was on private rangeland in Brooks County, Texas. Land uses on the study area included wildlife management for commercial hunting, primarily bobwhite and white-tailed deer (*Odocoileus virginianus*), and cattle production, as well as oil and natural gas production. Bobwhite hunting on the study sites was conducted by following dogs from vehicles.

Historical accounts of the region vary greatly (e.g., barren desert or lush grassland) due to high variation in rainfall, and depending on conditions at the time (Lehmann 1984). The study area was in a landscape composed predominantly of suitable quail habitat. The plant community was a mixed-brush community characteristic of the South Texas Plains (McLendon 1991). Common brush species included mesquite (*Prosopis* spp.), huisache (*Acacia farnesiana*), granjeno (*Celtis pallida*), and brasil (*Condalia hookeri*) (Everitt et al. 2002), and Texas prickly pear (*Opuntia lindheimeri*) (Hatch and Pluhar 1993). Common forbs included doveweed (*Croton* spp.) and sunflower (*Helianthus* spp.) (Everitt et al. 1999). Common grasses were seacoast bluestem (*Schizachyrium scoparium*), gulf cordgrass (*Spartina spartinae*), sandbur (*Cenchrus incertus*), and purple threeawn (*Aristida purpurea*) (Gould 1978). Sands (2010) provided detailed information regarding the study area.

Analyses

We used the harvest-population dynamics model developed by Sands (2010) to evaluate the probability of quasi-extinction (Guthery et al. 2000, DeMaso et al. 2011) for isolated populations of northern bobwhites at 0, 20, 25, 30, and 40% annual harvest rates. This represented a stochastic population dynamics model that estimated probability of population persistence under harvest rates ranging from 0 to 40%. The model followed the general approach of DeMaso et al. (2011) and Rader et al. (2011) where bobwhites were produced during the spring and summer, and were removed as a result of natural mortality during each season. The model represented a bobwhite population on a hypothetical property of 800 ha. Our model consisted of stocks (chick, juvenile, and adult bobwhites), flows (transfer of chick, juvenile, and adult bobwhites into or out of the model), and auxiliary variables (e.g., mortality rates, reproduction) that influenced flows. Harvest of bobwhites was considered to be partially additive to natural mortality based on the additive harvest model (Ricker 1958, Roseberry 1979, Guthery 2002:100). We conceptualized (Fig. 1) and programmed our model using STELLA Version 9.0 (ISEE Systems, Lebanon, NH, USA). Sands (2010) provides explicit details on model development and quantification.

We simulated the dynamics of the population and evaluated its probability of persistence for each harvest scenario over a 100-year period. Stochasticity was invoked during each 100-year simulation by randomly selecting values for production and survival from empirically derived Weibull probability distributions generated within SAS 9.1 (SAS Institute Inc., Cary, NC, USA). We used normal distributions for stochastic variables when Weibull parameters could not be estimated (DeMaso et al. 2011).

We conducted 50 preliminary stochastic baseline simulations to obtain variance estimates for the parameters: winter (hunted) population, winter (hunted) density, spring (post-hunt) population, spring (post-hunt) density, and harvest. We conducted 165 simulations for each level of harvest (0, 20, 25, 30, and 40%) because it was the largest number of simulations considered necessary to achieve our

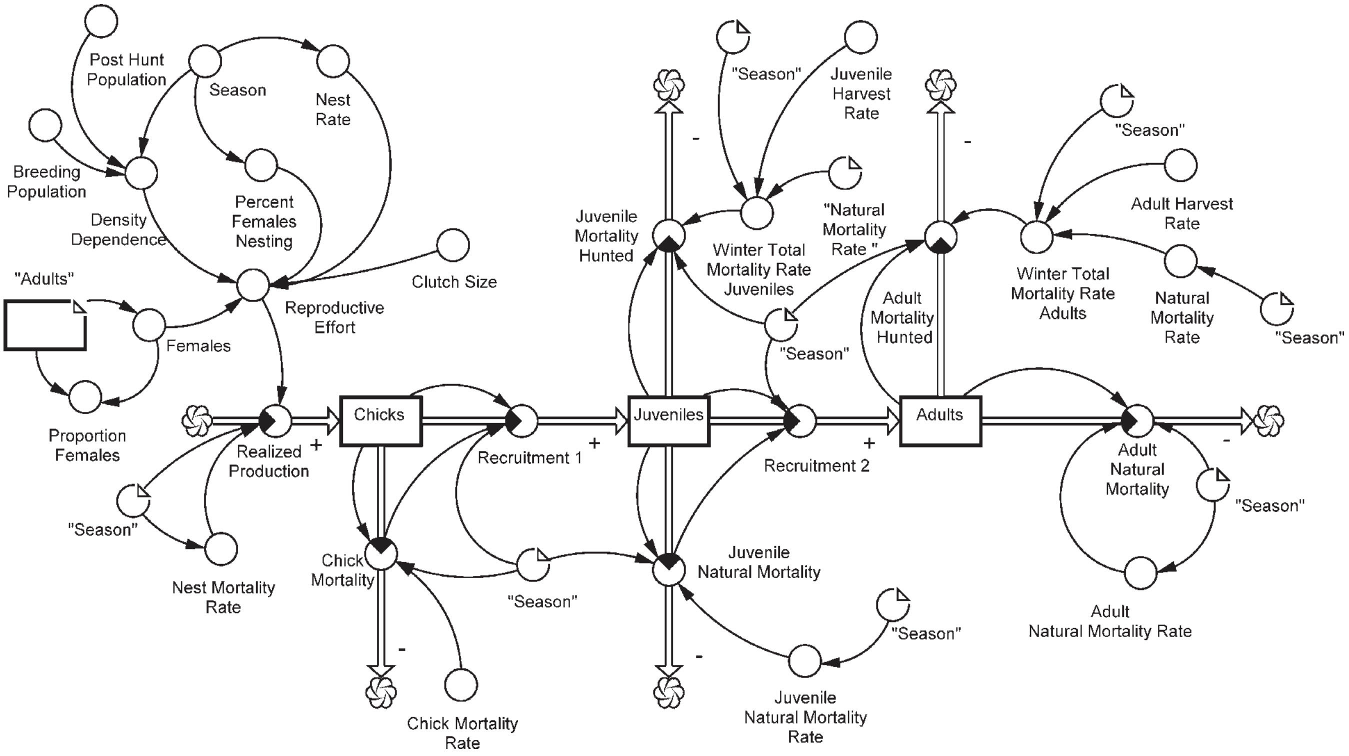

Fig. 1. Conceptual model of factors impacting northern bobwhite population dynamics in the South Texas Plains (Sands 2010). Boxes are variables which represent stocks of northern bobwhites at different age classes (chicks, juveniles, and adults). Circles represent driving variables, auxiliary variables and/or constants (e.g., natural mortality rates, density-dependence, harvest rates). Large arrows with centered circles represent flows. Flows transfer material into (+) or out of (–) state variables (e.g., production and mortality).

objectives for model power (DeMaso et al. 2011), based on the formula provided by Sokal and Rohlf (1969:247) and Grant et al. (1997:61–64). We set our quasi-extinction level at 0.05 bobwhites/ha (40 bobwhites, based on DeMaso et al. 2011) and calculated the probability of quasi-extinction for each 100 year simulation as:

$$P_{qe} = \frac{n_{qe}}{100} \tag{1}$$

where,

P_{qe} = probability of quasi-extinction in a given year, and

n_{qe} = number of quasi-extinctions per 100 year simulation.

We used the spatially implicit model developed by Levins (1970) to model the probability of local population persistence as:

$$P_n = (1 - p_{qe})^n \tag{2}$$

where,

P_n = probability that a population will exist for n years, and

p_{qe} = annual probability of local quasi-extinction.

We also modeled the probability of regional persistence (the probability that all patches within the metapopulation do not go simultaneously extinct):

$$P_x = 1 - (p_{qe})^x \tag{3}$$

where,

P_x = probability of regional persistence in a metapopulation, and

x = the number patches in the metapopulation.

Equation 3 does not assume that immigration or emigration occurs among patches. Instead, it predicts the probability that all patches within the metapopulation do not go simultaneously extinct (Gotelli 2001).

We calculated the mean and 95% confidence intervals for P_{qe}, P_n, and P_x based on 165 simulations for each harvest scenario (0, 20, 25, 30, and 40% annual harvest).

RESULTS

The baseline model (no annual harvest) indicated a 100% probability of population persistence (0.0 probability of quasi-extinction) for a simulated isolated bobwhite population. Annual quasi-extinction probability at a 20% annual harvest rate was 0.003 (95% CI: 0.001–0.006) and was 0.105 (95% CI: 0.083–0.126) at a 30% annual harvest rate. Annual probability of quasi-extinction increased to 0.773 (95% CI: 0.750–0.796) for a simulated population harvested at 40% annually.

The simulated population maintained a 95% probability of persistence for 15 years at a 20% annual harvest rate, whereas a simulated population at a 30% annual harvest rate had only a 33% probability of persisting for 10 years (Fig. 2). Isolated populations had a $<$ 1 probability of persisting for 5 years, given a 40% annual harvest rate (Fig. 2).

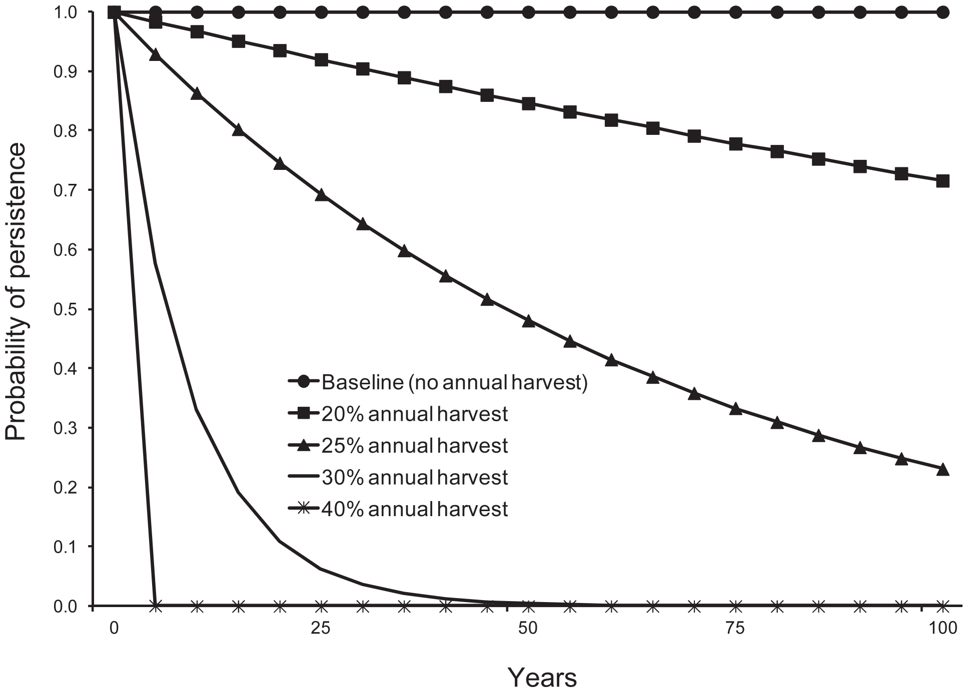

Fig. 2. Simulated 100-year probability of population persistence of an isolated South Texas Plains northern bobwhite population at 0, 20, 25, 30, and 40% harvest rates.

A regional bobwhite metapopulation persisted with relative certainty from baseline to 30% harvest rates given at least 1 (baseline, no annual harvest), 2 (20% harvest, 25% harvest), or 3 (30% harvest) habitat patches (Fig. 3A–C). The regional population did not reach 95% probability of persistence at a 40% harvest rate (Fig. 3D) until 12,800 ha of occupied habitat patches existed (Table 1).

DISCUSSION

Harvest and Bobwhite Metapopulation Persistence

Our simulation results were based on data collected within the South Texas Plains ecoregion (DeMaso 2008, Sands 2010, DeMaso et al. 2011). These results suggest at a minimum, given our hypothetical area of 800 ha, bobwhites require from 800 to 9,600 ha of available habitat space to maintain a 95% probability of regional metapopulation persistence as harvest rate varies from 0 to 40% annually. The South Texas Plains represents a relatively broad and contiguous landscape comprised of suitable bobwhite habitat, much of which persists as a direct result of management targeted directly for bobwhites. The Sands (2010) model indicated increasing populations based on estimates of finite rate of increase ($\lambda > 1$) for annual harvest rates up to 30%. Our results may not apply directly to other ecoregions where habitat fragmentation is more widespread or where harvest pressure is, on average, > 30%. However, the potential implications of our results for other portions of the bobwhite range are significant because they suggest multiple-patch habitat connectivity is necessary, especially when harvest pressure is relatively high. It is likely a greater number of habitat patches would be necessary to maintain a high probability of regional metapopulation persistence for declining populations in fragmented habitats subjected to consistently high harvest pressure (e.g., > 30% harvest annually).

Harvest pressure (e.g., hunter-days as a function of abundance) may increase as population abundance decreases (Guthery et al. 2004). Isolated populations (e.g., populations that are separated (~3–5 km) by a barrier that may impede, but not totally restrict, dispersal) in small habitat patches are more likely to be small. Thus, harvest may have little impact on northern bobwhite populations at large landscape scales (e.g., ≥1,000,000 ha), but it has potential to impact abundance and population persistence at the ranch or pasture scale (~800–2,000 ha), especially if dispersal among patches is inhibited by unsuitable habitat space.

Dispersal is one of the least studied aspects of northern bobwhite life history (but see Fies et al. 2002, Townsend et al. 2003, and Cook et al. 2009 for exceptions). However, it seems apparent that bobwhites are neither high dispersers nor are they sedentary. Bobwhite dispersal rates range from 25 to 41% (Fies et al. 2002, Townsend et al. 2003, Cook et al. 2009), and application of metapopulation theory to northern bobwhite management is theoretically appropriate. The metapopulation paradigm is consistent with the usable space hypothesis (Guthery 1997) and shows consistency with results of landscape genetics studies from South Texas (R. W. DeYoung, unpublished data).

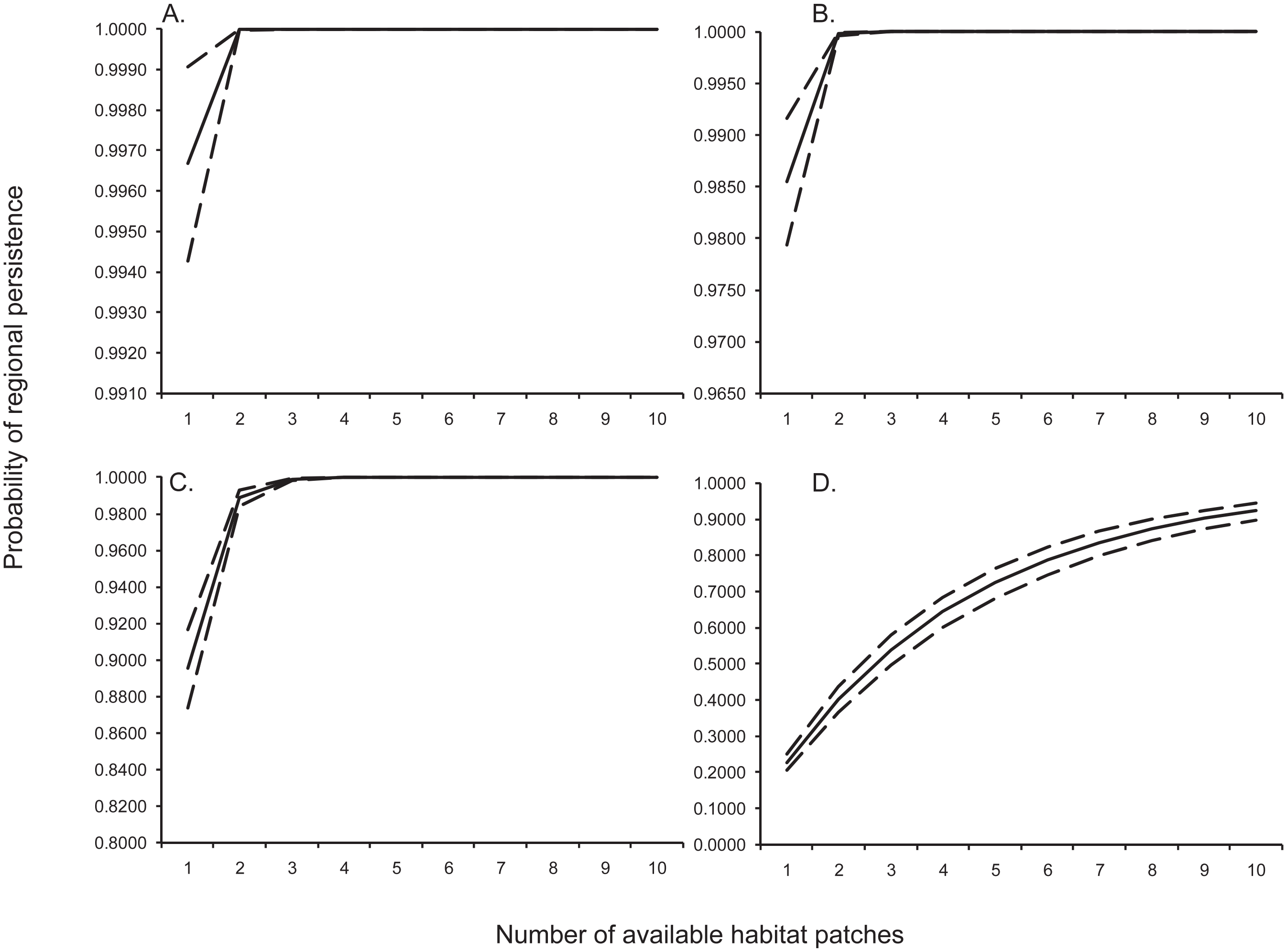

Fig. 3. Simulated probability of regional persistence for a northern bobwhite metapopulation in the South Texas Plains at (A) 20, (B) 25, (C) 30, and (D) 40% harvest rates. Dashed lines represent upper and lower 95% confidence intervals of population persistence.

A Call for Changing Research Priorities

Bobwhite populations have undergone a range-wide decline in abundance since at least the late 19th century and perhaps even earlier. The number of suitable bobwhite habitat patches has also decreased through landscape scale habitat loss. Thus, it is reasonable to assume the proportion of remaining suitable habitat patches occupied by bobwhites has also decreased. Our results represent a first approximation of how spatially implicit classical metapopulation models (Levins 1970, Gotelli 2001) can be applied to bobwhite population dynamics. Spatially explicit models will be necessary to move our understanding of bobwhite metapopulation and landscape ecology from theoretical to empirical.

Research that focuses on quantifying the spatial and temporal aspects of bobwhite dispersal as related to landscape characteristics, and the dynamics of density and weather, would represent a step forward in improving knowledge of bobwhite ecology. Models that incorporate a suite of parameters including rates of dispersal (immigration and emigration) should prove useful in evaluating northern bobwhite metapopulation dynamics for specific regions. Metapopulation theory is applicable to bobwhite biology. These parameters have large implications for bobwhite population dynamics. Researchers must first identify multiple habitat patches within a landscape and obtain a sufficiently large sample of bobwhites to estimate dispersal among patches. Long-term (e.g., $\geq$ 10 year) studies would be invaluable for learning about individual patch and metapopulation

Table 1. Number and area (ha) of available habitat patches necessary to sustain a 95% probability of population persistence of a simulated bobwhite metapopulation in the South Texas Plains (n = 165, 100-year simulations).

Annual harvest rate	Available habitat patches	Area (ha)
Baseline (no annual harvest)	1	800
20–25%	2	1,600
30%	3	2,400
40%	12	9,600

dynamics. The majority of current bobwhite research does not address these issues, despite the existence of quantitative methodology and GIS technologies that make doing so possible.

MANAGEMENT IMPLICATIONS

Bobwhite conservation will be more effective if implemented at spatial scales consistent with bobwhite population processes; this would allow managers to prioritize biologically meaningful habitat conservation and restoration efforts. Viable bobwhite populations need large patches of habitat that are connected on a landscape scale. Managers should recognize individual blocks of habitat (e.g., 800–1,500 ha) may represent only one of several patches within a metapopulation network. Thus, processes such as metapopulation dynamics and dispersal among habitat patches should be considered when designing conservation strategies.

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LITERATURE CITED

Brady, S. J., C. H. Flather, and K. E. Church. 1998. Range-wide declines of northern bobwhite (*Colinus virginianus*): land use patterns and population trends. Gibier Faune Savage 15:413–431.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

Cook, M. P., R. G. Hamrick, and J. P. Carroll. 2009. Effects of age, sex, and habitat on northern bobwhite spring dispersal patterns. Proceedings of the National Quail Symposium 6:135–145.

DeMaso, S. J. 2008. Population dynamics of northern bobwhites in southern Texas. Dissertation. Texas A&M University-Kingsville, USA.

DeMaso, S. J., W. E. Grant, F. Hernández, L. A. Brennan, N. J. Silvy, X. B. Wu, and F. C. Bryant. 2011. A population model to simulate northern bobwhite population dynamics in southern Texas. Journal of Wildlife Management 75:319–332.

Everitt, J. H., D. L. Drawe, and R. I. Lonard. 1999. Field guide to the broad-leaved herbaceous plants of South Texas. Texas Tech University Press, Lubbock, USA.

Everitt, J. H., D. L. Drawe, and R. I. Lonard. 2002. Trees, shrubs and cacti of South Texas. Texas Tech University Press, Lubbock, USA.

Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. Annual Review of Ecology, Evolution, and Systematics 34:487–515.

Fies, M. L., K. M. Puckett, and B. Larson-Brogden. 2002. Breeding season movements and dispersal of northern bobwhites in fragmented habitats of Virginia. Proceedings of the National Quail Symposium 5:173–179.

Gotelli, N. J. 2001. A primer of ecology. Sinauer Associates Inc., Sunderland, Massachusetts, USA.

Gould, F. W. 1975. Texas plants: a checklist and ecological summary. MP-585/ Revision. Agricultural Experiment Station, Texas A&M University, College Station, USA.

Gould, F. W. 1978. Common Texas grasses, an illustrated guide. Texas A&M University Press, College Station, USA.

Grant, W. E., E. K. Pedersen, and S. L. Marin. 1997. Ecology and natural resource management: systems analysis and simulation. John Wiley and Sons Inc., New York, USA.

Guthery, F. S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 61:291–301.

Guthery, F. S. 2002. The technology of bobwhite management: the theory behind the practice. Iowa State University Press, Ames, USA.

Guthery, F. S., M. J. Peterson, and R. R. George. 2000. Viability of northern bobwhite populations. Journal of Wildlife Management 64:646–662.

Guthery, F. S., M. J. Peterson, J. J. Lusk, M. J. Rabe, S. J. DeMaso, M. Sams, R. D. Applegate, and T. V. Dailey. 2004. Multistate analysis of fixed, liberal regulations in quail harvest management. Journal of Wildlife Management 68:1104–1113.

Hanski, I. 2001. Population dynamic consequences of dispersal in local populations and metapopulations. Page 283–298 *in* J. Clobert, E. Danchin, A. A. Dhondt, and J. D. Nichols, eds. Dispersal. Oxford University Press, New York, USA.

Hatch, S. L., and J. Pluhar. 1993. Texas range plants. Texas A&M University Press, College Station, USA.

Lehmann, V. W. 1984. Bobwhites in the Rio Grande Plain of Texas. Texas A&M University Press, College Station, USA.

Levins, R. 1970. Extinction. Pages 75–1047 *in* M. Gerstenhaber, ed. Some mathematical questions in biology. Lecture notes on mathematics in the life sciences. The American Mathematical Society, Providence, Rhode Island, USA.

McLendon, T. 1991. Preliminary description of the vegetation of South Texas exclusive of the coastal saline zones. Texas Journal of Science 43:13–32.

Rader, M. J., L. A. Brennan, K. A. Brazil, F. Hernández, and N. J. Silvy. 2011. Simulating northern bobwhite population responses to nest predation, nesting habitat, and weather in South Texas. Journal of Wildlife Management 75:61–70.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Bulletin 19. Fisheries Research Board of Canada, Ottawa, Ontario, Canada.

Roseberry, J. L. 1979. Bobwhite population responses to exploitation: real and simulated. Journal of Wildlife Management 43:285–305.

Sands, J. P. 2010. Testing sustained-yield harvest theory to regulate northern bobwhite hunting. Dissertation. Texas A&M University-Kingsville, USA.

Saunders, D. A., R. J. Hobbs, and C. R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5:18–30.

Sokal, R. R., and F. J. Rohlf. 1969. Biometry. W. H. Freeman and Company, San Francisco, California, USA.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. Charles Scribner's Sons, New York, USA.

Townsend II, D. E., D. M. Leslie Jr., R. L. Lochmiller, S. J. DeMaso, S. A. Cox, and A. D. Peoples. 2003. Fitness costs and benefits associated with dispersal in northern bobwhites (*Colinus virginianus*). American Midland Naturalist 150:73–82.

Walters, J. R. 1998. The ecological basis of avian sensitivity to habitat fragmentation. Pages 181–192 *in* J. M. Marzluff, and R. Sallabanks, eds. Avian conservation: research and management. Island Press, Washington, D.C., USA.

A COUNTY-BASED NORTHERN BOBWHITE HABITAT PRIORITIZATION MODEL FOR KENTUCKY

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ABSTRACT

Planning the management of northern bobwhite (*Colinus virginianus*) habitat at a statewide-scale is daunting. Native grassland restoration is difficult to manage in Kentucky because $>$ 99% of the Commonwealth's original grassland area has been lost to agriculture, succession, and development. We created a county prioritization model designed to target areas of grasslands and landowners likely to participate in conservation programs. Our goal was to identify 10% of the state as high priority for bobwhite habitat restoration. We created an east and west model divided by the Appalachian Mountains. The west model was designed to target production-oriented operators farming marginal lands, whereas the east model targeted reclaimed minelands. We used agricultural, landcover, and staff data to build county prioritization models in 2006 and 2011. The models targeted 16.6% and 17.6% of the state in 2006 and 2011, respectively. However, if areas of large, contiguous blocks of forests were excluded, the area total was much closer to 10%. Fifty percent of the high priority counties changed in the west model, and 33% of the counties in the east model changed over 5 years. Implementing a county prioritization model in conjunction with a finer-scale, biological targeted approach could focus conservation efforts with greater potential for success, but the models should be reconstructed at 5- to 10-year intervals to account for changes in conservation delivery potential. A modification of our technique may serve to validate or as an alternative to improve National Bobwhite Conservation Initiative 2.0.

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Key words: *Colinus virginianus*, delivery, grasslands, habitat, Kentucky, model, northern bobwhite, prioritization, restoration, target

INTRODUCTION

The northern bobwhite was once a prominent component of the rural landscape in Kentucky. Widespread changes in land management, agriculture, and development decimated native grasslands and decreased wild bobwhite populations over the course of half a century (Morgan and Robinson 2008). Bobwhites had declined by $\sim$ 83% between 1968 and 2010 (NBCI 2011). The Northern Bobwhite Conservation Initiative (NBCI) was developed by 2002 and generated a call to action for stopping the decline and restoring the species to the population levels of 1980 (Dimmick et al. 2002).

The plan was designed as an umbrella, providing a single vision for range-wide bobwhite restoration. Member states agreed to 'step-down' NBCI goals to local levels using Bird Conservation Regions within their jurisdictions (Dimmick et al. 2002). Delivering state-wide conservation for bobwhite in Kentucky was impractical and infeasible with limited funding and personnel. We faced the challenge of prioritizing management efforts across the state to generate a positive bobwhite population response with the least amount of effort (money and personnel) and the highest potential for success.

Researchers and biologists have developed techniques to improve conservation across broad landscapes (Johnson et al. 2004; Twedt et al. 2006, 2007). However, the focus has been on biological parameters and fail to include social and economic considerations which are critical for conservation delivery potential. We aspired to build a model that incorporated biological and conservation delivery components designed to ensure bobwhite restoration occurred on the ground. This model would function as an operational program for bobwhite restoration in Kentucky (Knight et al. 2006).

We created a mechanism to use available spatial data, bobwhite population data, and expertise of field personnel on private lands to build a county prioritization model for

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bobwhite habitat development. The county level was selected because it is widely understood among the public, it served as a base unit for conservation delivery (e.g., state and federal personnel are assigned to counties), and there were many data sets at that scale. The goal was to identify a maximum of 10% of the state's area as high potential for bobwhite restoration over a 10-year period.

STUDY AREA

The Commonwealth of Kentucky ranks 26th nationally in terms of population (4,314,113 people) which increased 6.7% from 2000 to 2009 (USDC 2009a). Historically a rural state, 44% of the population now lives in an urban area (USDC 2004). There are 120 counties that function as important political and social units. Private landowners hold ~90% of the land base (Wethington et al. 2003). Agriculture remains a vital part of the economy employing nearly 113,000 workers (Kentucky State Data Center 2005) with 86,000 farms, 56,656 km^2 in production, and average farm size of 66 ha (USDC 2009b). Extensive coal fields in eastern and west-central Kentucky are also important to the state's economy.

All of Kentucky is within the Köppen climatic classification of Humid Subtropical characterized by relatively long, hot summers and short, mild winters with brief episodes of severe cold (McKnight 1990). A moderate north-south precipitation gradient exists with southern counties receiving slightly more (127 cm) annual precipitation while northern counties receive less (114 cm) (Prism Climate Group 2006). Forest covered much of Kentucky at the time of European settlement with extensive grasslands and wetlands present in the western portions of the state. Satellite imagery reveals that about 50% of Kentucky remains forested while most grasslands and wetlands have been converted to agriculture (Kentucky Division of Geographic Information 2007c).

A distinct east-west elevation gradient heavily influences natural vegetation, as well as human settlement and land use patterns. The eastern one-third of Kentucky is within the Level II Ozark ecoregion, Ouachita-Appalachian Forests or Appalachian Plateau (Commission for Environmental Cooperation 1997). Elevation is generally below 900 m with few exceptions. The topography throughout this region is extremely steep and rugged with shallow soils limiting potential for agriculture. Surface mining, including mountain top removal, has left large, relatively flat, open areas where none existed previously.

Central and west-central Kentucky are within the Level II Southeastern USA Plains ecoregion or Interior Low Plateau (Commission for Environmental Cooperation 1997). The topography is less rugged and soils are more conducive for agriculture. However, steep hillsides are common and their use is primarily marginal pasture land. Extreme western Kentucky contains the Mississippi Alluvial Plains and Southeast USA Coastal Plains Level II ecoregions (Commission for Environmental Cooperation 1997). This area is relatively low and flat sharing many aspects with more southern coastal plain states. Soils are generally deep and highly fertile allowing for intensive row crop agriculture.

METHODS

We divided Kentucky into eastern and western zones to account for major differences in landcover, topography, and agriculture. The east-west dividing line roughly follows the Level II Appalachian Plateau ecoregion. County lines were used to define the boundary rather than purely physiographic ecoregions to allow use of county level statistics. Bordering counties were assigned based upon the percent within east or west zones. The eastern Kentucky zone included 32 counties (29,265 km^2, 28% of the state) while the western Kentucky zone included 88 counties (75,385 km^2, 72% of the state).

Data were selected to target counties with relatively high existing northern bobwhite populations, high potential to support bobwhite habitat, predominately production farms on marginally productive soil or reclaimed minelands, potential to deliver conservation objectives, and potential to benefit other species. The variables analyzed differed between the west (Table 1) and east (Table 2) zones. We assembled the most recent data available in 2006 and in 2011.

Bobwhite populations were indexed through the Mail Carrier Survey, a Kentucky Department of Fish and Wildlife Resources (KDFWR) data set containing reports from rural mail carriers of bobwhite road-side observations relative to kilometers driven. We quantified potential quail habitat in the west zone using county enrollment (total ha) in Conservation Reserve Program (CRP) while the National Landcover Database (NLCD) (Kentucky Division of Geographic Information, 2007b, c) was used in the east. Counties with high enrollment were targeted for the west region and counties with large areas of open habitat were targets for the east. Production farmers with marginal soils were assumed to better realize the economic benefits of agricultural retirement and buffer or field border programs. A Corn Index was developed to focus on marginal soils, and counties with low production were assumed to have more marginal soils (USDA 2002).

We approached delivery of conservation objectives (potential for future management) through several data sets. KDFWR public access agreements with large landowners (primarily reclaimed mine land) represent the best opportunity to enhance significant open habitat areas in the east zone. County rating and USDA rating data sets were created by polling KDFWR private lands biologists and farm bill biologists across the state (Morgan and Robinson 2008). Each survey participant provided a qualitative county rating that was converted to a numerical value (3, 2, and 1) with high scores representing preferred counties. Scores were averaged when multiple biologists provided surveys for the same county. Statewide Overlapping Conservation Areas from the Kentucky State Wildlife Action Plan (SWAP) provided information about potential benefit to other species (KDFWR 2010).

Table 1. Description, target, and county-level data sources for the 2006 and 2011 northern bobwhite county prioritization model in western Kentucky.

Variable	Description	Target	2006 Data source	2011 Data source
CRP[a]	Total area[b] (double weighted)	Existing grass; delivery	2006 USDA[c] data	2010 USDA data
Corn Index	Corn planted for all purposes as yield per ha[d]	Marginal soil	2006 Corn data	x̄ from 2001–2010
Farmers	% of farmers as principle operator	Production farmers	1997 Farm statistics	2007 Farm statistics
USDA rating	KDFWR[e] field staff rating of USDA county's effectiveness and wildlife interest	Delivery	2006 Staff	2006 Staff
NRCS[f] office	Presence or absence of a NRCS service center	Delivery	2006 Staff	2006 Staff
Mail Carrier	Bobwhite mail carrier survey	Bobwhite presence	Mean from 2001–2006	Mean from 2007–2011
County rating	KDFWR field staff rating on county's overall potential for bobwhite restoration	Delivery	2006 Staff	2011 Staff
SWAP[g]	Intersection of SWAP priority areas and county layers; taking highest priority level	Multi-species benefit; funding	2005 SWAP priority areas	2005 SWAP priority areas

[a] Conservation Reserve Program.

[b] Included Conservation Practices 1, 2, 25, and 33 in 2006 and Conservation Practices 1, 2, 10, 22 (in Conservation Reserve Enhancement Program counties only), 25, 29, 33, and 38 in 2011.

[c] U. S. Department of Agriculture.

[d] Corrected for extent by multiplying by thousands of hectares planted.

[e] Kentucky Department of Fish and Wildlife Resources.

[f] Natural Resources Conservation Service.

[g] State Wildlife Action Plan.

Data management was performed using MS Access (Microsoft, Redmond, WA, USA) with ArcMAP (ESRI, Redlands, CA, USA) serving to spatially integrate data sources and produce maps. Access 2003 and ArcMAP 9.3 were used to process data in 2006, and Access 2007 and ArcMAP 10.0 were available in 2011. These software upgrades posed no problems for data analysis.

Kentucky county polygons were used as the minimum mapping unit (Kentucky Division of Geographic Information 2007a). Most data sources existed as county level tables, but some required manipulation. ArcMAP was used to intersect county polygons with NLCD landcover types, SWAP priority areas, KDFWR access agreement areas, and extract tables that were imported into Access.

The general process for generating county values for analysis involved ranking each county variable, summing those ranks, and ranking the summed scores again. County tables were loaded into ArcMAP, divided into 5 classes, and assigned scores of 1–5 using the Jenks Natural Breaks method (Jenks 1967). Each variable score was summed for each county generating a summed score.

Table 2. Description, target, and county-level data sources for the 2006 and 2011 northern bobwhite county prioritization model in eastern Kentucky.

Variable	Description	Target	2006 Data source	2011 Data source
Grass and shrub	Sum (%) of grass and shrub landcover; (double weighted)	Existing grass	2001 NLCD[a]	2005 NLCD
Barren	% barren landcover	Existing grass	2001 NLCD	2005 NLCD
Access	KDFWR[b] access agreements on reclaimed mine areas	Delivery	2006 Public hunting boundary	2011 Public hunting boundary
Mail Carrier	Bobwhite mail carrier survey	Bobwhite presence	Mean from 2001–2006	Mean from 2007–2011
County rating	KDFWR field staff rating on county's overall potential for bobwhite restoration	Delivery	2006 Staff	2011 Staff
SWAP[c]	Intersection of SWAP priority areas and county layers; taking the highest priority level	Multi-species benefit; funding	2005 SWAP priority areas	2005 SWAP priority areas

[a] National Landcover Data.

[b] Kentucky Department of Fish and Wildlife Resources.

[c] State Wildlife Action Plan.

The CRP score was double weighted for the western region as was the summed proportions of barren, grass, and shrubs in the east region. Summed county scores were converted to a 1–4 rank (High, Medium, Low, and Very Low) following Jenks (1967). We used 4 categories to meet the 10% statewide area goal.

This methodology was applied separately to the eastern and western zones. West zone scores were assigned to all 120 counties, while east zone scores were limited to the 32 counties comprising that zone. We investigated both within year variability and change between years. Within year variable independence was tested with Spearman's rank correlation and Pearson Product Moment Correlation. Principle Component Analysis (PCA) was used to examine the within year drivers of county prioritization in the model.

We analyzed how county priority scores changed between 2006 and 2011 in response to updated data (Tables 1, 2). Only SWAP priority areas data did not change. New county level tables were generated and the process was repeated. We examined the correlation between 2006 and 2011 for county rating and USDA rating to investigate the effect of varying KDFWR staff. ArcMAP was used to identify and visually depict changes in county priority between years.

RESULTS

The models performed well for prioritizing bobwhite conservation in Kentucky. The 2006 model identified 15 high priority counties across the state totaling 1,648,737 ha (1,440,274 west, 208,463 east), whereas the 2011 model had 15 high priority counties totaling 2,248,320 ha (1,506,917 west, 741,403 east) (Figs. 1, 2). Fifty percent of the high priority counties changed in the west and 33% in the east between the 2006 and 2011 models.

The models yielded 16.6% and 17.6% of the state in the high priority category from 2006 and 2011, respectively. Eliminating large, forested tracts within high priority counties would have resulted in being closer to our 10% target (12.7% in 2006 and 13.6% in 2011). Our procedure emphasized the western zone (83% of the high priority counties) where the greatest potential for bobwhite restoration exists.

The western model could have been simplified and yielded similar results. Fourteen of the 28 paired comparisons were correlated ($P < 0.05$) making the model not highly orthogonal. The first 3 axes of the PCA for the 2006 west model explained 64% of its variability. The driving variables were the SWAP priority areas (axis 1), the USDA staff rating (axis 2), and the percent of farmers as principle operators (axis 3). Sixty-four percent of the variation in 2011 was also captured by the first 3 axes, but they were mail carrier, USDA score, and Natural Resources Conservation Service (NRCS) office, respectively. The Corn Index and staff county rating added little prioritization value to the model. Presence or absence of CRP likely was representative of soil quality across the county and had a large role in a staff member's county rating. Staff county rating and USDA rating were highly inter-related, and using only one would be appropriate.

The eastern model was more parsimonious and yielded a reasonable product. Only 3 of 15 variable combinations had significant correlations ($P < 0.05$), and the PCA of the 3 primary axes accounted for 70% of the model variation in 2006. Grass and shrub score, SWAP priority areas, and staff county rating were the factors with highest loadings on the first, second, and third axis, respectively. The same three variables at each axis in 2011 accounted for 75% of the variability.

Data currency and quality were a problem in our models. Staff changes resulted in potential inconsistencies among survey parameters. The rating a county received by staff in 2006 and 2011 was correlated ($P < 0.001$) with staff change. However, USDA staff county ratings between years were not correlated ($P > 0.05$) despite staff change.

The 2006 west model relied upon on-line Farm Service Agency (FSA) data for CRP enrollment. We believed it was one of least reliable metrics regarding data quality, yet the most important to target. We dramatically improved data quality in the 2011 western model by working directly with Kentucky-based FSA staff. The 2011 model was superior, because of the higher quality CRP data set.

The eastern model targeted scrub-shrub, barren, and grassland landcovers for prioritization. The most current landcover data in 2006 was from 2001. Mining activity in eastern Kentucky is far from static, and many areas had changed since initial classification. The 2011 model exhibited the same shortcoming, but the data were from 2005. KDFWR access agreements in the model presented an ever-changing target. Areas were frequently added through agreements and were occasionally annulled.

DISCUSSION

The 2006 county prioritization model was a key component of Kentucky's bobwhite restoration plan (Morgan and Robinson 2008). The models' purpose was to help direct personnel, funds, and conservation programs to counties with the highest potential for bobwhite restoration in 10 years. High priority counties were elevated in placement for Farm Bill biologists, considered in Wildlife Habitat Improvement Program rankings, referenced when modifying Conservation Priority Areas in CRP, and targeted for advertisement and bonus payments in support of Farm Bill conservation programs. The majority of sub-county level focus areas were within high priority counties.

Our approach was a hybrid technique of using ecological parameters, such as grassland and bobwhite presence, coupled with potential for conservation delivery (i.e., targeting production farmers working marginal soil with strong USDA collaboration) (Higgins and Esselman 2006). Knight et al. (2006: 409) contend that "many publications in peer reviewed journals represent systematic conservation assessments, not conservation planning, because they contain no links to processes for developing

Fig. 1. Change in northern bobwhite county prioritization models for 2006 and 2011 in western Kentucky.

implementation strategies or stakeholder collaboration and so are unlikely to be effectively implemented." County prioritization was designed to minimize effort for conservation delivery and maximize likelihood of bobwhite response, and we believe our model delivered that product.

Our models were too coarse for targeted bobwhite habitat restoration efforts. County boundaries as a minimal unit worked well for conservation delivery, but opportunities for bobwhite habitat development are not county-wide in most cases. Habitat restoration efforts could be further delineated in small areas within country boundaries. We believe there is potential for our approach to better prioritize conservation actions, but they should be paired with more sophisticated, finer-scale, conservation mapping such as Twedt et al.'s (2007) biological potential layer for bobwhite or NBCI Version 2.0 (NBTC 2011).

Twedt et al. (2006) focused on bottomland hardwood forest, and suggested biological parameters in conserva-

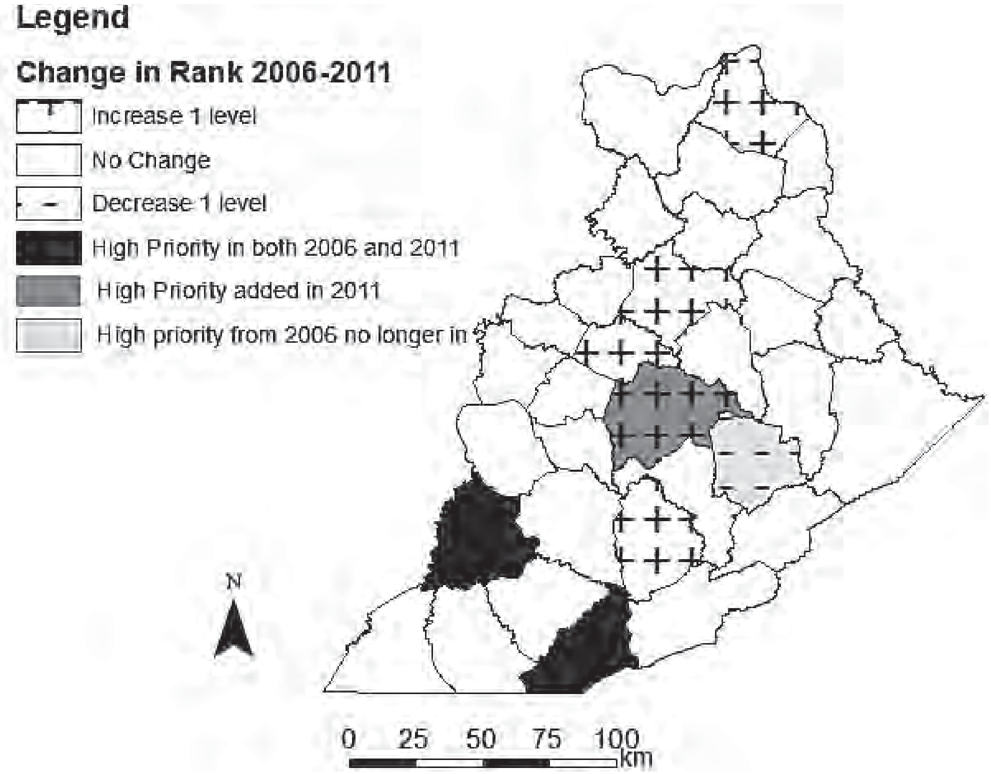

Fig. 2. Change in northern bobwhite county prioritization models for 2006 and 2011 in eastern Kentucky.

tion implementation should be paramount as socio-economic considerations are more fleeting (e.g., subject to commodity prices or changes in government programs). We agree societal measures alone should not drive ecological planning, but they must be a major contributor to short- (e.g., < 5 years) and long-term (e.g., > 20 years) conservation actions. Future land use is difficult to predict, but production of crops and energy is likely to expand; conservation prioritization must include parameters to account for those realities.

It is desirable that a county prioritization model is nimble to change in response to socio-economic factors, but the variability among our models across short periods of time was a shortcoming. Annual fluctuations in the county-based data sets could be better controlled by using multi-year averages to stabilize county prioritization. The use of the Jenks Natural Breaks Method should also help control annual variations by grouping data.

Taking advantage of on-the-ground expertise was a unique and powerful component of our prioritization. Field personnel understand the landowner and conservation communities, and their values with respect to natural resource management. Including that perspective can be important to successful conservation delivery. The cost and effort of collecting that information was far less than a statewide human dimensions survey.

Personnel surveys have shortcomings. Personal bias and other uncontrolled variability may erroneously categorize landowner and conservation personnel's interest and capabilities. Staff opinion polls with more objective questions and a minimum 3 to 5 years experience could provide more consistent and accurate measures. By expanding our survey to a broader conservation community (i.e., USDA, cooperative extension), a population of responses for a county could be collected. The result could be a more representative evaluation of the conservation delivery potential for specific counties

We struggled to replicate our modeling procedures despite having written procedures. We believe the 2011 analysis was a strong replicate of the 2006 approach, but time was lost confirming details of the procedure and discussing the 2006 logic of our decision making process. We recommend having a process diagram and written procedures that highlight the logic of the decision making process.

MANAGEMENT IMPLICATIONS

Targeted private lands management is paramount for successful wildlife conservation, including northern bobwhite restoration. Conservation agencies and their partners could improve effectiveness by identifying social conservation targets (e.g., recreational landowners or production farmers using marginal land) that maximize conservation delivery potential at the county level. Data sets can be identified or created and interfaced with those targets within finer biological models. The results of those models could be followed by localized personnel, advertising, and focused conservation programs resulting in habitat on the ground.

NBCI 2.0 was developed by state-based workshops in collaboration with state fish and wildlife agencies (NBTC 2011). Participants were divided into teams to map bobwhite restoration potential including threats and opportunities. This technique was a tremendous step forward, but created a potential conservation delivery bias towards fish and wildlife agency personnel, bias from dominant individuals within teams, and relied on subjective interpretations of conservation delivery potential. Our approach can be modified to address those shortcomings with direct polling of conservation delivery staff with more objective questions and a broader base of conservation delivery personnel. It could serve to enhance or validate NBCI 2.0.

Our models demonstrated conservation delivery targets change over time. Fluctuations in commodity prices, modifications to agricultural programs, and transitions in landowners and conservation delivery personnel can influence habitat enhancement opportunities. The creation of the NBCI 2.0 data set was expensive and arduous. It is unknown when that process will be replicated. A modification of our approach may be the most cost-effective and timely way for states to improve the model in the future.

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LITERATURE CITED

Commission for Environmental Cooperation. 1997. Ecological regions of North America-toward a common perspective. Communications and Public Outreach Department of CEC Secretariat, Montreal, Quebec, Canada.

Dimmick, R. W., M. J. Gudlin, and D. F. McKenzie. 2002. The northern bobwhite conservation initiative. Southeastern Association of Fish and Wildlife Agencies, Columbia, South Carolina, USA.

Higgins, J., and R. Esselman, eds. 2006. Ecoregional assessment and biodiversity vision toolbox. The Nature Conservancy, Arlington, Virginia, USA.

Jenks, G. F. 1967. The data model concept in statistical mapping. International Yearbook of Cartography 7:186–190.

Johnson, C. J., D. R. Seip, and M. S. Boyce. 2004. A quantitative approach to conservation planning: using resource selection functions to map the distribution of mountain caribou at multiple spatial scales. Journal of Applied Ecology 41:238–251.

Kentucky Department of Fish and Wildlife Resources (KDFWR). 2010. Kentucky's comprehensive wildlife conservation strategy. Frankfort, USA. fw.ky.gov/kfwis/stwg

Kentucky Division of Geographic Information. 2007a. County boundary polygons of Kentucky. Kentucky Geoportal, Frankfort, USA. kygisserver.ky.gov/geoportal/catalog/search/viewMetadataDetails.page?uuid=%7B42438C18-0D34-47C6-B902-79D6E94BF180%7D

Kentucky Division of Geographic Information. 2007b. Kentucky 2005 Land Cover–Anderson Level II. Kentucky Geoportal, Frankfort, USA. kygisserver.ky.gov/geoportal/catalog/search/viewMetadataDetails.page?uuid=%7B47906D61-FFB5-4A13-BF2A-EB6A14F17040%7D

Kentucky Division of Geographic Information. 2007c. Kentucky NLCD01.Kentucky Geoportal, Frankfort, USA. kygisserver.ky.gov/geoportal/rest/document?id=%7B0484AA9B-4633-4A36-B212-0C8EC1BE686D%7D

Kentucky State Data Center. 2005. REIS employment by industry charts, Kentucky and counties. Louisville, USA. ksdc.louisville.edu/sdc/reis/empl_by_industry_reisdata.xls

Knight, A. T., R. M. Cowling, and B. M. Campbell. 2006. An operational model for implementing conservation action. Conservation Biology 20:408–419.

McKnight, T. L. 1990. Physical geography: a landscape appreciation. Third edition. Simon and Schuster, Englewood Cliffs, New Jersey, USA.

Morgan, J. J., and B. A. Robinson. 2008. Road to recovery: the blueprint for restoring the northern bobwhite in Kentucky. Kentucky Department of Fish and Wildlife Resources, Frankfort, USA.

National Bobwhite Conservation Initiative (NBCI). 2011. State of the bobwhite 2011 report: grassland conservation at a crossroads. National Bobwhite Technical Committee Publication, Knoxville, Tennessee, USA.

National Bobwhite Technical Committee (NBTC). 2011. W. E. Palmer, T. M. Terhune, and D. F. McKenzie, eds. The National Bobwhite Conservation Initiative: a range-wide plan for recovering bobwhites. National Bobwhite Technical Committee Publication, Version 2.0. Knoxville, Tennessee, USA.

Prism Climate Group. 2006. Average annual precipitation, 1971–2000, Kentucky. Oregon State University, Corvallis, USA. www.prism.oregonstate.edu/state_products/index.phtml?id=KY

Twedt, D. J., W. B. Uihlein III, and A. B. Elliott. 2006. A spatially explicit decision support model for restoration of forest bird habitat. Conservation Biology 20:100–110.

Twedt, D. J., R. R. Wilson, and A. S. Keister. 2007. Spatial models of northern bobwhite populations for conservation planning. Journal of Wildlife Management 71:1808–1818.

U.S. Department of Agriculture (USDA). 2002. National Agricultural Statistics 2002 census data. USDA, National Agricultural Statistics Service. Washington, D.C., USA www.agcensus.usda.gov/Publications/2002/index.asp

U.S. Department of Commerce. 2004. United States summary: 2000 population and housing unit counts. USDC, Census Bureau. Washington, D.C., USA www.census.gov/prod/cen2000/phc3-us-pt1.pdf#page=44

U.S. Department of Commerce 2009a. Cumulative estimates of resident population change for the United States, regions, states, and Puerto Rico and region and state rankings: April 1, 2000 to July 1, 2009 (NST-EST2009-02). USDC, Census Bureau. Washington, D.C., USA. www.census.gov/popest/states/NST-pop-chg.html

U.S. Department of Commerce. 2009b. Table 825. Farms–number and acreage by state. USDC, Census Bureau. Washington, D.C., USA www.census.gov/compendia/statab/2012/tables/12s0825.xls

Wethington, K., T. Derting, T. Kind, H. Whiteman, M. Cole, M. Drew, D. Frederick, G. Ghitter, A. Smith, and M. Soto. 2003. The KY Gap Analysis Project Final Report. USDI, Geological Survey, Biological Resources Division, Frankfort, Kentucky, USA.

NORTHERN BOBWHITE HABITAT MODELING ON A MILITARY INSTALLATION IN RELATION TO RED-COCKADED WOODPECKER MANAGEMENT

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ABSTRACT

The Department of Defense (DoD) manages natural resources on ~ 8 million ha of land. A top priority for much of this land is to restore and maintain native ecosystems and associated wildlife species. However, given the typical location (i.e., threatened ecosystems) and size of DoD lands, management conflicts usually occur among endangered/threatened species and game species. Military installations in the southeastern United States are commonly managed to protect red-cockaded woodpecker (*Piciodes borealis*) (RCW) populations and longleaf-wiregrass ecosystems. Mandated RCW management is not entirely compatible with other declining species such as northern bobwhite (*Colinus virginianus*). Land managers need to be equipped with spatially-explicit habitat models that can be used to make informed decisions on how to manage for particular species. Data collected on Fort Gordon Military Installation, Georgia from male bobwhite whistle counts during summer 2010 and 2011 will be used to construct competing models on the relationship between RCW management and other habitat structure metrics as it relates to bobwhite habitat suitability. These data were collected using a robust occupancy sampling design to allow open and closed population assumptions. Preliminary data suggests the RCW habitat ranking matrix is a poor predictor of bobwhite habitat suitability and, more alarmingly, RCW population performance. These models will assist natural resource managers on DoD land in making efficient decisions in the face of uncertainty.

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Key words: *Colinus virginianus*, Department of Defense lands, northern bobwhite, *Piciodes borealis*, red-cockaded woodpecker

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DEVELOPMENT AND IMPLEMENTATION OF A SUCCESSFUL NORTHERN BOBWHITE TRANSLOCATION PROGRAM IN GEORGIA

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ABSTRACT

Gamebird translocations have been used for many years to establish or re-establish populations in North America. A long-term severe decline of northern bobwhites (*Colinus virginianus*) over much of their range has brought this issue to the forefront for this species as well. Field studies in Georgia over the last decade have documented site fidelity, high survival, reproductive success, and population response from bobwhites translocated into large blocks of well-managed habitat. The Georgia Department of Natural Resources/ Wildlife Resources Division developed an official wild quail translocation policy in 2006. Five translocation projects have been permitted and conducted since the policy was established. Extensive large scale habitat modifications were required on the recipient sites while donor sites were required to have existing high density bobwhite populations. These projects have resulted in translocation of > 800 bobwhites and the establishment of 7,480 ha of new wild quail population centers thereby contributing to the National Bobwhite Conservation Initiative (NBCI) recovery goals. Average fall densities on completed projects have increased from < 0.5 birds/ha to > 1.25 birds/ha.

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Key words: *Colinus virginianus,* Florida, Georgia, northern bobwhite, National Bobwhite Conservation Initiative, translocation

INTRODUCTION

Translocation of upland game birds to establish, re-establish, or augment existing populations is not new in North America. This is true for wild bobwhites as well with interstate translocations documented by state game agencies dating to 1906 (Latham and Studholme 1954) and shipments arriving from Mexico beginning in 1910 (Phillips 1928). Stoddard (1931) conducted the earliest known study of translocated bobwhites in Georgia when he banded 2,516 bobwhites imported from Mexico and released them on large estates near Thomasville. He stated these birds were imported "not because the native stock was depleted and restocking was necessary in consequence, but simply in the belief that to do so would improve the shooting by replacing a portion of the birds shot" (Stoddard 1931:480). He concluded these birds represented themselves fairly well when compared to native stock but "it is likely that the same expenditure of funds on field development as recommended in this report would in the long run give more satisfactory results" (Stoddard 1931:488).

Bolstered by a new understanding of the biology of bobwhites (Stoddard 1931) and the emerging field of game management; a unique set of socioeconomic, political, and biological circumstances created the perfect situation for quail populations and quail hunting to thrive for the next several decades. Statistics peaked in 1960–1961 when 142,000 (SE = 20,000) quail hunters in Georgia comprised 50% of the state's licensed resident hunters and harvested an estimated 3,365,000 (SE = 888,000) wild bobwhites (Georgia Game and Fish Commission 1961). Unfortunately this was not to last. The Breeding Bird Survey for the southeastern United States has revealed population declines of > 5% annually since 1980 (Sauer et al. 2011) and, by the 2008–2009 season, the number of quail hunters in Georgia had decreased to 22,423 (SE = 1,064) and comprised only10% of licensed resident hunters. These hunters harvested an estimated 808,036 (SE = 37,977) bobwhites, of which ~

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97% were reported as pen-raised birds (Duda et al. 2009). Bobwhite densities in much of Georgia are reported to have declined to below the level needed to attract and maintain hunter interest and, in some landscapes, particularly the northern half of the state, viable bobwhite populations are no longer apparent (Thackston and Tomberlin 2010). Severe loss, degradation, and fragmentation of early successional habitat (Brennan 1991) coupled with changing predator dynamics (Hurst et al. 1996, Rollins and Carroll 2001) are the most cited problems. Consequently, there has been escalating use of pen-raised birds and frustration among biologists, landowners, and managers as habitat management techniques were not producing the expected results. It was these circumstances that renewed interest in translocation from biologists in the southeast in the 1980s and spawned a series of radiotelemetry studies that produced variable results (DeVos and Mueller 1989, Jones 1999, Parsons et al. 2000, Liu et al. 2002). Terhune (2008:144) eloquently summarized these changing dynamics when he stated "today the utility of translocation in most circumstances highlights the imperiled status of bobwhites. The use of translocation as a luxury has shifted to that of a necessity". Our objectives are to describe: (1) the development of Georgia's translocation policy, (2) implementation of this policy to date, and (3) the preliminary findings on the quail recovery generated by this program.

DEVELOPMENT OF POLICY

The Albany Quail Project (Sisson and Stribling 2009) began a series of studies on bobwhite translocation in 1997. During 1997 and 1998 they compared and found no difference in survival, home range, movement, site fidelity, and reproductive characteristics of 74 translocated and 166 resident radio-marked bobwhites on study sites in southwest Georgia (Terhune et al. 2005, 2006). They then implemented a large scale translocation of 202 wild bobwhites during 2000–2002 and documented increased hunting success on all sites the following fall (Terhune et al. 2006). These studies led to the conclusion that wild bobwhite translocation into high quality habitat prior to the breeding season could augment low density populations, help fill voids within populations, and have the potential to facilitate preservation and conservation of isolated bobwhite populations by augmenting restoration efforts focused on habitat management.

The opportunity to test this idea occurred in 2003 on a property in Marion County, Georgia that was a 1,200-ha isolated 'island' of well-managed habitat surrounded by a matrix of poorer quality landscapes. Under a special research permit from the Georgia Department of Natural Resources, Wildlife Resources Division (GA WRD) during 2003–2004, 127 (70 male, 57 female) bobwhites were radiomarked and translocated from sites near Albany. No differences in survival, movement, and site fidelity between resident and translocated bobwhites were detected (Terhune et al. 2010); similar nesting rates, clutch sizes, hatching success, and nesting success between the 2 groups was measured (Terhune 2008). In addition, a 115% post-translocation population increase was documented in the core of the translocation site (3.25 birds/ha) compared to only a 40% increase (1.5 birds/ha) on the control portion of the same property. The success of this project was attributed to having a relatively large recipient site of intensively-managed, high-quality bobwhite habitat coupled with a reliable source of wild bobwhites available for translocation.

This project also generated questions that were addressed in additional studies. The first was what role infusion of novel genes might have had in the documented population increases. A 3-way 'genetic swap' was conducted in a separate pilot study and revealed no evidence that introducing potentially novel genes had any impact on any of the 3 populations (Sisson and Palmer 2006). This topic was later addressed by Terhune (2008) for the Marion County site from genetic samples taken from all resident and translocated birds used in the study. He concluded (2008:144) "the hypothesis that translocation would benefit genetically depauperate populations and serve in the capacity of 'genetic rescue' could not be adequately investigated in this study because genetic variation was high on the study site prior to translocation." Apparently the site was not sufficiently isolated to measure a decline in bobwhite genetic diversity and to be in need of 'rescue'. The final issue addressed was the timing of translocation. A pilot study was conducted on 2 sites during the fall-spring of 2010–2011 which showed a much lower percentage of the fall translocated birds ($< 50\%$) survived to the onset of breeding season than when relocation occurred just prior to the breeding season ($> 90\%$) (D. C. Sisson, unpublished data).

TRANSLOCATION POLICY

The GA WRD developed **Game Management Policy Statement: Q-1 Quail Translocation** in 2006**.** The stated purpose (2006:001**)** was "to establish guidelines … for the translocation of wild bobwhites from private land with high density populations to lands with newly developed high quality habitat and ongoing management, but which have low density populations". The objective of the policy is to expedite bobwhite population recovery on sites conducting quality habitat management. The highlights of the full policy (www.georgiawildlife.com/hunting/game-management/quail management) include 5 major points.

1. Recipient property must be a minimum of 600 ha of contiguous high quality habitat as confirmed by a WRD Biologist, have a low density population (< 0.5 birds/ha) based on fall covey census, and have a long-term habitat management plan on file with WRD.
2. Donor sites must be high density (> 2.5 birds/ha) based on fall covey census and cannot receive any form of payment for the provision.
3. Translocation must be conducted by a Wildlife Biologist approved by WRD acting as an agent who is also responsible for covey censuses of the

Table 1. Northern bobwhites translocated in southwest Georgia under special permit from Georgia DNR/WRD from 2003 to 2011.

					Density (birds/ha)	
Project #	County	ha	Years	# Birds translocated	Pre	Post
*	Marion	1,200	2003-04	127	0.75	3.25
WRD-001	Baker	800	2006	100	0.50	1.25
WRD-002	Baker	800	2007-09	219	0.35	1.56
WRD-003	Stewart	1,920	2011-13	348	0.08	1.00
WRD-004	Mitchell	600	2012-13	50	0.13	NA
WRD-005	Lee	3,360	2012-14	101	0.38	NA
Totals		8,680		945		

* Conducted under special research permit.

population prior to, during, and for 2 years after translocation to document the effects.

4. Recipient property must agree to discontinue use of pen-raised quail on the property and not hunt quail on the property during the duration of the translocation.
5. Recipient property must agree to being added to a list of potential donors for future translocation projects.

POLICY IMPLEMENTATION

Translocation permits have been issued for 5 separate projects since the policy was created in 2006. Two of the permitted projects have been completed, one is in its second year, and the final 2 are in year 1. The first (WRD-001) was in 2006 on a 800-ha property in Baker County where a change in ownership from an industrial forest company to a private individual interested in quail hunting brought a change in management regime from heavily-stocked pine (*Pinus* spp.) trees with no prescribed fire to an open canopy pine forest maintained by frequent burning. One hundred wild bobwhites were moved to this site from north Florida in March 2006 resulting in a population increase based on fall covey census from < 0.5 birds/ha to 1.25 birds/ha (Table 1). This satisfied the new landowners desire to jump start the population and no further translocations were conducted.

The second project (WRD-002) was conducted on another 800-ha property also in Baker County. This property consisted of 336 ha of intensive row-crop cultivation with most of the remainder in unmanaged pine woodlands. The new owner purchased this property for the purpose of quail hunting and initiated major habitat developments for wild quail. All woodland areas were treated by thinning and prescribed fire, as well as mechanical removal of undesirable upland hardwoods. The agricultural fields were subdivided with hedgerows of native vegetation and planted shrub thickets, and field borders were developed around each field. One hundred twenty hectares of longleaf pines (*P. palustris*) were also planted in strips in the agricultural fields. In addition to the habitat work, a year round supplemental feeding and nest predator trapping program was initiated; both of which are permitted through GA WRD. The 2006 fall covey census revealed the baseline bobwhite population was very low at only 0.35 birds/ha. A source of wild birds for translocating was secured from a nearby quail plantation and a translocation program was implemented in 2007 to augment the habitat improvements. During March 2007, 94 wild birds were moved to the property. Additional releases of 67 and 58 birds were translocated in March 2008 and 2009, respectively, resulting in a total 3-year translocation of 219 birds (Table 1). Population response was measured with point counts ($n = 6$ points) that were distributed throughout the property and conducted 3 times each in May for whistling males and October/November for fall coveys. Population response was very satisfactory with large increases in whistling male counts and the fall point-count covey census indicating a population of 1.56 birds/ha in fall 2009 (Fig. 1).

The third project (WRD-003) is ongoing and is being conducted on a 1,920-ha property in Stewart and Chattahoochee counties. Most of this property had also been under ownership of an industrial forest company for many years until the current owner added it to his holding for recreational land. A heavy timber thinning was applied to the entire property and frequent prescribed fire was re-introduced. Permanent openings were created in the timber and a year-round supplemental feeding and nest predator trapping programs were initiated. An extremely low density of native bobwhites was documented by covey census on this property in fall 2010 (0.08 birds/ha). This project is unique because it involves translocation of

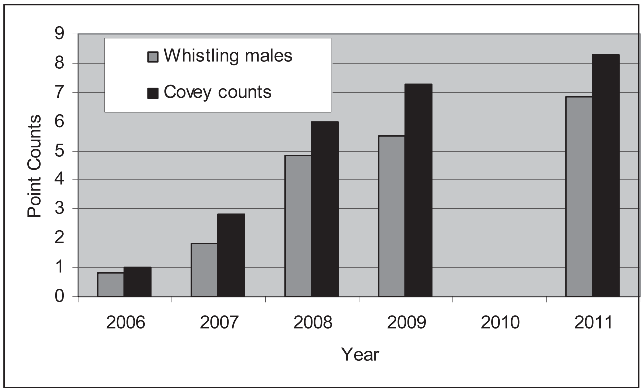

Fig. 1. Increases in the average number of both whistling males and fall coveys heard from 6 points on northern bobwhite translocation site (WRD-002) in southwestern Georgia from 2006 to 2011.

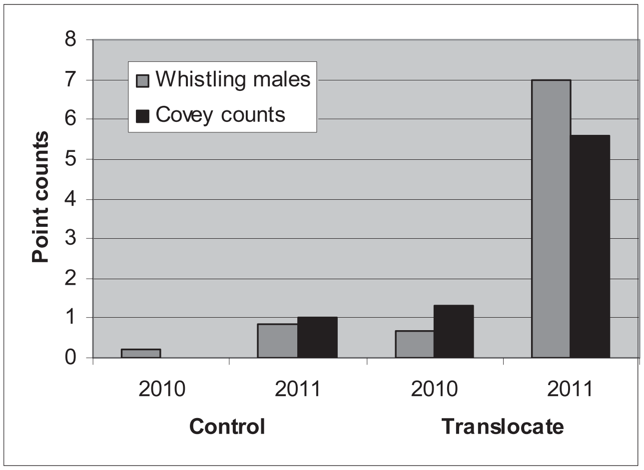

Fig. 2. Increases in the average number of both whistling males and fall coveys from point-counts on translocation (x = 3 points) and control sites (x = 6 points) on northern bobwhite translocation site (WRD-003) in southwestern Georgia during 2010 and 2011.

wild birds from the initial recipient of translocated wild quail in Georgia in Marion County. This property was divided into thirds for translocations due to its size with each third receiving birds in 1 of 3 years (2011–2013). Translocations began in March 2011 with 220 birds with an additional 128 birds translocated in March 2012 far a current total 348 (Table 1). Spring whistle counts conducted in May/June 2011 give some indication of early success as the listening points where translocations occurred that year ($n = 3$ points) averaging 7 males/stop compared to the control points ($n = 6$ points) where translocation had not yet occurred averaging < 1 whistling male/stop (Fig. 2). Point-count covey censuses conducted on these same points during fall 2011 indicated the same trend with an increase from 1.3 coveys heard per point to an average of 5.6 on the translocation site (Fig. 2). Additional translocations will occur on this property in 2013.

The final 2 projects (WRD-004, WRD-005) are in their first year with initial translocations conducted on each during March 2012. Only pre-translocation monitoring has been conducted at this time. WRD-004 is being conducted on a 600-ha property in Mitchell County that has been modified from industrial forest land to recreational land through timber thinning, creating openings, and prescribed burning. A pre-translocation fall point-count covey census ($n = 6$ points) in 2011 revealed a low population density of 0.13 birds/ha. Fifty wild quail were translocated onto this property in March 2012 (Table 1). WRD-005 is being conducted on a 3,360-ha property in Lee County that is an existing plantation that has been extensively renovated and has discontinued a pen-raised bird release program. Pre-translocation fall point-count covey census ($n = 9$ points) in 2011 revealed a population of only 0.38 birds/ha and 101 wild quail were translocated there in March 2012 (Table 1). This brings the total to 945 wild northern bobwhites that have been translocated under special permit in Georgia onto properties totaling 8,680 ha (Table 1).

DISCUSSION

The development and implementation of a wild quail translocation program in Georgia is a good example of research affecting natural resource policy and ultimately management of an imperiled species. This program is significant because it is resulting in establishment and maintenance of large blocks of quality early succession habitat capable of supporting high density bobwhite populations, benefitting numerous other species of conservation concern, and making strong contributions to the NBCI goals. Some of this acreage would not have been purchased and/or managed for wild quail without the ability to translocate wild birds and expedite population recovery onto these sites with extremely low densities. At best these properties would have been used for pen-raised bird releases. The confidence instilled into new landowners by having this program has contributed to their willingness to spend the time, effort, and money to do very intensive habitat improvements over large areas. The carefully thought out program by the GA WRD insures these sites are adequate in habitat quality and scope before a valuable resource can be moved there and sets standards to avoid the pitfall of wildlife privatization. It keeps the focus on creating new centers of quail habitat but also provides the tool to augment these populations where necessary due to extremely low densities currently occurring over much of the landscape.

MANAGEMENT IMPLICATIONS

The conservation ethic of the landowners involved in these research and translocation projects cannot be overstated. It takes a large commitment (and leap of faith) to purchase a large piece of property with very few wild quail and commit resources to the management necessary to make it suitable for a high density bobwhite population. The donor properties should receive special recognition as they are the key to this process. This program is creating new source populations as landowners who benefited from the program now feel compelled to help others just getting started. This is evidenced by the original recipient of wild birds in Georgia now being a source for the most recent project. The GA WRD policy has recently been modified to require that recipient properties allow their names to be placed on a list of potential future donors. Not only do these properties create new population centers of wild quail, but they are a boost to the local rural economies. These properties, through job creation, equipment and supply purchases, property taxes, and other avenues are in every case a boost to the areas where they occur. Management of these properties contributes significantly to achieving the goals of NBCI (Palmer et al. 2011) and also creates great habitat for many other wildlife species, a number of which are in serious decline.

ACKNOWLEDGMENTS

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LITERATURE CITED

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

DeVos, T., and B. S. Mueller. 1989. Quail relocation – can we fill the void? Quail Unlimited 12**:** 2–4.

Duda, M. D. 2009. Harvest of small game in Georgia 2008–2009. Responsive Management National Office, Harrisonburg, Virginia, USA.

Georgia Game and Fish Commission. 1961. Annual report. Federal Aid in Wildlife Restoration Research, Atlanta, USA.

Hurst, G. A., L. W. Burger, and B. D. Leopold. 1996. Predation and galliform recruitment: an old issue revisited. Transactions of North American Wildlife and Natural Resources Conference 61:61–76.

Jones, J. G. 1999. Effects of relocating wild northern bobwhites into managed quail habitat in middle Tennessee. Thesis. Tennessee Technical University, Knoxville, USA.

Latham, R. M., and C. R. Studholme. 1954. The bobwhite quail in Pennsylvania. Pennsylvania Game News. Special Issue Number 4.

Liu, X., B. S. Mueller, D. S. Parsons, and D. R. Dietz. 2002. Movement patterns of resident and relocated northern bobwhites in east Texas. Proceedings of the National Quail Symposium 5:168–172.

Palmer, W. E., T. M. Terhune, and D. F. McKenzie, eds. 2011. The National Bobwhite Conservation Initiative: a range wide plan for recovering bobwhites. National Bobwhite Technical Committee Technical Publication. Version 2.0. Knoxville, Tennessee, USA.

Parsons, D. S., R. M. Whiting Jr., X. Liu, B. S. Mueller, and S. L. Cook. 2000. Reproduction of relocated and resident northern bobwhites in east Texas. Proceedings of the National Quail Symposium 4:132–136.

Phillips, J. C. 1928. Wild birds introduced or transplanted in North America. U.S. Department of Agriculture Technical Bulletin 61: 21–33.

Rollins, D., and J. P. Carroll. 2001. Impacts of predation on northern bobwhite and scaled quail. Wildlife Society Bulletin 29:39–51.

Sauer, J. R., J. E. Hines, I. Thomas, and J. Fallon. 2011. The North American Breeding Bird Survey, results and analysis 1966–2007. Version 5.15.2008. USDI, Geological Survey, Patuxent Wildlife Research Center. Laurel, Maryland, USA.

Sisson, D. C., and W. E. Palmer. 2006. Response of established bobwhite populations to genetic exchange. Final Report to Georgia Wildlife Resources Division. Office of Game Chief, Social Circle, USA.

Sisson, D. C., and H. L. Stribling. 2009. The Albany Quail Project. Miscellaneous Publication Number 18. Tall Timbers Research Station and Land Conservancy. Tallahassee, Florida, USA.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner's Sons, New York, USA.

Terhune, T. M. 2008. Effects of translocating on population genetics and demographics of a northern bobwhite population among a fragmented landscape in southwestern Georgia. Dissertation. Auburn University, Auburn, Alabama, USA.

Terhune, T. M., D. C. Sisson, and H. L. Stribling. 2006. The efficacy of relocating wild northern bobwhites prior to the breeding season. Journal of Wildlife Management 70:914–921.

Terhune, T. M., D. C. Sisson, H. L. Stribling, and J. P. Carroll. 2005. Home range, movement, and site fidelity of translocated northern bobwhite in southwest Georgia, USA. European Journal of Wildlife Research 51:119–124.

Terhune, T. M., D. C. Sisson, W. E. Palmer, B. C. Faircloth, H. L. Stribling, and J. P. Carroll. 2010. Translocation to a fragmented landscape: survival, movement, and site fidelity of northern bobwhites. Ecological Applications 20: 1040–1052.

Thackston, R. E., and J. Tomberlin 2010. Georgia's Bobwhite Quail Initiative; accomplishments 2000–2010 and future restoration strategy. Proceedings of the Annual Conference of the Southeastern Fish and Wildlife Agencies 64:18–23.

WHAT'S A QUAIL WORTH? A LONGITUDINAL ASSESSMENT OF QUAIL HUNTER DEMOGRAPHICS, ATTITUDES, AND SPENDING HABITS IN TEXAS

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ABSTRACT

Funds generated and spent on the pursuit of quail (*Colinus virginianus, Callipepla squamata*) hunting in Texas are sizable. We surveyed a population of quail hunters in Texas in 2000 and 2011 to assess hunter demographics and spending habits. The population of hunters for the 2000 survey consisted of members of Quail Unlimited who lived in Texas while the 2011 population consisted of the former group's successor in Texas—Quail Coalition. The initial (2000) survey was a mail questionnaire while the 2011 survey instrument was delivered electronically. We achieved response rates of 47% in 2000 but only 9% in 2011. The number of resident quail hunters in Texas decreased 72% from 1981 to 2010. Quail hunters in Texas can be characterized as white males (97%) and affluent (65% reported annual household incomes above $125,000 in 2010). Survey respondents documented an average expenditure of $8,606 in pursuit of quail during an average of 8.8 days of hunting during the 2010–2011 season. This resulted in a cost of $254 per quail bagged when combined with harvest estimates provided by respondents; an estimated increase of 23% over the last 10 years.

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Key words: *Callipepla squamata*, *Colinus virginianus*, community development, demographics, economics, hunting, northern bobwhite, scaled quail, Texas

INTRODUCTION

Quail hunting is a pastime steeped in tradition and culture for many American sportsmen, especially in the southeastern United States and southern plains. Those sportsmen lament the steady decline in their favorite game bird, the northern bobwhite and the recreation it has afforded for the past century. Today, bobwhite abundance is only a remnant of what it was just 30 years ago for most of the southeastern United States (Sauer et al. 2011). More recently (within the past decade), hunters in traditional strongholds like Oklahoma and Texas have witnessed dramatic reductions in quail abundance (Fig. 1). Bobwhite and scaled quail, the 2 most popular of Texas' 4 species of quail, declined to record low abundance in 2011 (Texas Parks and Wildlife Department 2011). Breeding Bird Survey data indicate annual declines of 5.3 and 3.1% for bobwhites and scaled quail, respectively, from 1999 to 2009 (Sauer et al. 2011).

The decline of quail in Texas has prompted a concomitant decrease in number of hunters pursuing quail (Fig. 2). Quail hunter participation in Texas declined 79% from 1981 to 2010 (Purvis 2011). Attrition in the ranks of quail hunters is disconcerting in several respects (Rollins 2002). First, revenues lost from a decrease in hunting license sales affects effort, and at times interest, in quail management from state wildlife agencies. Second, an important avenue for income diversification for many rural landowners and local economies (i.e., fee-based hunting) is threatened (Burger et al. 1999). Continued participation of quail hunters is rapidly approaching critical mass in Texas. Quail hunting in Texas is an economically important sport and industry (Brennan et al. 2007, Conner 2007). Many rural counties in West and South Texas receive an economic pulse during the hunting season from increased hunting-related tourism. Hunting equipment (e.g., shotguns), amenities (e.g., off-road vehicles), and dog-related expenses (e.g., training collars, veterinary fees) contribute to sizeable expenditures (Conner 2007). Fee-hunting for quail provides an economic boon to private landowners in Texas who often receive more for hunting lease fees than for grazing leases (Rollins 2007).

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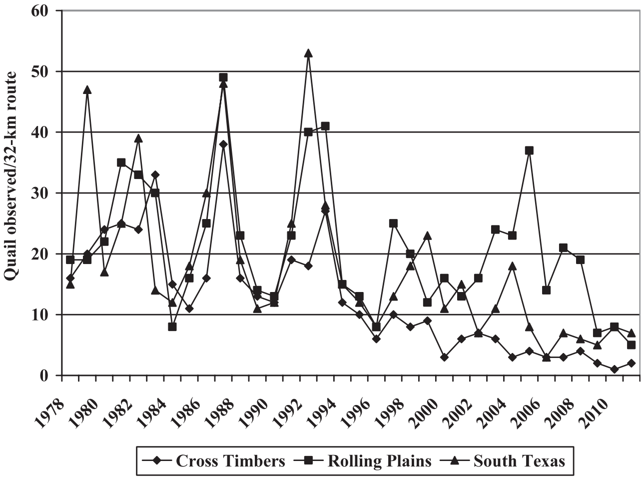

Fig. 1. Population trends of northern bobwhites in 3 ecoregions of Texas, 1978–2011, estimated from roadside counts (Texas Parks and Wildlife 2011).

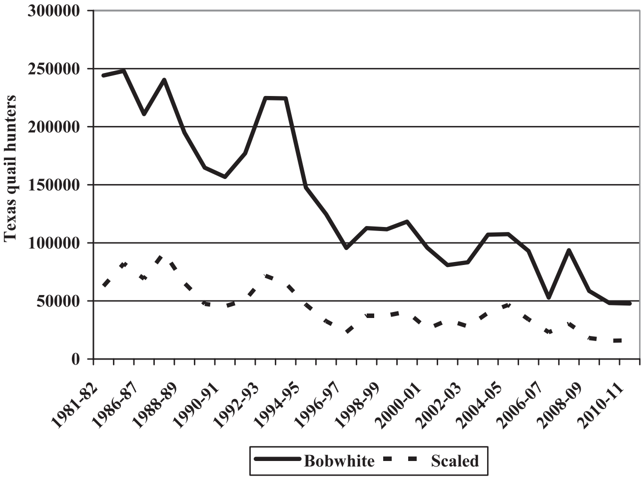

Fig. 2. Hunter participation for bobwhite and scaled quail in Texas, 1981–2011. Data from Purvis (2011).

The most thorough and comprehensive review of hunting demographics and economic impact is the U.S. Department of the Interior (USDI) 2006 National Survey of Fishing, Hunting, and Wildlife-associated Recreation (USDI 2008). This survey indicates 979,000 Texas residents hunted in Texas in 2006 and Texas was the destination for 1.1 million hunters. Texas hosted over 14 million days of hunting during 2006 with the average hunter pursuing game for about 13 days. The average Texas hunter spent $1,984 on a broad array of hunting and travel-related amenities.

The USDI (2008) survey documented that: 62% of Texas hunters come from urban residences (i.e., population $> 250{,}000$); 92% are male; 98% are Caucasian; and 25% had household incomes exceeding $100,000. Approximately 45% of Texas hunters were 35 to 54 years old with 25% over age 55. Educational levels indicated 40% of Texas hunters had a high school education or less with 60% having pursued higher education at some level.

The USDI (2008) survey estimated that small game hunters (359,000) spent an average of $286 per hunter with 2.9 million days of participation. There were 163,000 Texas quail hunters within the small game category with 835,000 days of participation. No average expenditure was reported for individual small game species.

The specific demographics, hunting activity, and expenditure patterns of the average hunter might not reflect those that could be considered ‘avid’ quail enthusiasts. It is likely this type of hunter is willing to spend significantly more time, money, and energy in pursuit of their quail hunting experience. We surveyed a population of Texas quail hunters in 2000 to assess their demographics, spending habits, and attitudes about quail management. Quail abundance was still ‘good’ at that time, but has decreased to record lows. We initiated a study in 2011 to re-assess demographics, activities, spending habits, and perceptions of quail hunters in Texas. The time-lag between the 2 surveys allowed us to assess the current status and trends and examine if recent declines in quail abundance had affected behaviors and attitudes of Texas quail hunters. Our objective was to conduct a longitudinal comparison in demographics, participation, spending patterns, and perceptions of quail hunters in Texas across the years 2000 and 2011.

METHODS

We conducted a longitudinal trend study involving solicitation of responses to the same questions and measuring the same variables in 2000 and 2011 focusing on a population of hunters that could be considered avid quail enthusiasts (i.e., members of a quail-focused conservation organization). Samples were of the same general population, but were not necessarily composed of the same individuals; the differences observed were less likely to be the result of cultural differences across generations. Longitudinal studies are often used in sociology to study events and behaviors throughout lifetimes or generations allowing researchers to distinguish short- from long-term phenomena. This methodology allowed us to analyze changes in the population and combine data from several studies of the same population to show a trend. We used hunter-harvest data obtained from Texas Parks and Wildlife Department (Purvis 2011) to evaluate trends in participation rates.

Mail Survey

The questionnaire for the 2000 survey was designed to capture data to describe the profile, activities, and attitudes of avid quail hunters. Survey questions were designed to capture intensity of quail hunting activities (e.g., days afield, number of hunting dogs owned), expenditure categories, and perceptions about the trends in huntable quail populations. We administered this survey in 2000 by direct mail to a random sample of 250 Quail Unlimited members with Texas addresses. The survey instrument was accompanied by a cover letter explaining the need to document economic impact

Table 1. Demographic profile of avid resident quail hunters in Texas across 2 time periods, 2000 and 2011.

	Year of survey			
	2000		2011	
Method	Direct mail		Internet	
n	250		3,940	
Response rate (%)	47.2		8.8	
Gender	100% Male		98% Male	
Average age in years (median)	53 (55)		55 (56)	
Ethnicity	97% Caucasian		97% Caucasian	
Education				
High School	15%		11%	
College	43%		54%	
Post-Graduate	42%		35%	
Household Income	< $10K	0%	< $10K	1%
	$10K - $40K	8%	$10,001 - $25K	0%
	$40K - $75K	16%	$25,001 - $50K	5%
	$75K - $125K	34%	$50,001 - $75K	7%
	> $125K	42%	$75,001 - $125K	22%
			$125,001 - $250K	32%
			> $250K	33%

information specifically focused on quail hunting activities and a postage-paid return envelope. A reminder postcard was sent to survey recipients 3 weeks following the initial mailing, resulting in a completed survey from 118 quail hunters (47.2% response rate).

Internet Survey

We administered the questionnaire for 2011 through an internet survey company, Survey Monkey (www.surveymonkey.com). The questions on the 2011 survey were changed slightly from the initial (2000) survey to conform to the internet website. A link to the electronic questionnaire was delivered by e-mail to 3,940 members of the Quail Coalition, a quail conservation organization in Texas (www.quailcoalition.org) which essentially succeeded Quail Unlimited in Texas in 2009. The questionnaire followed Dillman et al.'s (2008) tailored design method for internet surveys.

The e-mail contained a pre-survey letter, signed by the chairman of the Quail Coalition and a quail biologist, stating the purpose of the survey and requested member participation. The e-mail also contained a hyperlink to the internet-based questionnaire and a request that members click the link to begin. A reminder e-mail, identical to the first, was sent to all members 17 days later resulting in a total of 345 Quail Coalition members answering ≥ 1 question (8.8% response rate). We made no attempt to assess non-response bias in either survey.

RESULTS

Quail Hunter Trends

The number of quail hunters in Texas decreased 71.7% from 1981 to 2010 (Fig. 2). Most of the decline occurred from 1981 to 1996 with numbers thereafter remaining relatively stable. Resident hunters accounted for 85 to 99% of the total quail hunters with the proportion comprised by non-residents generally increasing over time. Texas residents accounted for 98.6% of quail hunters in 1981. However, in 2008 (the year with the highest participation by non-residents) that number slipped to 89.5%. The number of non-resident quail hunters increased about 206% from 1981 to 2008.

Hunter Demographics

Texas quail hunters (50% older than 56 years of age) were somewhat older than the average Texas hunter (25% older than 55 years of age) identified in the 2006 national survey and possessed higher average household incomes and levels of education (Table 1). Gender and ethnicity reflected similar patterns to the national survey indicating the overwhelming majority of quail hunters were Caucasian men. Household incomes of quail hunters confirmed an affluent status (defined as $>$ \$125,000 annual income), a statistic that increased from 42% in 2000 to 65% in 2010.

Hunter Participation and Spending Patterns

Quail hunting participation declined $\sim$ 50% from 15.3 days in 2000 to 8.8 days in 2010 (Table 2), but participation from the surveyed population was 72% greater than participation levels cited for quail hunters in the 2006 national survey. The number of respondents that had purchased land in the last 10 years for quail hunting fell just short of 20% in both 2000 and 2011. More than half (54 and 51%, respectively) leased hunting properties for quail in 2000 and 2010, respectively, and $>$ 40% leased ≥ 1 properties for quail hunting. Survey respondents cited average round- trip distances exceeding 643 kilometers (400 miles) to their hunting destinations. Bird dog ownership declined by 25% over the last 10 years, but $>$ 50% of respondents still owned bird dogs in 2010. However, among dog owners, the number of bird dogs

Table 2. Quail-related hunting activities of avid resident quail hunters in Texas across 2 time periods, 2000 and 2011.

	2000 Quail Unlimited		2011 Quail Coalition	
Quail hunting participation	2000	15.3 days	2010	8.8 days
	1995	17.8 days	2005	15.5 days
	1990	19.7 days	2000	17.4 days
Purchased land in the last 10 years for quail hunting	19%		18%	
Number of properties leased for quail hunting				
None	46%		49%	
One	25%		33%	
Two	15%		11%	
Three	10%		4%	
Four or more	4%		2%	
Average travel distance to hunting destination	647 kilometers		671 kilometers	
Hunting locations				
Quail lease	54%		57%	
Leased land as guest	45%		31%	
Land owned by friend/relative	45%		46%	
Land owned by self	36%		57%	
Public land	11%		9%	
Bird dog ownership - 1 or more	77%		51%	
Average among owners	6 dogs		3 dogs	
Hunted pen-raised quail	62%		86%	
Location of pen-raised quail:				
Shooting preserve	44%		31%	
Personal property	56%		41%	
both	n/a		28%	
Hunter success	1999/2000 season		2010/2011 season	
Bobwhites per day	3.14		3.31	
blue quail per day	1.37		0.44	

owned declined by 50% between the 2000 and 2011 periods. Additionally, > 62% of survey respondents indicated they had hunted pen-raised quail with > 40% using pen-raised birds on their personal property.

Survey respondents were asked to provide a number of details itemizing their quail hunting expenditures (Table 3). Lease rates per acre (2.4 ha) during the 11-year span between surveys increased 21% while per day leases increased 2%. Average quail hunting expenditures by respondents declined by 17% between the 2 study periods. Lease fees accounted for the largest quail hunting expense category, ranging from 28 to 35% of total expenditures. Travel-related categories (lodging, meals, and transportation) increased in terms of dollars and percentage of the hunting expenditure between 2000 and 2011. Dog-related, feed-food plots, and vehicle expenditures decreased 46, 44, and 56%, respectively reducing their combined market share of hunting expenditures from 46% in 2000 to 27.5% in 2011. Both surveys indicated that > 60% of annual hunting expenditures occurred away

Table 3. Expenditure patterns of avid Texas resident quail hunters across 2 time periods, 2000 and 2011.

	2000 Quail Unlimited		2011 Quail Coalition	
Average annual quail hunting expenditure	$10,354		$8,606	
Expenditure categories				
Guns and ammunition	$570	5.5%	$478	5.6%
Lease fees	$2,900	28.0%	$2,982	34.7%
Lodging	$577	5.6%	$626	7.2%
Meals	$283	2.7%	$482	5.6%
Dog-related	$2,004	19.4%	$1,068	12.4%
Transportation	$779	7.5%	$941	10.9%
Feed-food plots	$645	6.2%	$359	4.2%
Vehicles on site	$2,122	20.5%	$938	10.9%
Miscellaneous	$474	4.6%	$732	8.5%
Location of hunting expenditure				
County of residence	34%		36%	
En route to destination	13%		18%	
At destination county	54%		46%	
Average cost per bagged quail	$207		$254	

from the hunter's county of residence. Dividing the average quail hunting expenditures by quail harvest numbers reported by respondents indicated the estimate of the average cost per quail bagged increased 23% between surveys.

There was a unified perception among respondents that quail populations had declined versus those that were present 10 years prior (Table 4). A small percentage of each survey (< 10%) indicated that populations had actually improved over the previous 10 years. This suggests that some respondents were convinced the quail hunting environment had improved in certain locations. Survey respondents, when asked to identify the most important factors affecting quail populations most frequently cited weather, land use changes, predators, and overgrazing as the primary culprits. Attribution to disease-parasites was elevated taking prominence away from fire ants as additional factors affecting populations. Respondents were least likely to name pesticides and overhunting in both surveys as influencers on quail populations.

Table 4. Perceptions concerning quail population trends by survey respondents in 2 time periods, 2000 and 2011.

	2000 Quail Unlimited	2011 Quail Coalition
How have quail numbers changed where you hunt over the last 10 years?		
Increased	7%	5%
No change	6%	7%
Decreased	87%	88%
Which factors have affected quail populations in areas where you hunt?		
Weather	78%	82%
Land use changes	48%	39%
Predators	42%	41%
Overgrazing	39%	32%
Fire ants	33%	16%
Disease-parasites	16%	30%
Pesticides	15%	8%
Overhunting	15%	4%

DISCUSSION

Our studies confirm that a slightly older, more affluent, group of Texas quail hunters has emerged that are willing to absorb the 23% increase in the average cost per bird ($254), despite quail populations reaching an all-time low. There was a striking consistency of results across the 2 surveys separated by 11 years and using different delivery methods. Thus, a number of conclusions can reasonably be drawn that have implications for land managers, rural community leaders, and business owners that benefit from hunting expenditures of Texas quail hunters.

First, quail hunter numbers have declined 60% since 1990 and continue to decline; yet, within the population of small game hunters, there exists a passionate base of quail enthusiasts despite declining quail populations. These individuals are generally older than the average Texas hunter and possess relatively higher levels of education and household income. This cadre of hunters has demonstrated a willingness to travel long distances and spend money at higher levels than the average hunter (of any type of game). Bird dog ownership has decreased by 25% over the last 10 years, but a majority of respondents still own bird dogs, demonstrating an ongoing commitment to quail hunting. Any landowner or business venture wanting to capitalize on the spending habits of these hunters would be well advised to consider how they might position their products, services, and offerings to better appeal to this type of target market.

Second, landowners and managers capable of providing a reliable huntable quail population could reap financial benefits by catering to this group of hunters' desire for a quality quail hunting experience. Difficulty in finding properties suitably managed for quail has motivated a respectable proportion (20%) of the survey respondents to purchase land for themselves, while the majority of respondents rely on leased properties to provide their hunting opportunities. Hunting pen-raised quail increased 24% over the last 10 years, demonstrating the extent that hunters will go for quail hunting and to provide hunting opportunity for their bird dogs. Most rangelands that support quail are typically cattle operations (Texas Parks and Wildlife Department 2005, Rollins 2007). Proper land management (e.g., stocking rates) to enhance huntable quail populations can actually be complementary to prudent management for livestock (Conner 2007, Rollins 2007). However, conflict often arises between the cattle operator-lessor and the quail hunting lessee. We also surveyed landowners from 13 counties where quail leases were popular as a portion of our 2000 survey (D. Rollins, unpublished data). As an example of the disconnect between these livestock-oriented landowners and quail hunting lessees, 39% and 31% of hunters identified overgrazing as a serious concern for quail in the 2000 and 2011 surveys, respectively, whereas only 1% of landowners suggested overgrazing as a concern. Both enterprises could benefit financially from the use of cattle grazing that is planned around the quail lifecycle with flexible stocking rates and rested pastures. This dual species accommodation requires a willingness to forego short-term economic gains that might accrue to a livestock-only management program in return for long-term financial gains.

There is no denying that hunting has a genuine, and substantial, economic impact in Texas. The magnitude and breadth of benefits resulting from hunting are not limited to the landowner and hunter. The results from our study identify that a large percentage of a quail hunter's annual expenditures occur en route to, and at, the hunting destination. Ironically, many hunters come from urban areas making quail hunting one of those rare social and economic activities that draw money from urban to rural communities. This economic injection accrues not only to the landowners, but also to the general merchants throughout Texas who cater to the needs of those who travel across the state in pursuit of quail. Expenditures per quail hunter decreased by ~ $2000 over the last 10 years.

Thus, a dedicated effort to preserve and protect suitable quail habitats is likely a worthwhile goal for both landowners and rural economic development advocates.

Data are available for non-resident hunter participation, but there are no numbers on expenditure patterns for this segment of quail hunters in Texas. Numerically they account for about 10% of the quail hunters, but their increasing trend suggests they have a growing economic impact on quail hunting in Texas. Bobwhite populations have declined in Texas, but the state remains a popular destination for non-resident quail hunters, a pattern that will continue given even more dire declines further east of Texas. Thus, further research is warranted on their spending patterns.

We recognize and caution that our survey population likely does not represent the mainstream quail hunter in Texas, but likely those more affluent and more committed to pursuing a quality quail hunting experience. Our characterization of the quail hunting public in Texas in terms of demographics, conforms to that of quail hunters across the southeastern U.S. (Burger et al. 1999) relative to gender and race ($>$ 97% white males), but differs in regards to age and annual income with Texas having older and more affluent hunters on average. We cannot estimate whether our study population accounts for a minor or major portion of quail hunters. Additional information is needed from the less affluent quail hunters and their relative share of the quail hunting market in Texas. Our estimates may be typical and not exceptional given the expense of hunting quail on private lands in Texas, and the paucity of public hunting opportunities (about 97% of Texas is privately-owned land).

ACKNOWLEDGMENTS

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LITERATURE CITED

Brennan, L. A. 2007. The future of quail hunting and sustainability science. Pages 421–427 *in* L. A. Brennan, ed. Texas quails: ecology and management. Texas A&M University Press, College Station, USA.

Burger, L. W., D. A. Miller, and R. J. Southwick. 1999. Economic impact of northern bobwhite hunting in the southeastern United States. Wildlife Society Bulletin 27:1010–1018.

Conner, R. J. 2007. Economic aspects of Texas quails. Pages 313–326 *in* L. A. Brennan, ed. Texas quails: ecology and management. Texas A&M University Press, College Station, USA.

Dillman, D. A., J. D. Smyth, and L. M. Christian. 2008. Internet, mail, and mixed mode surveys: the tailored design method. Third edition. John Wiley and Sons, Hoboken, New Jersey, USA.

Purvis, J. 2011. Small game harvest surveys, 1981–2010. Texas Parks and Wildlife Department, Austin, USA.

Rollins, D. 2002. Sustaining the "quail wave" in the southern Great Plains. Proceedings of the National Quail Symposium 5:58–68.

Rollins, D. 2007. Quails on the Rolling Plains. Pages 117–141 *in* L. A. Brennan, ed. Texas quails: ecology and management. Texas A&M University Press, College Station, USA.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski Jr., and W. A. Link. 2011. The North American Breeding Bird Survey, results and analysis 1966–2009. Version 3.23.2011. USGS, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Texas Parks and Wildlife Department. 2005. Where have all the quail gone? Special publication W7000-1025. Austin, USA.

Texas Parks and Wildlife Department. 2011. Quail forecast 2011-12. Austin, USA. www.tpwd.state.tx.us/huntwild/hunt/planning/quail_forecast/forecast/

U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U. S. Department of Commerce, U. S. Census Bureau (USDI). 2008. 2006 National survey of fishing, hunting, and wildlife-associated recreation, Texas. U. S. Government Printing Office, Washington, D.C., USA.

VALUE OF PRIVATE LANDS MANAGED FOR WILD NORTHERN BOBWHITES IN THE DEEP SOUTH

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ABSTRACT

Successful northern bobwhite (*Colinus virginiaus*) management creating huntable bobwhite populations in the southeastern United States is largely practiced on private lands. These properties not only support high density bobwhite populations, they also support biodiversity including many declining or endangered species associated with frequently-burned pine savannas. The private land model has proven sustainable over centuries and has recently increased with $>$ 20,000 ha of wild bobwhite lands added in Georgia, Florida, and South Carolina since 2000. The NBCI recognizes private lands are critical to restoration of bobwhites but, despite their conservation value, no studies have quantified areas under wild bobwhite management. We mapped 259 properties totaling $\sim$ 345,614 ha with wild bobwhite management principally in Georgia, Florida, Alabama, and South Carolina, and are completing mapping in Mississippi, Virginia, and North Carolina. Our survey data found management actions were consistent across these properties including maintaining open pine canopy, reducing hardwoods in upland areas, prescribed fire on areas of appropriate sizes and distribution, year-round supplemental feeding, nest predator management, and conservative harvest rates. Adoption of these management practices are a result of long-term research demonstrating their efficacy. Density of bobwhites on a property was related to landscape composition with lower densities on more fragmented sites. Properties in core areas surrounded by other managed properties often achieved bobwhite densities of 5–8 quail/ha. Bobwhite densities on smaller isolated properties densities were $\sim$ 2.5 quail/ha during fall. Aspects of this successful management model may be useful to other private lands as well as public management areas focused on northern bobwhite.

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Key words: *Colinus virginianus,* NBCI, northern bobwhite, private land management, southeastern United States

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PRIVATE LANDOWNERS' WILLINGNESS TO ENROLL THEIR PROPERTIES IN A PUBLIC HUNTING ACCESS PROGRAM IN NORTHEAST MISSOURI

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ABSTRACT

State wildlife agencies have successfully used public hunting access fees to increase hunting opportunity and to provide a financial incentive to private landowners for maintaining habitat. Typical payments per hectare (ac) include \$3.29 (\$1.25) on average in Kansas, \$2.47-\$3.71(\$1-\$1.50) for pheasant hunting in Colorado, \$2.47-\$12.36 (\$1–\$5) in North Dakota for pheasant hunting, and \$4.45 (\$1.80) on average in South Dakota. We studied the USDA Conservation Reserve Program (CRP) in 2004 in Adair, Knox, Macon, Monroe, Ralls, Randolph, Schuyler, and Scotland counties in northeast Missouri as part of a quail and songbird habitat restoration initiative. CRP is prominent in these counties with 83,040 ha (205,197 ac) enrolled. We conducted a mail-back survey of all CRP contract holders, totaling 3,283 landowners to study their willingness to enroll their properties in a hypothetical public-access hunting program. The survey was designed to provide information about landowner demographics, attitudes toward wildlife and hunting, and knowledge of wildlife habitat management aspects of the CRP. We used the Kansas Department of Wildlife and Parks Walk-In Hunting Access Program as an example for questions related to the concept of public-access hunting, and presented landowners with hypothetical annual lease payments for enrolling, using a discrete-choice modeling framework. Survey response rate was relatively high at 59.5%. The average respondent had 34.6 ha (85.5 ac) enrolled in CRP, and field size averaged 6.47 ha (16.0 ac), ranging from 0.04 to 84.9 ha (0.1–209.7 ac). Wildlife as a product of the CRP was 'very' or 'somewhat important' to 89% of respondents and, among a list of wildlife species and native plants, northern bobwhite (*Colinus virginianus*) was most popular with 80% of respondents checking 'very' or 'somewhat important' on the survey. The corresponding values were 53–66% for wild turkey (*Meleagris gallopavo*), deer, rabbit, pheasant, and songbirds. We asked if landowners would enroll any of their CRP land in a public-access hunting program (PAHP). We used 8 different versions of the survey, each with a different 'offer' level in the question to evaluate the potential costs of a PAHP program. The structure of the survey specified whether landowners would accept payment of \$X/ac, where X was one value randomly selected from the set of \$1, \$2, \$3, \$4, \$5, \$7, \$10, or \$20. None of respondents chose 'yes' at a PAHP value of \$0, 91.9% chose 'no', and 8.1% chose 'don't know'; respective values (\$) and choices (%) (yes, no, don't know) were: **\$1**-1.7%, 91.3%, and 6.9%; **\$2**-3.0%, 90.2%, and 6.8%; **\$3**-4.0%, 84.9%, and 11.2%; **\$4**-3.4%, 87.7%, and 9.0%; **\$5**-4.7%, 83.4%, and 11.9%; **\$7**-7.1%, 82.1%, and 10.7%; **\$10**-8.4%, 77.0%, and 14.7%; and **\$20**-14.8%, 71.3%, and 13.9%. Respondents were asked what kind of hunting they would allow on their land in a PAHP program. Almost all would allow deer hunting, whereas only 48% would allow small game hunting, such as quail. Respondents were given a choice of reasons for not enrolling in PAHP and, of the negative responses, $>$ 90% said that having 'strangers on my land' was an issue while $>$ 85% cited 'damage to property, crops or livestock' as a potential problem; $>$ 90% mentioned the need for a liability law protecting landowners. We asked those landowners responding 'yes' to PAHP how many of their CRP acres they would enroll. At a payment level of \$2/ac (\$4.94/ha), $\sim$ 3% of landowners said they would enroll an average of about 86% of their CRP acres. Two dollars per acre is well within the range of payments offered by neighboring states. This would amount to $>$ 2,023 ha (5,000 ac) (of the 83,040 ha total CRP) area being enrolled in the 8 Missouri counties in this study, at an annual cost of about \$10,500. About 1,012 ha (2,500 ac) would be designated for quail hunting of this hypothetical PAHP area, based on respondents' answers to what type of hunting they would allow. We estimate that 5,261 ha (13,000 ac) would be enrolled with 2,489 ha (6,150 ac) open for quail hunting at an annual cost of about \$90,000 if the payment level was raised to \$7/ac (\$17.30/ha). There is potential to improve the feasibility of CRP lands for bobwhite hunting in northeast Missouri by adding a public-access hunting incentive, but managers will be challenged to use this approach successfully. Landowners' inclination to allow access for deer hunting, but not for quail hunting, reduces an agency's

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justification for using quail hunting access as an approach to improve conservation of bobwhites, in addition to the relatively high cost.

Citation: Treiman, T. B., T. V. Dailey, R. A. Reitz, and H. J. Scroggins. 2012. Private landowners' willingness to enroll their properties in a public hunting access program in northeast Missouri. Proceedings of the National Quail Symposium 7:301–302.

Key words: *Colinus virginianus*, economics, financial incentives, Kansas Walk In Program, landowner attitudes, Missouri, motivation, private lands, public access hunting, values, willingness-to-accept payment (WTA)

ROWING AGAINST THE TIDE: GETTING LANDOWNERS TO MANAGE HABITAT FOR THEIR FAVORITE WILDLIFE SPECIES, BOBWHITES

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ABSTRACT

A primary cause of the decline of northern bobwhite (*Colinus virginianus*) is that landowners often lack adequate motivation for the arduous task of creating and managing habitat. We gained insight into some of these motivations through survey questionnaires and focus groups in Missouri, and report findings from 3 studies containing 3,057 survey responses during 2004–2007. One of the surveys targeted Conservation Reserve Program (CRP) lands ('CRP survey'), another lands with potential for bobwhite restoration ('bobwhite survey'), and the third focused on grassland bird restoration. Landowners in each survey identified bobwhites as the most popular (>80% of respondents chose 'somewhat' or 'very' 'important' to have bobwhites 'on my land') natural resource among a list that included deer, turkeys, prairie-chickens, native plants, grassland birds, rabbits, hawks/owls, etc. Bobwhites were highly valued by landowners, but other answers in these surveys revealed many obstacles to habitat management including economics, time, knowledge, skill, and equipment. For example, only 39% of respondents in the bobwhite survey were interested in joining a habitat restoration cooperative, and <50% of respondents in all surveys were willing to adopt quail-friendly habitat management (prescribed fire, disking, herbicides, moderate grazing, native vegetation, presence of weeds, etc.). Bobwhite restoration programs, because of the gap between landowners' fondness for quail, but being less willing to take action, must include a comprehensive approach, ranging from local community involvement by agency biologists and non-government organizations to resource-use policy in Washington, D.C.

Citation: Dailey, T. V., R. A. Reitz, H. J. Scroggins, W. T. White, T. B. Treiman, and N. Hoilet. 2012. Rowing against the tide: getting landowners to manage habitat for their favorite wildlife species, bobwhites. Proceedings of the National Quail Symposium 7:303.

Key words: *Colinus virginianus*, Conservation Reserve Program, habitat management, landowners, northern bobwhite

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USING THE CONSERVATION PLANNING TOOL TO EFFECTIVELY RECOVER NORTHERN BOBWHITES: AN EXAMPLE FOR STATES TO EFFECTIVELY STEP-DOWN THE NBCI PLAN

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ABSTRACT

The National Bobwhite Conservation Initiative (NBCI) 2.0 provides a sound foundation for recovering northern bobwhites (*Colinus virginianus*) range-wide, regionally and, to some extent, even locally. However, the NBCI does not provide detailed guidance to states on how to step-down the plan for efficacious delivery of on-the-ground management actions prescribed via biologists within the plan itself. States often must incorporate multiple planning efforts (e.g., state wildlife action plans) and geospatial layers not directly included in the NBCI plan (see NBCI Appendix in these Proceedings) to make tenable decisions which best guide allocation of resources and benefit multiple species of greatest conservation concern. The Conservation Planning Tool (CPT), developed as part of NBCI 2.0, provides the infrastructure for states and conservation organizations to capture biologist information coalesced in the plan while incorporating other data (e.g., species emphasis areas, current CRP implementation, etc.) germane to conservation planning. We use 3 states (Kansas, Florida, and Virginia) to demonstrate the utility of the CPT and to develop a step-down implementation plan, via creation of a habitat prioritization model, for recovery of bobwhites in each state. We explore the implications associated with creation of focal areas with respect to high versus medium ranked areas and underscore the importance of inclusion of major land-use opportunities and constraints prescribed within the plan to garner successful bobwhite recovery. We propose a framework for the integration of monitoring efforts into the step-down model to assess bird response and evaluate NBCI success through estimating bobwhite population density.

Citation: Terhune, T. M., W. E. Palmer, T. V. Dailey, B. Dukes, C. L. McKelvy, J. J. Morgan, J. C. Pitman, M. Puckett, and R. E. Thackston. 2012. Using the conservation planning tool to effectively recover northern bobwhites: an example for states to effectively step-down the NBCI plan. Proceedings of the National Quail Symposium 7:304.

Key words: *Colinus virginianus*, Conservation Reserve Program, National Bobwhite Conservation Initiative, northern bobwhites

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AN ANALYSIS OF MASKED BOBWHITE COLLECTION LOCALES AND HABITAT CHARACTERISTICS

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ABSTRACT

We evaluated the collecting locales of 251 masked bobwhite (*Colinus virginianus ridgwayi*) specimens in museum collections. Eighteen were from 4 sites in Arizona—all collected by Herbert Brown. The vast majority (93%) of specimens were from the Mexican State of Sonora. We visited and photographed each of the Arizona collection locations and most of the sites in Sonora. Collector descriptions indicate the bird's principal habitat affiliations were with tall grass-weed (= forb) pastures, savannas, and farm fields. All historic localities visited were either in grass-forb habitats along drainages or in present or former savannas adjacent to woody cover and/or agricultural fields between 240 and 1,060 m elevation. These sites were remarkably similar to other bobwhite habitats in subtropic-tropic South Texas and Oaxaca, Mexico. Masked bobwhite habitat was a diverse tropic-subtropic grassland within or adjacent to dense woody cover (thornscrub) and/or farmland. These habitats experienced alterations and loss of the tall grass-weed component due to livestock husbandry. Some former habitat sites appear to have recovered, however, and restoration of the subspecies might be possible if suitable stock exists. Unfortunately, this bird may now be functionally extinct.

Citation: Brown, D. E., K. B. Clark, R. D. Babb, and G. Harris. 2012. An analysis of masked bobwhite collection locales and habitat characteristics. Proceedings of the National Quail Symposium 7:305–328.

Key words: Arizona, Buenos Aires National Wildlife Refuge, *Colinus virginianus ridgwayi*, domestic quail, endangered species, grass, grassland, masked bobwhite, museum collections, savanna, Sonora

INTRODUCTION

> "*It is doubtless properly a Mexican species, which extends northward for only a short distance beyond the Arizona line, and southward into Mexico for an unknown distance, where possibly—we may almost say probably—it merges into* C. graysoni."
> J. A. Allen 1886a: 287

Few events generated more interest within the ornithological community than discovery in Arizona of the masked bobwhite by Herbert Brown on 6 March 1884 (Brown 1884; Grinnell 1884; Allen 1886a, b, c; 1887). That all of the U.S. specimens of this unique subspecies of a favorite American bird originated with Herbert Brown, and that his identification was twice challenged by Robert Ridgway of the U.S. National Museum, created an aura of mystique that continues to this day (Ridgway 1884, 1886). Especially intriguing to naturalists was the bird's isolation from other bobwhite populations and restricted range in 1 U.S. and 1 Mexican state (Aldrich and Duvall 1955). This isolation, coupled with the bird's disappearance from Arizona by 1900, generated a number of conservation efforts, none of which succeeded.

Describing masked bobwhite habitat requirements is difficult since the bird's original habitats have been greatly altered. Only one scientific study of wild birds has been conducted (Tomlinson 1972a, b), and that of a relict population discovered in Sonora after the bird was thought to have vanished (Gallizioli et al. 1967). This population also appears to have vanished, and reintroduction attempts on and off Buenos Aires National Wildlife Refuge in Arizona, appear to have been unsuccessful (Unpublished reports, U.S. Fish and Wildlife Service, Albuquerque, NM, USA). Locating wild birds and maintaining a wild population of masked bobwhites are essential if the taxon is to survive.

We reasoned the key to locating any relict populations of masked bobwhite depends on being able to define and locate suitable habitats where birds may survive. That such an evaluation remains possible is due to the bird's

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collectors, Herbert Brown, H. C. Benson, J. C. Cahoon, Frank Stephens, Robert T. Moore, J. T. Wright, W. W. Brown, David M. Gorsuch, J. Stokley Ligon, Louis L. Lawson, and A. J. Van Rossem, who, cognizant of the bird's unique character, not only plotted the localities of their collections but, in many cases, described the bird's habitat affinities. Also helpful were the observations of earlier investigators such as Neff (1947), who observed a covey of ~ 30 birds a few kilometers south of Punta Agua in the north end of the Valle de Agua Caliente, Sonora.

METHODS

We examined all available museum records, articles, field notes, and correspondence accompanying masked bobwhite collection locales. The location of each collection was mapped and data from the nearest weather station having mean monthly precipitation and temperatures were recorded. The collector's notes and publications were reviewed along with any descriptions of the elevation, landscape physiognomy, and vegetation composition/structure. Our intention was to describe what constituted masked bobwhite habitat at the time the collections were made.

Facilitating this effort in Arizona was former University of Arizona bird collection curator Tom Huels' (2009) transcription of Herbert Brown's field notes and specimen records, data that he generously shared. We visited collections holding masked bobwhite at the San Diego Natural History Museum, Moore Laboratory of Zoology at Occidental College, University of California, Los Angeles, University of Arizona, Los Angeles County Museum of Natural History, U. S. National Museum, University of New Mexico, and the British Museum of Natural History. We extracted any habitat information including habitat descriptions by Robert Moore at Occidental College. All collection locales were mapped (Fig. 1).

We arranged two flights with Sandy Lanham of Environmental Flying Services (Tucson, AZ) to survey all former collection locales in Sonora not previously visited on the ground and historically difficult of access such as the Yaqui Indian lands (Table 1). This was accomplished by flying a general survey over mapped collection sites, and conducting low-level (120–150 m) transects ~ 2 km apart over the most promising appearing sites with abundant grass and/or forb cover. Flights were in a 4-seat Cessna aircraft, the observers (DEB and KBC) directing the pilot to re-survey areas having good grass and/or weed cover. Flight paths were recorded with a Global Positioning System (GPS) unit and positions and photographs taken of the most promising sites.

Our first flight covered most of the bobwhite range in Sonora and identified several promising areas for further investigation. Small rivers such as the Ríos Moctezuma and Sonora at the northern end of the range showed extensive agricultural areas with fallow fields and river bottoms supporting abundant grass and weed cover. Another area worthy of further investigation included the volcanic mesas southeast of Moctezuma near the town of Tepache. This area supports varying densities of shrub cover interspersed with savanna-like herblands (Fig. 2). The volcanic rock nature of these mesas limits water development and the ability of cattle to disperse, resulting in dense patches of herbaceous vegetation in openings and underneath the scrub.

The second flight included habitats in the Valle Agua Caliente east of Sierra Bacatete. This area is south of Rancho Las Arenas where W. W. Brown collected > 100 specimens in December 1905 and January 1906 (Appendix). Areas south of Rancho Las Arenas have been difficult to access due to their status as Yaqui Indian territory (Moore 1932). Our over-flight in December 2011 revealed potential habitat continues south of Las Arenas for ~ 20 km, in the vicinity of Rancho Agua Caliente. These lands, mostly on the Yaqui Indian Reservation, contained the most promising sites seen to date and necessitated a ground survey before making any evaluation of the bird's status in Sonora.

All collection locales in Arizona were visited on the ground as were the most important sites in Sonora. Photographs and GPS locations of what appeared to have been bobwhite habitat were taken in the immediate vicinity of the collection locales with notes taken on the date, elevation, vegetation present, and overall habitat condition. These photographs were compared to descriptions of the earlier collectors with both positive and negative changes noted.

On 23, 24, and 25 February 2012, we (DEB, RAB, KBC) conducted a ground survey on the Yaqui Indian lands based on historic collection locales and an aerial reconnaissance. Sites selected represented both *sabana* (savanna) and *bajio* (bottomland) habitats and included the best appearing bobwhite habitats remaining in Sonora. Ing. Cristina Melendez and Eberado Sanchez Camero (Comisión de Ecología y DesarrolloSustentable del Estado de Sonora [CEDES]) coordinated the survey led by Anibella Carlón Flores, representing the Yaqui Nation. Accompanying us at all times were Yaqui Vigilancias: Jefe Guadalupe (Pluma Blanca) Ochoa, José Juan Terán Enríquez, Isábel Lugo (Chabelo) Molina, Eladio Molina (Layo) Azvala, and Marco Antonio Carlén Flores, who also assisted in the search and bird identification.

We conducted 8 separate surveys, each with a pair of trained hunting dogs (English pointers), in the vicinity of Rancho Agua Caliente. All 12 hrs of survey time were during the early morning or late afternoon to prevent the dogs from overheating. Six surveys were in the vicinity of GPS locations having abundant grass and/or tall, weedy vegetation within open thornscrub with another in the vicinity of a reservoir. One morning was spent surveying an *Amaranthus*-choked bottomland bordered by savanna and thornscrub. Several verdin (*Auriparus flaviceps*) and cactus wren (*Campylorhynchus brunneicapillus*) nests were examined, and those feathers that could not be identified as not belonging to bobwhite collected for comparison to museum specimens. In toto, 20.76 km of surveys were conducted covering 159 ha of habitat.

We (DEB, RDB, KBC) also visited and photographed bobwhite habitat sites in tropical arid environments in the vicinity of Salina Cruz, Oaxaca, and Laguna Atascosa

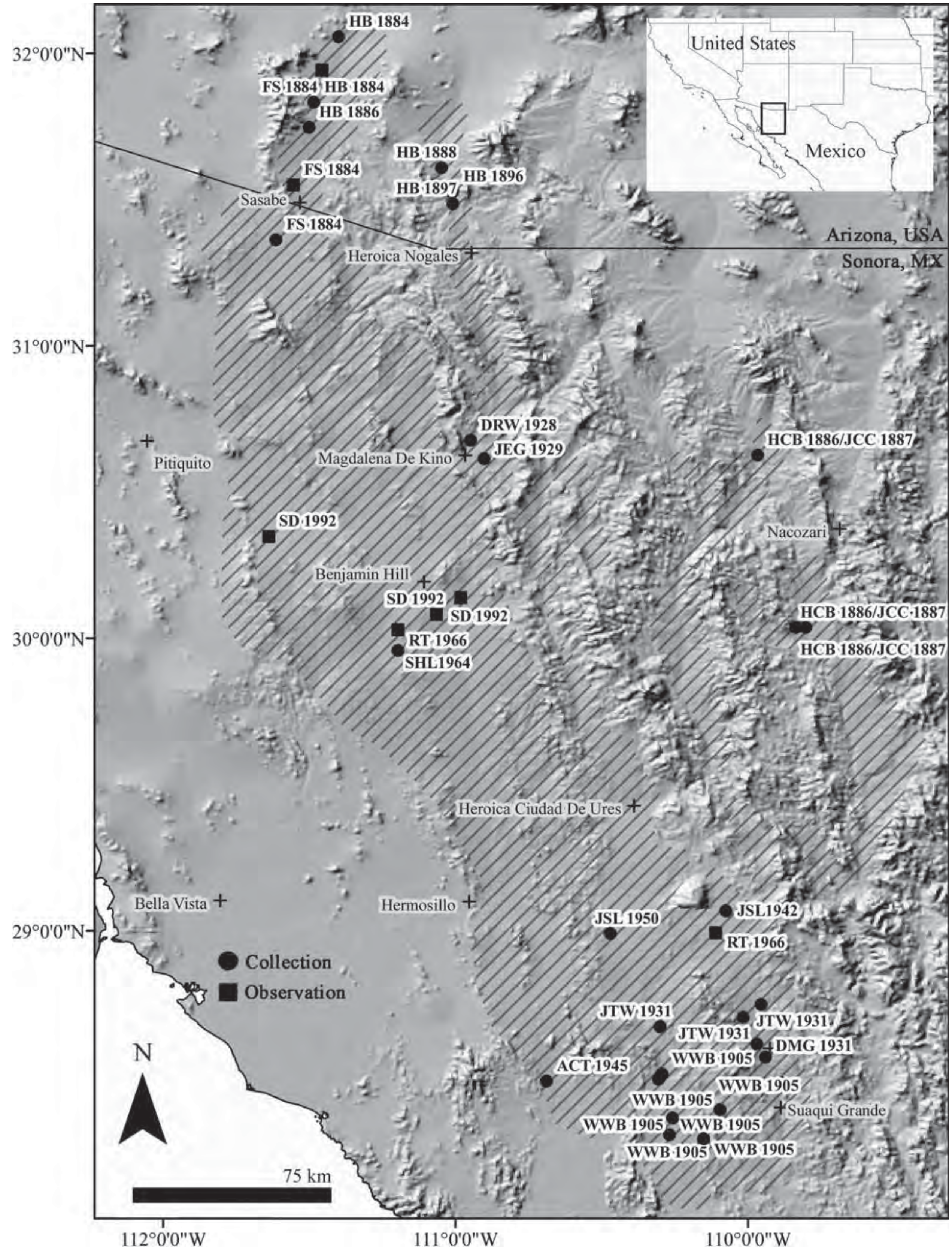


Fig. 1. Locations and years of masked bobwhite collections in southern Arizona and Sonora, Mexico, 1884–1992.

Table 1. Aerial and ground surveys for masked bobwhite habitat field work, 2009–2012.

Dates	Locations	Purpose
Aerial reconnaissance 14–17 Dec 2009	Overview of all historic collection locales in Sonora	Assess current condition of vegetation and locate potential sites for ground visits
Ground reconnaissance 19–20 Jan 2010	Rancho Carrizo, Rancho El Arpa, Rancho El Cuervo, Benjamin Hill, Sonora	Assess habitat of last remaining wild population of masked bobwhite
Ground reconnaissance 29 Aug-4 Sep 2010	San Marcial and La Misa vicinities; Rancho El Triguito, Rancho Las Arenas areas in Sonora	Ground check habitat of promising locales seen from over flight
Ground reconnaissance 7-11 Feb 2011	Salina Cruz, Oaxaca	Assess habitat of healthy tropical bobwhite population
Ground reconnaissance 16 Jul-21 Aug 2011	Tubac, Calabasas, Altar Valley, Arizona	Assess habitat in historic collection locales in AZ
Ground reconnaissance 12–16 Oct 2011	Laguna Atascosa NWR, Sal del Ray NWR, Texas	Assess habitat of healthy subtropical bobwhite population
Ground reconnaissance 19–23 Oct 2011	Cumpas, Moctezuma, Bacoachi, Arizpe, Sonora	Assess habitat in historic collection locales in northern Sonora.
Aerial reconnaissance 29 Nov-2 Dec 2011	Valle Agua Caliente, Sonora	Overflight of potential habitat at southern edge of historic range.
Ground search with bird dogs 23–25 Feb 2012	Valle del Agua Caliente area of Yaqui Indian Reservation, Sonora	Search for presence of masked bobwhite

Fig. 2. Savanna vegetation on the volcanic mesa between Moctezuma and Tepache, Sonora at ~ 650 m elevation. Arid, and difficult to develop for water, such sites retain much of their original character and would be promising locales to look for bobwhites. Photograph by D. E. Brown.

National Wildlife Refuge in Texas where good populations of similar races of bobwhites occur. These sites were photographed and the elevations, landscape physiognomy, and plant species structure recorded for comparison with masked bobwhite collection locales.

Mean monthly precipitation, annual temperature, and number of days above freezing were obtained from climatological stations nearest to the collection locales maintained by the National Oceanic and Atmospheric Administration (U. S. Department of Commerce 2010) or from Hastings and Humphrey (1969) for Sonora. Similar data were collected for habitats where bobwhites had been observed in Texas and Oaxaca.

COLLECTION LOCALES

We located 251 masked bobwhite specimens in 19 museum collections including locations reported by Tomlinson (1972b; Appendix, Fig. 1). The vast majority of sites (> 99%) where birds were collected were in tropic-subtropic environments below 1,060 m elevation with mean annual temperatures of 18 °C or above. All sites were characterized by annual precipitation > 350 mm with 250 mm (70% +) occurring during June through September (Table 2; Koss et al. 1968, U.S. Department of Commerce 2010).

Bobwhite Collections in and Adjacent to Altar Valley, Arizona

Herbert Brown and his agents collected at least 18 masked bobwhite in Altar Valley including 2 partial specimens sent to the U. S. National Museum. Two males and 2 females were provided to the American Museum of Natural History in New York (Appendix), and 5 males and 5 females were sent to George B. Sennett and another pair to Manly Hardy of Brewer, Maine (Allen 1886a, Brown 1887).

Brown (1885: 445) described a collection trip he made to Altar Valley in September 1885:

> "*We entered the Altar Valley at a point about twenty-eight miles southwest of Tucson, followed the valley southward fifteen miles then turned westward toward the peak, which over a smooth grass-covered mesa was here distant twenty odd miles. By noon on the 27th we were camped under the shadow of the great rock* [Baboquivari Peak]..."

Brown (1885: 445) goes on to describe the importance of grass to the quails' habitats:

> "*The 'hooded quail'* (*Colinus ridgwayi*) *was three years since* [1882], *abundant in the neighborhood of Bolle's Well, a stage station on the Quijotoa road, near the northern end of the Barboquavari [sic] range, twenty-nine miles southwest of Tucson, and about forty miles north of the Mexican boundary line* [An 1890 map in the Arizona State Library Archives shows Bolles

Table 2. Climatological information for select masked bobwhite collection locales compared with locations where bobwhites were observed in South Texas and Oaxaca.

	Mean monthly precipitation													Σ June-Sep	Σ # days	Σ annual				Habitat
Location	J	F	M	A	M	J	J	A	S	O	N	D	Tot	Precip. mm	<0° C	Temp °C	Alt	Lat	Long	type
Tumacacori (Tubac-Calab.)	21	15	17	6	3	10	101	92	34	18	15	30	361	237	119	18.7	996	31°34	111°03	river bottom
Anvil Ranch (Bolles Well)	20	18	18	7.6	30	7.6	64	61	36	20	13	23	317.4	169	53	19.0	2,750	31°58	111°23	bajio-sabana
7 mi NW Sasabe (Syc. Mesa)	31	25	18	7	3	6	98	94	50	14	25	58	428	248		17.5	1,094	31°29	111°13	bajio-sabana
Nacozari (18 mi. n Cumpas)	35	25	27.4	13	6	30	147	90	59	37	17	56	541.8	326		18.9	1,100	30°23	109°41	river bottom
Bacoachi	7	19	13	5	3	19	132	112	34	24	16	29	436	297		17.6	1,050	33°30	109°58	river bottom
Rancho Carrizo	16	7	8	2	t	7	96	121	43	14	8	21	344	267		22.9	732	30°03	115°15	bajio-sabana
Moctezuma	31	15	12.5	3.4	2.4	27	152	119	61	28	5.9	27	484.1	359		21.3	609	29°48	109°41.5	sabana/river
Raymondville, TX	41	33	22	39.1	95	68	33	69	130	68	35	24	655	300	23	22.9	9	26°30	97°48	savanna
Hondo (Laguna Atascosa) TX	66	30	39	24	220	96	187	81	110	28	7.4	3.6	892.8	474	40	23.2	9	29°20.5	99°83	coastal grass
Salina Cruz, OX	9	4	3	2	63	286	135	198	300	66	24	9	1,099	919	0	28.0	13	16°16	95°20	sabana

Fig. 3. Former masked bobwhite habitat ~ 10 km south of Bolles Ranch along Brawley Wash in Altar Valley, Arizona, where Herbert Brown collected a masked bobwhite. Photograph by D. E. Brown.

> Ranch about 1.6 km west of present day Three Points]. *As the station was then comparatively new, the grass thereabouts was high, and these quail could be had for the taking; but now that stock has eaten away the grass, the birds have not, for a year or more, been seen about the place.*"
>
> "*Ten miles south of Bolle's in the Altar Valley, we came across a small covey—there were, perhaps, a dozen in all... We secured but one, a male, the rest secreting themselves in the tall sacaton grass, which at this point was between four and five feet high, and as we had no dog we did not follow them. Our next place to find them was on the mesa southeast of the Peak, where we camped to hunt for them but they were scarce*."

Brown (1885: 445) described the physiognomy of the preferred habitats for 3 species of Arizona quail emphasizing that bobwhites preferred both level mesas and open valleys:

> "*The base of the Barboquivari* [sic] *range is at intervals broken into immense canyons, which lie at right angles with the main body of the mountains, and stretch far to the plains below. For a mile or more after leaving the base proper they are filled with an almost impenetrable growth of underbrush, weeds and grass. Lower down, however, they flatten out and largely lose their canyon characteristics, but seldom sufficiently so to be the feeding ground of Colinus ridgwayi. To determine this point we worked these canyons for two consecutive days in vain, inasmuch as we failed to see or hear one, other than those on the intervening mesas. Arizona quail-Lophortyx gambeli on the other hand, seem partial to a rough country, where such country is possible with them. In the canyons they swarmed by thousands. In this respect I think them peculiar. On our way out we found them plentiful in the rough passes of the Tucson Mountains, but on the plains beyond and in Altar Valley they disappeared and gave place to the scaled or blue quail* (*Callipepla squamata*). *These were likewise plentiful, but they too disappeared almost with the first rise in the mesa*.
>
> *In the canyons, twenty miles above here, we as elsewhere stated, again met with the Gambels, but we found none of the scaled quail until we again returned to the valley. Between the feeding grounds of these two birds I never saw a line*

Fig. 4. Mesa southeast of Baboquivari Peak and northeast of old Sycamore Ranch thought to be the approximate site of the last masked bobwhite collected in Altar Valley. This photograph, taken in August 2011, shows a semi-desert grassland savanna at 1,060 m elevation, which is thought to be at the upper elevation range for this race of bobwhite. Photograph by D. E. Brown.

> *more clearly drawn. In this respect they differ from the ridgwayi, which were found both in the valley and on the mesa.*"

In a letter dated 9 February 1886 Brown wrote Allen (1886a:288) that the collectors whom he had sent out especially for these birds reported to him the locations as:

> "*. . .having found but one small flock in a tramp of four days, and out of it they succeeded in getting the five* [sent to Allen]. *This was in the Altar Valley.*"

In a later letter on 24 April 1886, Brown stated the quail he had sent Allen (1886a: 288) were " *taken at least eighteen miles north of the Sonora line* [3.2 km north of Brown Canyon]... *Thirty-three or thirty-five miles is the farthest north of the line that I have ever known this quail*" [9.6 km south of Bolles Ranch or ~ 53 km north of the border]; (Fig. 3).

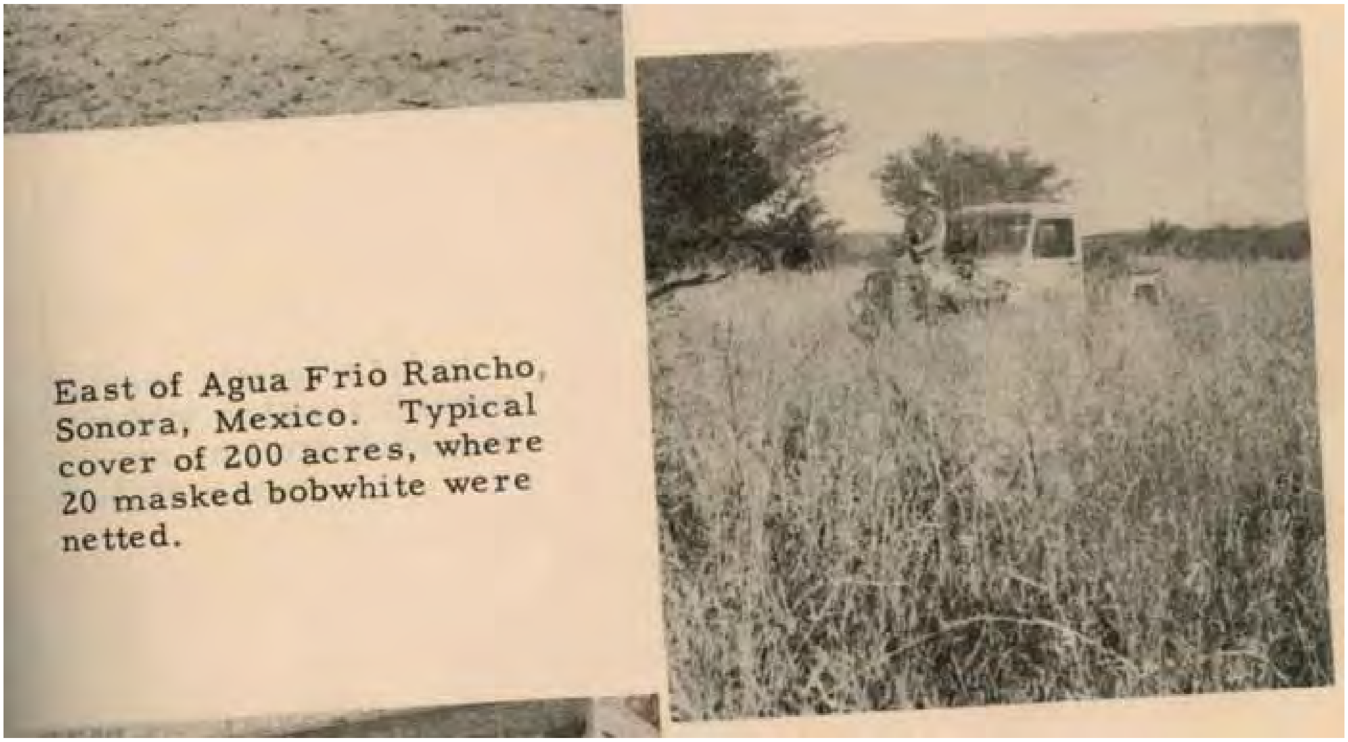
The birds were decidedly scarce by fall 1886, and in December 1886, Herbert Brown (1900: 32) received his last bobwhite from the Altar Valley area (UA 3953):

> "*to my surprise, high up on the eastern slope of the Baboquivari Mountains. Heretofore I had never known them to range higher than the foothills.*"

Specimen data indicate this bird was taken on a mesa northeast of Sycamore Ranch in Brown Canyon (no relation) at an elevation of ~ 1,060 m (3,480 ft.). This location at the lower edge of semidesert grassland appears atypical as befits the occurrence of a remnant individual no longer finding its preferred areas suitable (Fig. 4). Brown's descriptions indicate most bobwhites in Altar Valley were in the level plains and mesas at the lower, more subtropic elevations $<$1,000 m.

Collections from Santa Cruz Valley, Arizona

Not all of the bobwhites collected in Arizona came from Altar Valley. Nor was the bird taken on 14 December 1886, the last bobwhite taken in Arizona. Brown's specimen records show at least two bobwhites (UA 3954 and UA 3955) collected "*near Tubac 70 miles south of Tucson*" on 10 October 1888 (T. R. Huels, personal communication). These birds, which were almost certainly sent to Brown by someone else, would have been taken in the Santa Cruz River Valley at an altitude of ~ 984 m at the upper elevation limits of the Sonoran Desert.



East of Agua Frio Rancho, Sonora, Mexico. Typical cover of 200 acres, where 20 masked bobwhite were netted.

Fig. 5. Photograph by L. L. Lawson of a pasture where he and J. Stokley Ligon trapped 25 masked bobwhite in 1950. Note the tall grasses and dense herbaceous cover.

More birds were collected nearly a decade later in the Santa Cruz Valley. On 22 November 1896, Brown was "*pleasantly surprised*" to receive 4 of 6 birds killed by George Atkinson from a covey of ~ 20 that "*were feeding in a field near Calabasas*" (T. R. Huels, personal communication). This location proved viable for at least 1 more year when Brown added 3 more bobwhite from Calabasas to his collection including UA 3958 and 3959 on 29 December 1897. These birds, the last to be collected in the U.S., were taken in a retired farm field, and had what were probably the seeds of *Amaranthus palmeri* in their crops (T. R. Huels, personal communication). This river bottom location, at 1,058 m elevation, while within the range of tropic-subtropic vegetation, represents, along with the bird on Sycamore Mesa southeast of Baboquivari Peak, the highest collection locales.

Later reports by Brown (1900, 1904: 213) summed up his opinion why the masked bobwhite disappeared:

> "*The causes leading to the extermination of the Arizona Masked Bob-white* (*Colinus ridgwayi*) *are due to overstocking of the country with cattle, supplemented by several rainless years. This combination practically stripped the country bare of vegetation. Of their range the Colinus occupied only certain restricted portions, and when their food and shelter had been trodden out of existence by thousands of hunger-dying stock, there was nothing left for poor little Bob-white to do but go out with them. As the conditions in Sonora were similar to those in Arizona, birds and cattle suffered in common.*
>
> *The Arizona Bob-white would have thriven well in the agricultural country, in brushy fence corners, tangled thickets and weed covered fields, but such things were not to be had in their habitat. Unless a few can still be found on the upper Santa Cruz we can, in truth, bid them a final good-bye*."

It appears that masked bobwhite habitat in Arizona consisted of grassland, grass-forb pastures, and farm fields. Brown's explanation for the demise of the birds would be repeated dozens of times in the years to come by collectors and ornithologists in both Arizona and Sonora (e.g., Breninger 1904, Sheffler 1931, Lawson 1951, Ligon 1952, Tomlinson 1972a).

Habitats in Sonora, Mexico

Those who collected masked bobwhite in Sonora reiterated the relationships with grasses, grass-forb-pastures, and farm fields. For example, Frank Stephens (1885), who collected the type specimen, emphasized the bird's association with grass and grassland, both where he had seen birds in Arizona and where he collected his specimen 28.8 km southwest of the custom house at Sasabe at an elevation of ~ 850 m (Brewster 1885). Previous to entering Sonora, Stephens (1885: 227) mentions awakening to the calls of "bob-white" on 30–31 August in a camp in "the best grass we saw on the route". That morning he attempted to collect a bobwhite in the "open prairie," and spent a day just north of Sasabe

Fig. 6. Rancho Carrizo's *llanos* as they appeared in 1966 and described by Tomlinson (1972b). Photograph by D. E. Brown taken in 1968.

in good grass searching for bobwhites but failed to find any—the area he described being close to 1,220 m.

That farm fields could provide a favorite haunt for masked bobwhite was shown by Lt. H. C. Benson a year later when he collected a series of masked bobwhite and elegant quail (*Callipepla douglasi* = *elegans*) ~ 30 km north of Cumpas where he found masked bobwhite "fairly abundant," but that "*they only frequented cultivated fields, where wheat and barley had been raised*." (Brown 2010:21). The following year, 1887, Benson returned with J. C. Cahoon to the same site (~ 850 m asl) and to fields in the vicinity of Bacoachi, Sonora (1,050 m asl), where Cahoon told Brewster (1887:160) that they found both elegant quail and masked bobwhite "*abundant (several large coveys were seen and eight specimens shot in one day), haunting patches of weeds in gardens and barren 'sand wastes.' where they fed on the seeds of a plant called 'red-root*'"(*Amaranthus palmeri*; Kearney and Peebles 1960).

Masked bobwhites were subsequently collected near San Marcial, Suaqui Grande, Moctezuma, and other tropic-subtropic locations in south-central Sonora (Fig.1). R. T. Moore (1932:74): collected 8 males and 8 females at Rancho Carrizo southwest of Noria on the Southern Pacific de Mexico railroad where he found the birds "scarce" during the nesting season on 31 July in "*luxuriant growth along the washes (arroyos) affording cover for protection and nesting, feeding on insects lady bugs, small white grubs, grasshoppers and buds of pigweed*" [Amaranthus palmeri].

Moore (1932: 74) took 2 females from a covey of 8 near Tecoripa (Noria) "*an extensive rolling area bounded on the south by the Sierra de BacaTete (Yaqui country); on the north by a low broken mountain range... The sides and gentle slopes at the foot of the mountains are covered with brush—largely mesquite. The rolling area is covered with grass (at least six species) with brush, mesquite, catclaw, etc., along the washes. The height of the grass varies from knee to shoulder high, the latter height being predominant*."

J. T. Wright, who also collected masked bobwhite at Rancho Noria de Pesqueira in 1931, told Tomlinson (1972a: 298) that "*the country at that time consisted of wide, grass-covered valleys with certain grasses reaching over the heads of the native white-tailed deer*." Bobwhites were then moderately plentiful but disappeared due to grazing.

Van Rossem (1931, 1945: 72), the foremost authority on the birds of Sonora, stated the masked bobwhite was

Fig. 7. Habitat of *Colinus virginianus coylocos* near the village of Montecillo Santa Cruz, Oaxaca. Note the savanna-like aspect of the vegetation with grasses and tropical deciduous trees, such as *Crescentia alata*. Two coveys of bobwhite were seen and photographed at this site in February 2011. Photograph by R. D. Babb.

Fig. 8. Texas bobwhite savanna on Sal del Rey National Wildlife Refuge near Raymondville, Texas—October aspect. Three coveys of bobwhites were seen in the vicinity. The dominant understory grass is buffelgrass; the trees are Texas honey mesquite. Photograph by D. E. Brown.

Fig. 9. Former masked bobwhite habitat across the Santa Cruz River from the Tubac, Arizona graveyard in June 2011—Elevation 983 m; July aspect. One suspects that bobwhite would survive in this area today if wild birds were introduced here. Photograph by D. E. Brown.

"*resident of grass plains, river valleys and foothills in the lower Sonoran zone*."

Ligon (1942, 1952:48), who had located and captured several populations, said: "*this quail is definitely a dweller of deep-grass-weed habitat, a type of cover incompatible with heavy use by livestock*." Ligon (1952: 48) stated that in 1937, "*after a careful investigation of the Tecoripa section . . . two small coveys of the quail were located and netted*." But it was not until he talked to a ranchman at San Marcial that he was told to go to the "Llanos" (flat, grassy plains) to look for bobwhite. As Ligon (1952: 48) noted, "*this lead proved to be profitable as the birds were quite numerous over a limited area that was still in practically primitive state. More than a hundred were obtained*."

Ligon (1952: 48) also explained how the rapid decline of the birds in the Agua Caliente Valley came about: "*Although the birds were present in considerable numbers on the* "*Llanos*" *segment of the wide Yaqui Valley . . . their doom was already foreshadowed by the upsurge in the cattle business which was resulting in the development of ranches where previously the land had been practically unused. This quail is definitely a dweller of a deep grass-weed habitat, a type of cover incompatible with heavy use by livestock. Subsequent visits sustained our most extreme fears-the face of the land had deteriorated into a state of desolation*."

Lawson (1951:4) agreed that the Bobwhite quail was doomed to extinction in Mexico; "*especially so if the drought and over-grazing continues. The* "*spreadouts*" *and* "*bottoms*" *with deep grass and weeds where the masked bobwhite were formerly found are rapidly disappearing* [Fig. 5]. *To be certain that this bird isn't extirpated, a section or two of land within its historical range should be set aside and fenced against grazing by live stock*."

Phillips et al. (1964: 28) described masked bobwhite as inhabiting "*tall grass-mesquite plains*," and Gallizioli et al (1967:571) noted that "*early references and recent observations in Sonora indicate that dense stands of perennial grasses are an important component of masked bobwhite habitat*."

More recently, Tomlinson (1972a: 300) described a western, arid fasciation of the masked bobwhite's habitat on Rancho El Carrizo south of Benjamin Hill as "*former mesquite-grassland range at an elevation of approximately 2,400 feet. The habitat is a Sonoran plains type which consists mainly of annual grasses and forbs with woody shrubs and trees in and surrounding the water drainages. The grassy* 'llanos' *have been steadily invaded*

Fig. 10. Calabasas—this site at an elevation of 1,058 m is where the last masked bobwhites were collected in Arizona in 1897. It is June and the Mexican elder-berries (*Sambucus mexicanus*) are flowering at this historic location, which was recently burned and will soon be converted to an industrial park. Photograph by D. E. Brown.

by woody species because of overgrazing by livestock and a lack of fire."

Tomlinson's (1972a, b; 2006) evaluations, which, while pertaining to the western edge of the bird's range, then being re-constituted by brush-clearing, are the only detailed descriptions of the vegetation present when wild masked bobwhite were still present. Hence, his observations of the grasses present are particularly valuable even though Rancho Carrizo lacked the taller grasses found in more mesic areas farther east and south (Fig. 6).

Brown and Ellis (1977: 4), based on their own and Tomlinson's testimony, observed that "*masked bobwhite use the more open grasslands during the summer and early fall for nesting cover. Weedy plants and numerous legumes are important sources of food. During the winter, bobwhite coveys may use tangled thickets for screening or dense patches of coarse weeds and grasses for resting and protection*."

Garza-Salazar et al. (1992) termed the habitats where they found five populations of masked bobwhite, "*Sonoran Savanna Grassland*" based on a definition proposed by Brown (1982: 471).

EVALUATION OF HISTORIC HABITATS

We interpreted descriptions and photographs of historic masked bobwhite habitat to consist of grassy *llanos* (plains) and weedy *bajios* (lowland depressions) interspersed with copses of woody trees and scrub in a savanna or bottomland setting populated by annual and perennial grasses and forbs from 50 to 100 cm tall. Annual precipitation ranged from 300–350 to 500 mm with mean summer precipitation usually > 200 mm with mean annual temperatures > 18 °C. Environments were subtropical to tropical with elevations ranging from ~ 240 m northeast of Guaymas, Sonora to 1,060 m in southern Arizona. All historic localities in Arizona and Sonora were deficient in precipitation when compared to analogous tropical bobwhite habitats near Salina Cruz, Oaxaca, and South Texas (Table 2; Figs 7, 8).

A large percentage of the birds in both Arizona and Sonora were collected in farmlands along watercourses where rank grasses and forbs grew in pastures adjacent to farm plots and dense riparian vegetation. Examples include birds collected in Arizona in the Santa Cruz Valley (Figs. 9, 10), and in Sonora, 29 km north of Cumpas (Fig. 11), the vicinity of Bacoachi (Fig. 12), and

Fig. 11. Former masked bobwhite habitat 25.6 km north of Cumpas, Sonora, where Lt. H. C. Benson and J. C. Cahoon collected both masked bobwhite and elegant quail. The fallow fields at an elevation of 850 m had residual stalks of both barley and maize while grasses and forbs, especially *Amaranthus palmeri*, grow rank along the edges, which are bordered by velvet mesquites (*Prosopis velutina*).

near the town of Moctezuma. Here, numerous pastures with dense *Amaranthus* (1.2 to 1.8 m tall) occur adjacent to grassy fields and wooded riversides. We can only speculate that pasturing of livestock in these areas during droughts, possibly combined with subsistence trapping of quail, led to the disappearance of masked bobwhite from these areas.

An investigation of other collection locales showed the species also occurred in savannas where both suitable escape cover and food plants were present. In addition to Rancho Carrizo, such areas once occurred in Altar Valley, Arizona; south of San Marcial; and on the volcanic mesa between Moctezuma and Tepache, Sonora (Fig. 2). Most valley sites such as those in the vicinity of Mazatán have been severely impacted by water development and appear heavily grazed, but a few areas still support open savanna type vegetation. Most of these sites occur in the Valle del Agua Caliente where suitable conditions may still be found.

Nearly all of the early collectors emphasized the importance of grasses with tall grass-forb pastures and savannas being prominently mentioned. Grasses in or near former bobwhite habitat were mostly tropic-subtropic annuals such as *Bouteloua rothrockii* and *Aristida* spp. mixed in, or supplanted by *Cathsectum erectum*, *Sporobolus cryptandrus, S. wrightii, Muhlenbergia porteri*, *Trichachne californica*, and other bunchgrasses. The actual composition of these rapidly disappearing grasslands has yet to be documented.

Do potentially suitable habitats remain? The sole remaining habitats ‘restored’ for masked bobwhites are within Buenos Aires National Wildlife Refuge (BANWR) in southern Arizona, and on or near Rancho Carrizo south of Benjamin Hill, Sonora, Mexico, where the last known wild population was centered (Kuvlesky et al. 2000, Hernández et al. 2006, Tomlinson 2006). Perennial grasses are abundant on BANWR, but we fear most of the refuge is too high in elevation and marginal masked bobwhite habitat (Russell 1984). This interpretation is based on the paucity of collected specimens in Arizona above 1,060 m and the early disappearance of the subspecies from Altar Valley in the 1880s—coincident with arrival of large numbers of livestock but prior to the great droughts of the 1890s (Turner et al. 2003).

We also consider the Rancho Carrizo area near Benjamin Hill as marginal habitat as this area is relatively dry, at the lower edge of the precipitation required for bobwhite and at the western periphery of the bird’s historic range (Table 2, Fig.1). Masked bobwhites likely survived here not because it was prime habitat, but more

Fig. 12. Small fields, waste corners, and copses of riparian vegetation just upstream from the village of Bacoachi, Sonora, in October 2011. Despite this area's appearance of being ideal quail habitat neither bobwhite nor Gambel's quail were heard or seen leaving one to wonder if local trapping might be impacting their numbers.

due to delayed water development and year-long livestock use (Tomlinson 1972a). Rancho Carrizo and its environs, while the site of some of the most recent observations, were not necessarily the best habitat, but one of the last habitats to be exploited. Unfortunately, this site in Mexico may no longer support masked bobwhite, as no birds have been detected on surveys here within at least the last 3+ years (Dan Cohan, personal communication). The prime habitats for masked bobwhites occurred near the center of the bird's distribution, where most birds were collected (Fig. 1, Appendix).

The primary cause of the masked bobwhite's demise has been habitat loss, i.e., the destruction of subtropical grasslands in Arizona after 1890, and in Sonora after 1945 through livestock grazing and fire suppression (Brown and Glinski 2009). Grazing became ubiquitous after 1900 in Arizona and after 1950 in Sonora, a practice facilitated by wells and water development (Lawson 1951, Ligon 1952, Gallizioli et al. 1967, Tomlinson 1972b). Livestock removed the fine fuels, which resulted in cessation of fires and invasion of woody plants (Swetnam and Baisan 1996). Bahre (1985) noted that large fires within the confines of what is now the Sonoran Desert virtually ceased in the 1880s in Arizona. Tomlinson (1972a) and Brown (1989) described a similar situation in Sonora beginning in the 1930s. By 1975, even those few relict grasslands remaining, such as those at Rancho Carrizo south of Benjamin Hill, were either being grazed or converted to buffelgrass (*Pennisetum ciliare*) pasture (Lanham 1994) with the result that all masked bobwhite habitats in Sonora are managed for livestock instead of bobwhites (Hernández et al. 2006).

Masked bobwhite habitats may yet persist, however, even though the birds may not. Sites such as the former collecting locales north of Cumpas and around Bacoachi appear to have recovered to the point that masked bobwhite could survive there if wild birds were available. These localities and numerous small farms within former masked bobwhite habitat in Sonora again appear suitable for bobwhite. There are even sites (e.g., Tubac and Calabazas) in the Santa Cruz Valley in Arizona, based on the descriptions of historical habitats, which appear suitable for the species. These latter two sites are endangered, however, as one is adjacent to residential developments and the other is about to become an industrial park.

Probably the best habitats remaining for the masked bobwhite today are in the Agua Caliente Valley in and adjacent to the Yaqui Indian Reservation where both *sabana* and *bajio* habitats persist in altered form. We

Fig. 13. Former *sabana* being invaded by cholla and thornscrub on the Yaqui Indian Reservation near Agua Caliente Valley, Sonora. Although such sites appeared promising, the only quail located were elegant quail and Gambel's quail. This site appears to be a remnant savanna on sandy substrate. Photograph by Anibella Carlón Flores.

conducted 20.76 km of foot surveys covering 159 ha of the best appearing habitat in an attempt to learn if masked bobwhite might still be present on the Yaqui Reservation. Six coveys of Gambel's quail (*Callipepla gambelii*) and 4 coveys of elegant quail were located but no bobwhite. Nor did any of the gallinaceous bird feathers obtained from verdin and cactus wren nests belong to masked bobwhite on comparing them with museum specimens of *C. elegans*. Evidence that we and the dogs were searching optimum habitats was indicated by incidental sightings of rufous-winged (*Peucaea carpalis*) and five-striped (*Amphispiza quinquestriata*) sparrows. One white-tailed hawk (*Buteo albicaudatus*) was observed over the Agua Caliente Valley on the first aerial reconnaissance.

The habitats we visited are believed to represent the best masked bobwhite sites remaining in Sonora, but these areas were heavily influenced by past livestock use. The remaining savanna habitats no longer have tall, ungrazed grasses, and are much reduced in extent due to the encroachment of cacti and woody plants. This disclimax thornscrub, while heavily invaded by cholla (*Opuntia fulgida* var. *mammilata*) continues to contain pastures heavily populated by Rothrock grama and other fine-stemmed grasses (Fig. 13). The bottomlands, composed of *Amaranthus palmeri*, *Sesbania herbacea*, *Acacia angustissima*, and other tall-weeds have also been heavily used by horses and cattle, and lack an understory of fine-stemmed grasses and forbs (Fig. 14).

We believe the possibility is increasingly remote that masked bobwhite may still exist in Sonora. All of the areas visited have been heavily impacted by livestock at some time and no one we interviewed has definitive knowledge of the presence of *las mascaritas*. Our evaluations of the Yaqui lands and other potential habitats were not exhaustive and should be followed by call-count surveys and other investigations during the breeding season. If a population of birds can be located, management actions such as reductions in grazing intensity and controlled burns could promote the bird's recovery. Until such time as a population of birds is located, this race of bobwhite must be considered functionally extinct.

ACKNOWLEDGMENTS

We are indebted to Seymour Levy, Steve Gallizioli, Roy Tomlinson, and Steve Dobrott for sharing their insights about masked bobwhite in Sonora, and to Steve Dobrott, Dan Cohan, and Mary Hunnicut for their recent

Fig. 14. A weedy *bajio* in the Valle del Agua Caliente—another former favorite masked bobwhite haunt now heavily impacted by livestock, in this case horses. Photograph by Anibella Carlón Flores. Not finding any sign of bobwhite here despite a 4-hr search was a major disappointment.

observations of behaviors of captive and released birds in Arizona. Also helpful to our investigations were Alberto Burquez and Ray Turner, who provided photographs of historic habitat in Sonora and accompanied us on 2 visits to former masked bobwhite locales. Eduardo Gomez accompanied us in the field for 2 days where he was of great assistance in locating and evaluating habitats north of the Las Arenas area. Consuelo Lorenzo Monterrubio graciously facilitated our visit to her study area in Oaxaca. Josh Smith hosted us in South Texas and showed us many excellent sites at Laguna Atascosa National Wildlife Refuge, and Mitch Sternberg showed us bobwhite habitat at Sal Del Rey and other area refuges.

Sandra Landham was not only essential for our aerial surveys, her extensive Mexican contacts enabled Biologos Cristina Melendez and Eberado Sánchez Camero to arrange our visit to the Yaqui country with Anibella Carlón Flores. Sra Flores not only provided the necessary permits and escorts, but also took excellent photographs of our activities on the Yaqui Reservation where we were accompanied at all times by Yaqui Vigilancias: Jefe Guadalupe (Pluma Blanca) Ochoa, José Juan Terán Enríquez, Isábel Lugo (Chabelo) Molina, Eladio Molina (Layo) Azvala, and Marco Antonio Carlén Flores.

LITERATURE CITED

Aldrich, J. W., and A. J. Duvall. 1955. Distribution of American gallinaceous game birds. Circular 34. USDI, Fish and Wildlife Service, Washington, D.C., USA.

Allen, J. A. 1886a. The masked bobwhite (*Colinus ridgwayi*) in Arizona. Auk 3: 275–276.

Allen, J. A. 1886b. The masked bobwhite (*Colinus ridgwayi*) of Arizona and its allies. Bulletin of the American Museum Natural History 7:273–291.

Allen, J. A. 1886c. The type specimen of *Colinus ridgwayi*. Auk 3:483.

Allen, J. A. 1887. A further note on *Colinus ridgwayi*. Auk 4:74–75.

Bahre, C. J. 1985. Wildfire in southeastern Arizona between 1859 and 1890. Desert Plants 7:190–194.

Breninger, G. F. 1904. Passing of masked bobwhite. The Warbler 2:70.

Brewster, W. 1885. Additional notes on some birds collected in Arizona and the adjoining Province of Sonora, Mexico. Auk 2:196–200.

Brewster, W. 1887. Further notes on the masked bob-white (*Colinus ridgwayi*). Auk 4: 159–160.

Brown, D., ed. 1982. Biotic communities of the Southwest: US and Mexico. Desert Plants 4:1–4.

Brown, D. E. 1989. Arizona game birds. University of Arizona Press, Tucson, USA.

Brown, D. 2010. Arizona's cavalryman/ornithologist: Lt. H. C. Benson. Arizona Wildlife Views, January-February: 18–22.

Brown, D. E., and D. H. Ellis. 1977. Masked bobwhite recovery plan. USDI, Fish and Wildlife Service, Office of Endangered Species, Region 2. Albuquerque, New Mexico, USA (Revised in 1984 by S. W. Hoffman).

Brown, D. E., and R. L. Glinski. 2009. The status of the white-tailed hawk in Arizona and Sonora, Mexico. Journal of the Arizona-Nevada Academy of Science 4 (1): 8–15.

Brown, H. 1884. *Ortyx virginianus* in Arizona. Forest and Stream 22 (6):104.

Brown, H. 1885. Arizona quail notes. Forest and Stream 25 (28):445.

Brown, H. 1887. Arizona bird notes. Forest and Stream 27:462.

Brown, H. 1900. Conditions governing bird life in Arizona. Auk 17:31–34.

Brown, H. 1904. Masked bobwhite (*Colinus ridgwayi*). Auk 21:209–213.

Gallizioli, S., S. Levy, and J. Levy. 1967. Can the masked bobwhite be saved from extinction? Audubon Field Notes 2:571–575.

Garza-Salazar, S., J. Dobrott, and J. M. E. Haro-Rodríquez. 1992. Observaciones recientes de laspoblaciones de cordoniz mascarita (*Colinus virginianus ridgwayi*) en Sonora, Mexico. Ecologia 2 (1):1–6.

Grinnell, G. B. 1884. A quail new to the United States fauna. Forest and Stream12:243.

Hastings, J. R., and R. R. Humphrey, eds. 1969. Climatological data and statistics for Sonora and northern Sinaloa. University of Arizona, Institute of Atmospheric Physics Technical Reports on the Meteorology and Climatology of Arid Regions Number 19:1–96.

Hernández, F., W. P. Kuvlesky Jr., R. W. DeYoung, L. A. Brennan, and S. A. Gall. 2006. Recovery of rare species: case study of the masked bobwhite. Journal of Wildlife Management 70:617–631.

Huels, T. R. 2009. Unpublished field notes and specimen records attributed to Herbert Brown. University of Arizona Bird Collection, Tucson, USA.

Kearney, T. H., and R. H. Peebles. 1960. Arizona flora (with supplement). University of California Press, Berkeley and Los Angeles, USA.

Koss, W. J., J. R. Owenby, P. M. Steurer, and D. S. Ezell. 1968. Freeze/frost data. Climatography of the U. S. Number 20, Supplement 1. National Climatic Data Center, Asheville, North Carolina, USA.

Kuvlesky Jr., W. P., S. A. Gall, S. J. Dobrott, S. Tolley, F. S. Guthery, S. A. Destefano, N. King, K. R. Nolte, N. J. Silvy, J. C. Lewis, G. Gee, G. Camou-Luders, and R. Engel-Wilson. 2000. The status of endangered masked bobwhite recovery in the United States and Mexico. Proceedings of the National Quail Symposium 4:42–57.

Lanham, S. 1994. The last conquistador: buffelgrass in the Sonoran Desert. Environmental Flying Service video in possession of author, Tucson, Arizona, USA.

Lawson, L. L. 1951. Masked bobwhite and Benson quail trapping in Sonora, Mexico. Federal Aid Job Completion Report, P-R Project W-40-R-2, Work Plan 2, Job 2. Arizona Game and Fish Department, Phoenix, USA.

Ligon, J. S. 1942. Masked bobwhite quail in southern Arizona and notes on efforts at restoration. U. S. Fish and Wildlife Service, Memorandum of 3 July. Arizona Game and Fish Department files, Phoenix, USA.

Ligon, J. S. 1952. The vanishing masked bobwhite. Condor 54:48–50.

Moore, R. T. 1932. Notes on the masked bobwhite (*Colinus virginianus ridgwayi*). Typewritten manuscript with four maps. Moore Laboratory of Zoology, Occidental College, Los Angeles, California, USA.

Neff, J. A. 1947. Notes on some birds of Sonora, Mexico. Condor 32–33.

Phillips, A. R., J. T. Marshall, and S. H. Levy. 1964. Birds of Arizona. University of Arizona Press, Tucson, USA.

Ridgway, R. R. 1884. *Ortyx virginianus* not in Arizona. Forest and Stream 22 (7):124.

Ridgway, R. R. 1886. Arizona quail. Forest and Stream 25 (25):484.

Russell, S. M. 1984. What price preservation? Pages 18–21 *in* M. R. Stromberg, T. Johnson, and S. W. Hoffman, eds. Masked bobwhite biology and conservation; proceedings of a symposium. Arizona Game and Fish Department, Tucson, USA.

Sheffler, W. J. 1931. Aviculturists seek the masked bobwhite (*Colinus ridgwayi*) in Mexico. Aviculture Magazine 3:135–138, 154–167.

Stephens, F. P. 1885. Notes of an ornithological trip in Arizona and Sonora. Auk 2:225–231.

Swetnam, T. W., and C. H. Baisan. 1996. Historical fire regime patterns in the southwestern United States since AD 1700. Pages 11–32 *in* C. D. Allen, ed. Fire effects in southwestern forests. Proceedings of the Second La Mesa Fire Symposium, 29–31 March 1994, Los Alamos, New Mexico. USDA, Forest Service General Technical Report RM-GTR-218. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.

Tomlinson, R. E. 1972a. Current status of the endangered masked bobwhite quail. Transactions of the North American Wildlife and Natural Resources Conference 37:294–311.

Tomlinson, R. E. 1972b. Review of literature on the endangered masked bobwhite. Resource Publication 108. USDI, Fish and Wildlife Service, Washington, D.C., USA.

Tomlinson, R. E. 2006. Habitat needs of the masked bobwhite in Mexico and a few thoughts about the current masked bobwhite situation in Sonora, Mexico, Summer 2006. Typewritten Reports. USDI, Fish and Wildlife Service, Albuquerque, New Mexico, USA.

Turner, R. M., R. H. Webb, J. E. Bowers, and J. R. Hastings. 2003. The changing mile revisited: an ecological study of vegetation change with time in the lower mile of an arid and semiarid region. University of Arizona Press, Tucson, USA.

U. S. Department of Commerce. 2010. National Climatic Data Center, NOAA summaries. Asheville, North Carolina, USA. www.wrcc.dri.edu

Van Rossem, A. J. 1931. Report on a collection of land birds from Sonora, Mexico. Transactions of the San Diego Society of Natural History 6:237–304.

Van Rossem, A. J. 1945. A distributional survey of the birds of Sonora, Mexico. Occasional Papers of the Louisiana Museum of Zoology 21:1–379.

APPENDIX

Institution	Accession	Country	State	Location	Sex	Collector	Date	Notes
AMNH	751313	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	22 Dec 1905	
AMNH	751314	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	21 Nov 1905	
AMNH	751312	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	15 Dec 1905	
AMNH	751316	Mexico	Sonora	Bacuachi	Female	Cahoon, John C.	08 Feb 1887	
AMNH	751315	Mexico	Sonora	Bacuachi	Male	Cahoon, John C.	08 Feb 1887	
AMNH	751311	USA	Arizona	Baboquivari Mts.	Female		08 Feb 1886	Submitted by Herbert Brown
AMNH	751310	USA	Arizona	Baboquivari Mts.	Male		08 Feb 1886	Submitted by Herbert Brown
ANSP	70761	Mexico	Sonora	Las Arenas	Male			
BMNH	1888.10.102795	USA	Arizona	Baboquivari Mtns.	Male	Brown, H.		Accessioned 10 Oct 1888
BMNH	1888.10.102796	USA	Arizona	Baboquivari Mtns.		Brown, H.		Accessioned 10 Oct 1888
BMNH	1913.5.16.3	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	09 Dec 1905	
BMNH	1913.5.16.4	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	18 Dec 1905	
BMNH	1913.5.16.1	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	05 Jan 1906	
BMNH	1913.5.16.2	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	09 Dec 1905	
BMNH	1939.12.9.290	Mexico	Sonora	La Bonancita	Male	Brown Jr., W. W.	15 Dec 1905	
BMNH	1887.1.27.82.	Mexico	Sonora	28 km southwest of Sasabe	Male	Stephens, F.	11 Aug 1884	Donated by G. R. Morcom
CAS	33888	Mexico	Sonora	Rancho Carrizo	Female	Wright, J. T.	04 Jul 1931	Site near Tecoripa
CAS	33889	Mexico	Sonora	Rancho Carrizo	Male	Wright, J. T.	10 Jul 1931	Site near Tecoripa
CMNH	27860	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	03 Dec 1905	
CMNH	26873	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	28 Nov 1905	
CMNH	130169	Mexico	Sonora	Moreno (72 km SE Agua Caliente)	Female	Twomey, A. C.	06 May 1945	
CMNH	130168	Mexico	Sonora	Moreno (72 km SE Agua Caliente)	Male	Twomey, A. C.	06 May 1945	
DMNH	18536	Mexico	Sonora	San Marcial, 22.4 km SE	Female	Gorsuch, D.	19 Dec 1937	
DMNH	18537	Mexico	Sonora	San Marcial, 22.4 km SE	Female	Gorsuch, D.	19 Dec 1937	
DMNH	18538	Mexico	Sonora	San Marcial, 22.4 km SE	Male	Gorsuch, D.	17 Dec 1937	
DMNH	18539	Mexico	Sonora	San Marcial, 22.4 km SE	Male	Gorsuch, D.	19 Dec 1937	
DMNH	54824	Mexico	Sonora	Hermosillo, 96 km E; Feliciano Ranch	Male	Ligon, J. S.	08 Dec 1950	
DMNH	23799	Mexico	Sonora	Tecoripa, slightly N	Female	Wooddell, Les	01 Mar 1937	
DMNH	23797	Mexico	Sonora	Tecoripa, slightly N	Male	Wooddell, Les	01 Mar 1937	
FMNH	36739	USA	Arizona		Female			Cory Collection 6434
FMNH	77247	Mexico	Sonora		Female		06 Jul 1931	
FMNH	77362	Mexico	Sonora	Tecoripa	Female		02 Nov 1931	
FMNH	127890	Mexico	Sonora	Rancho Carrizo	Female		10 Jul 1931	L. B. Bishop Collection 48097
FMNH	409092	Mexico	Sonora	Rancho Carrizo, 24 km SW of Noria	Female		04 Jul 1931	
FMNH	409094	Mexico	Sonora	Rancho Carrizo, 24 km SW of Noria	Female		06 Jul 1931	
FMNH	409095	Mexico	Sonora	Rancho Carrizo, 24 km SW of Noria	Female		09 Jul 1931	
FMNH	409098	Mexico	Sonora	Rancho Carrizo, 24 km SW of Noria	Female		10 Jul 1931	
FMNH	409099	Mexico	Sonora	Rancho Carrizo, 24 km SW of Noria	Female		11 Jul 1931	
FMNH	409293	Mexico	Sonora	Tecoripa	Female		20 Oct 1931	
FMNH	409295	Mexico	Sonora	Tecoripa	Female		20 Oct 1931	
FMNH	409297	Mexico	Sonora	Tecoripa	Female		29 Oct 1931	
FMNH	409301	Mexico	Sonora	Tecoripa	Female		30 Oct 1931	
FMNH	409302	Mexico	Sonora	Tecoripa	Female		30 Oct 1931	
FMNH	409303	Mexico	Sonora	Tecoripa	Female		31 Oct 1931	

APPENDIX. Continued.

Institution	Accession	Country	State	Location	Sex	Collector	Date	Notes
FMNH	409304	Mexico	Sonora	Tecoripa	Female		31 Oct 1931	
FMNH	409305	Mexico	Sonora	Tecoripa	Female		31 Oct 1931	
FMNH	77246	Mexico	Sonora		Male		03 Jul 1931	
FMNH	77361	Mexico	Sonora	Tecoripa	Male		03 Nov 1931	
FMNH	127891	Mexico	Sonora	Rancho Carrizo	Male		05 Jul 1931	L. B. Bishop Collection 48096
FMNH	409091	Mexico	Sonora	Rancho Carrizo, 24 km SW of Noria	Male		04 Jul 1931	
FMNH	409093	Mexico	Sonora	Rancho Carrizo, 24 km SW of Noria	Male		05 Jul 1931	
FMNH	409096	Mexico	Sonora	Rancho Carrizo, 24 km SW of Noria	Male		09 Jul 1931	
FMNH	409097	Mexico	Sonora	Rancho Carrizo, 24 km SW of Noria	Male		10 Jul 1931	
FMNH	409100	Mexico	Sonora	Rancho Carrizo, 24 km SW of Noria	Male		12 Jul 1931	
FMNH	409292	Mexico	Sonora	Tecoripa	Male		20 Oct 1931	
FMNH	409294	Mexico	Sonora	Tecoripa	Male		20 Oct 1931	
FMNH	409296	Mexico	Sonora	Tecoripa	Male		29 Oct 1931	
FMNH	409298	Mexico	Sonora	Tecoripa	Male		29 Oct 1931	
FMNH	409299	Mexico	Sonora	Tecoripa	Male		30 Oct 1931	
FMNH	409300	Mexico	Sonora	Tecoripa	Male		30 Oct 1931	
FMNH	409306	Mexico	Sonora	Tecoripa	Male		31 Oct 1931	
FMNH	409307	Mexico	Sonora	Tecoripa	Male		02 Nov 1931	
FMNH	409308	Mexico	Sonora	Tecoripa	Male		02 Nov 1931	
FMNH	409309	Mexico	Sonora	Tecoripa	Male		03 Nov 1931	
FMNH	409310	Mexico	Sonora	Tecoripa	Male		03 Nov 1931	
KU	73199	Mexico	Sonora			Cink, C. L.		Skeleton
KU	73026	Mexico	Sonora		Male	Smart, G.		"caught in Sonora, Mexico and died in September 1971"
KU	73020	Mexico	Sonora			Smart, G.		"raised in captivity" died in 1972
LSU	86248	Mexico	Sonora	200 km south of Nogales, Highway 15 west side	Male	Levy, S. H.	27 Jun 1964	SHL No. 1046; testes enlarged
MCZ	253944	Mexico	Sonora		Male	Benson, H. C.		Smithsonian Institution # 110512|
MCZ	114746	Mexico	Sonora	La Bonancita	Male	Brown Jr., W. W.	15 Dec 1905	
MCZ	114744	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	27 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	114745	Mexico	Sonora	Las Capomas	Female	Brown Jr., W. W.	12 Oct 1905	John E. Thayer Expedition of 1904–5
MCZ	302412	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	29 Nov 1905	John E. Thayer Expedition of 1904–5
MCZ	302413	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	27 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302414	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	07 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302415	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	11 Jan 1906	John E. Thayer Expedition of 1904–5
MCZ	302416	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	20 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302417	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	12 Jan 1906	John E. Thayer Expedition of 1904–5
MCZ	302418	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	12 Jan 1906	John E. Thayer Expedition of 1904–5
MCZ	302419	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	05 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302420	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W	04 Jan 1906	John E. Thayer Expedition of 1904–5
MCZ	302437	Mexico	Sonora	Las Arenas	Female	Brown, Jr., W. W.	09 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302438	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	31 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302439	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	03 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302440	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	01 Dec 1905	John E. Thayer Expedition of 1904–5

APPENDIX. Continued.

Institution	Accession	Country	State	Location	Sex	Collector	Date	Notes
MCZ	302442	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	15 Jan 1906	John E. Thayer Expedition of 1904–5
MCZ	302444	Mexico	Sonora	San Marcial	Female	Brown Jr., W. W.	08 Nov 1905	John E. Thayer Expedition of 1904–5
MCZ	302445	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	06 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302447	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	30 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302449	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	18 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302466	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	23 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302467	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	10 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302468	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	21 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302469	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	19 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302470	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	24 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302471	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	03 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302472	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	18 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302473	Mexico	Sonora	San Marcial	Female	Brown, Jr., W. W.	12 Nov 1905	John E. Thayer Expedition of 1904–5
MCZ	302474	Mexico	Sonora	San Marcial	Female	Brown Jr., W. W.	10 Nov 1905	John E. Thayer Expedition of 1904–5
MCZ	302475	Mexico	Sonora	La Bonancita	Female	Brown Jr., W. W.	17 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302477	Mexico	Sonora	San Marcial	Female	Brown Jr., W. W.	11 Nov 1905	John E. Thayer Expedition of 1904–5
MCZ	302478	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	09 Jan 1906	John E. Thayer Expedition of 1904–5
MCZ	302480	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	20 Nov 1905	John E. Thayer Expedition of 1904–5
MCZ	302481	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	28 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302482	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	24 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302483	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	15 Nov 1905	John E. Thayer Expedition of 1904–5
MCZ	302484	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	26 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302486	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	05 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302487	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	15 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302488	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	23 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302500	Mexico	Sonora	Las Capomas	Female	Brown Jr., W. W.	05 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302518	Mexico	Sonora	Las Arenas	Female	Brown Jr., W. W.	15 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	114742	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	21 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	114743	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	25 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302423	Mexico	Sonora	San Marcial	Male	Brown Jr., W. W.	10 Nov 1905	John E. Thayer Expedition of 1904–5
MCZ	302424	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	10 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302425	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	01 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302426	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	01 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302427	Mexico	Sonora	Near Batamote	Male	Brown Jr., W. W.	02 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302428	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	17 Jan 1906	John E. Thayer Expedition of 1904–5
MCZ	302429	Mexico	Sonora	La Bonacita	Male	Brown Jr., W. W	18 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302432	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	01 Jan 1906	John E. Thayer Expedition of 1904–5
MCZ	302433	Mexico	Sonora	Las Arenas	Male	Brown, Jr., W. W.	10 Jan 1906	John E. Thayer Expedition of 1904–5
MCZ	302434	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	02 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302435	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	01 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302454	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	11 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302455	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	27 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302456	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	28 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302458	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	31 Dec 1905	John E. Thayer Expedition of 1904–5

APPENDIX. Continued.

Institution	Accession	Country	State	Location	Sex	Collector	Date	Notes
MCZ	302459	Mexico	Sonora	Las Arenas	Male	Brown, Jr., W. W.	16 Nov 1905	John E. Thayer Expedition of 1904–5
MCZ	302460	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	02 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302462	Mexico	Sonora	La Bonancita	Male	Brown Jr., W. W.	01 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302463	Mexico	Sonora	La Bonancita	Male	Brown Jr., W. W.	18 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302464	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	04 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302465	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	04 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302489	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	31 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302490	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	18 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302491	Mexico	Sonora	La Bonacita	Male	Brown Jr., W. W.	16 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302492	Mexico	Sonora	San Marcial	Male	Brown Jr., W. W.	07 Nov 1905	John E. Thayer Expedition of 1904–5
MCZ	302493	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	14 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302494	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	03 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302495	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	18 Jan 1905	John E. Thayer Expedition of 1904–5
MCZ	302496	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	30 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302497	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	10 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302498	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	10 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302499	Mexico	Sonora	La Bonancita	Male	Brown Jr., W. W.	25 Nov 1905	John E. Thayer Expedition of 1904–5
MCZ	302501	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	22 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302502	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	13 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302503	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	19 Nov 1905	John E. Thayer Expedition of 1904–5
MCZ	302504	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	11 Jan 1906	John E. Thayer Expedition of 1904–5
MCZ	302506	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	20 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302507	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	20 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302508	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	30 Nov 1906	John E. Thayer Expedition of 1904–5
MCZ	302509	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	12 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302510	Mexico	Sonora	San Marcial	Male	Brown Jr., W. W.	15 Nov 1905	John E. Thayer Expedition of 1904–5
MCZ	302511	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	05 Jan 1906	John E. Thayer Expedition of 1904–5
MCZ	302514	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	02 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302515	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	11 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302516	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	10 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302519	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	01 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302520	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	15 Jan 1906	John E. Thayer Expedition of 1904–5
MCZ	302521	Mexico	Sonora	Las Cinches	Male	Brown Jr., W. W.	24 Nov 1905	John E. Thayer Expedition of 1904–5
MCZ	302522	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	18 Jan 1906	John E. Thayer Expedition of 1904–5
MCZ	302523	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	27 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302524	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	08 Nov 1905	John E. Thayer Expedition of 1904–5
MCZ	302525	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	17 Jan 1906	John E. Thayer Expedition of 1904–5
MCZ	302526	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	17 Jan 1906	John E. Thayer Expedition of 1904–5
MCZ	302527	Mexico	Sonora	Las Capomas	Male	Brown Jr., W. W.	03 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302529	Mexico	Sonora	San Marcial	Male	Brown Jr., W. W.	08 Nov 1905	John E. Thayer Expedition of 1904–5
MCZ	302530	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	26 Dec 1905	John E. Thayer Expedition of 1904–5
MCZ	302531	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	06 Jan 1906	John E. Thayer Expedition of 1904–5
MCZ	302532	Mexico	Sonora	Las Arenas	Male	Brown Jr., W. W.	30 Dec 1905	John E. Thayer Expedition of 1904–5

APPENDIX. Continued.

Institution	Accession	Country	State	Location	Sex	Collector	Date	Notes
MCZ	225000	Mexico	Sonora	Cumpas	Female	Cahoon, J. C.	02 Feb 1887	
MCZ	224995	Mexico	Sonora	Cumpas	Male	Cahoon, J. C.	02 Feb 1887	
MCZ	224996	Mexico	Sonora	Cumpas	Male	Cahoon, J. C.	02 Feb 1887	
MCZ	224997	Mexico	Sonora	Cumpas	Male	Cahoon, J. C.	02 Feb 1887	
MCZ	224998	Mexico	Sonora	Cumpas	Male	Cahoon, J. C.	02 Feb 1887	
MCZ	224999	Mexico	Sonora	Cumpas	Male	Cahoon, J. C.	02 Feb 1887	
MCZ	225001	Mexico	Sonora	Bacuachi	Male	Cahoon, J. C.	02 Feb 1887	
MCZ	225003	Mexico	Sonora	Bacuachi	Male	Cahoon, J. C.	02 Feb 1887	
MCZ	47971	Mexico	Sonora		Female	Toussaint, F. J.		
MCZ	331764	Mexico	Sonora		Female		01 Nov 1906	
MCZ	331765	Mexico	Sonora		Male		01 Nov 1906	
MLZ	6620	Mexico	Sonora	Mina Noche Buena	Female	Wright, J. T.	24 Mar 1932	
MLZ	6637	Mexico	Sonora	Tecoripa (Noria)	Female	Wright, J. T.	21 Oct 1931	
MLZ	6640	Mexico	Sonora	Mina Noche Buena	Female	Wright, J. T.	24 Mar 1932	
MLZ	6628	Mexico	Sonora	Tecoripa (Noria)	Male	Wright, J. T.	29 Oct 1931	
MVZ	93594	Mexico	Sonora	Tecaripa		Ligon, J. S.	25 Oct 1944	
MVZ	70414	Mexico	Sonora	Tecoripa, "Noria"		Wright, J. T.	09 Feb 1931	
MVZ	100357	Mexico	Sonora	Las Capomas			06 Dec 1905	
MVZ	100354	Mexico		No specific locality recorded			15 Sep 1937	
MVZ	93593	Mexico	Sonora	Tecaripa			24 Dec 1942	
MVZ	70415	Mexico	Sonora	Tecoripa, "Noria"			09 Feb 1931	
MVZ	70417	Mexico	Sonora	Tecoripa, "Noria"			09 Feb 1931	
MVZ	100356	Mexico		No specific locality recorded			01 Sep 1937	
MVZ	100358	Mexico	Sonora	Las Arenas			07 Jan 1906	
MVZ	100355	Mexico		No specific locality recorded			01 Sep 1937	
MVZ	70416	Mexico	Sonora	Tecoripa, "Noria"			09 Feb 1931	
SDNHM	20374	Mexico	Sonora	144 km S Nogales	Female	Green, J. E.	01 Mar 1929	
SDNHM	20375	Mexico	Sonora	144 km S Nogales	Male	Green, J. E.	01 Mar 1929	
SDNHM	12324	Mexico	Sonora	Near Magdalena	Male	Woodell, D. R.	15 Mar 1928	
SDNHM	12326	Mexico	Sonora	Near Magdalena	Female	Woodell, D. R.	15 Mar 1928	
SDNHM	12325	Mexico	Sonora	Near Magdalena	Male	Woodell, D. R.	15 Mar 1928	
UA	UAz-003953	USA	Arizona	Mesa East of Baboquivari Mtns.	Female	Brown, H.	14 Dec 1886	
UA	UAz-003954	USA	Arizona	Near Tubac	Female	Brown, H.	10 Oct 1888	
UA	UAz-003957	USA	Arizona	Calabasas	Female	Brown, H.	22 Nov 1896	
UA	UAz-003956	USA	Arizona	Calabasas	Male	Brown, H.	22 Nov 1896	
UA	UAz-003958	USA	Arizona	Calabasas	Male	Brown, H.	29 Dec 1897	
UA	UAz-003959	USA	Arizona	Calabasas	Male	Brown, H.	29 Dec 1897	
UA	UAz-003955	USA	Arizona	Tubac	Male	Brown, H.	10 Oct 1888	
UA	UAz-001137	Mexico	Sonora	9.6 km West Tecoripa	Female	Gorsuch, D.	20 Oct 1931	
UA	UAz-001138	Mexico	Sonora	9.6 km West Tecoripa	Male	Gorsuch, D.	20 Oct 1931	
UA	UAz-001156	Mexico	Sonora	9.6 km West Tecoripa	Female	Gorsuch, D.	20 Oct 1931	
UA	UAz-001136	Mexico	Sonora	9.6 km West Tecoripa	Female	Gorsuch, D.	20 Oct 1931	
UA	UAz-001157	Mexico	Sonora	9.6 km West Tecoripa	Male	Gorsuch, D.	21 Oct 1931	

APPENDIX. Continued.

Institution	Accession	Country	State	Location	Sex	Collector	Date	Notes
UA	UAz-001158	Mexico	Sonora	9.6 km West Tecoripa	Male	Gorsuch, D.	21 Oct 1931	
UA	UAz-016725	USA	Arizona	Pozo Nuevo, BANWR	Female	Shifflet, W.	09 Jun 1993	
UA	UAz-001350	USA	Arizona	Tucson		Vorhies, C. T.	15 Jan 1936	
UCLA	30729	Mexico	Sonora	Nogales, 144 km South	Female	Green, J. E.	00 Mar 1929	Donated by G Bancroft
UCLA	27876	Mexico	Sonora	Magdelena	Male	Green, J. E.	00 Aug 1929	Died in captivity. Caught 12 Jul 1928 by G. Bancroft
UMMZ	121779	Mexico	Sonora	Magdalena	Male	Bancroft Jr., Griffing	07 Mar 1929	
UMMZ	121780	Mexico	Sonora	Magdalena	Male	Bancroft Jr., Griffing	07 Mar 1929	
UMMZ	122858	Mexico	Sonora	Magdalena	Female	Bancrof Jr., Griffing	07 Mar 2029	
UMMZ	121776	Mexico	Sonora	Nogales, 144 km South	Male	Green, J Elton	00 Mar 1929	
UMMZ	121777	Mexico	Sonora	Nogales, 144 km South	Male	Green, J Elton	00 Feb 1929	
UMMZ	121778	Mexico	Sonora	Nogales, 144 km South	Male	Green, J Elton	00 Feb 1929	
UMMZ	69959	Mexico	Sonora	Tecoripa	Female	Wright, John T	29 Oct 1931	
UMMZ	69958	Mexico	Sonora	Tecoripa	Male	Wright, John T	00 Oct 1931	
UNM	934	Mexico	Sonora	Hermosilla; 96 km E	Female	Ligon, J. S.	30 Nov 1946	Masked bobwhite; died 02 Jul 1952
UNM	935	Mexico	Sonora	Hermosilla; 128 km SE, near Aqua Fria	Female	Ligon, J. S.	30 Nov 1946	Masked bobwhite; died 06 Jul 1952
UNM	936	Mexico	Sonora	San Marcial; 22.4 km SE	Female	Ligon, J. S.	18 Dec 1933	Masked bobwhite
UNM	944	Mexico	Sonora	San Marcial; 22.4 km SE	Male	Ligon, J. S.	18 Dec 1933	Masked bobwhite
UNM	948	Mexico	Sonora	Hermosilla; 128 km SE, near Aqua Fria	Male	Ligon, J. S.	13 Dec 1946	Masked Bobwhite; died 16 Jun 1952
UNM	14665	Mexico	Sonora	No specific locality recorded.	Female		16 Aug 1961	
USNM	110514	Mexico	Sonora	Mexico	Female	Benson, H. C.		
USNM	110515	Mexico	Sonora	Mexico	Female	Benson, H. C.		
USNM	110934	Mexico	Sonora	Mexico	Female	Benson, H. C.		
USNM	110932			Locality Unknown	Female	Benson, H. C.		
USNM	110507	Mexico	Sonora	Mexico	Male	Benson, H. C.		
USNM	110509	Mexico	Sonora	Mexico	Male	Benson, H. C.		
USNM	110510	Mexico	Sonora	Mexico	Male	Benson, H. C.	31 Jan 1887	
USNM	110511	Mexico	Sonora	Mexico	Male	Benson, H. C.		
USNM	110929	Mexico	Sonora	Mexico	Male	Benson, H. C.	3 Feb 1887	
USNM	110930	Mexico	Sonora	Mexico	Male	Benson, H. C.	28 Jan 1887	
USNM	110928			Locality Unknown	Male	Benson, H. C.		
USNM	329855	Mexico	Sonora	Mexico	Female	Brown Jr., W. W.	27 Dec 1905	
USNM	329854	Mexico	Sonora	Mexico	Male	Brown Jr., W. W.	2 Dec 1905	
YPM	6549	Mexico	Sonora		Female	Conover, H. B.	11 Jul 1931	
YPM	6548	Mexico	Sonora		Male	Conover, H. B.	10 Jul 1931	
YPM	70184	Mexico	Sonora	Hermosillo	Female	Ligon, J. S.	04 Nov 1951	

Institution	
AMNH	American Museum of Natural History, New York
ANSP	Academy of Natural Sciences, Philadelphia
BMNH	British Museum of Natural History, London
CAS	California Academy of Sciences

APPENDIX. Continued.

Institution	Accession	Country	State	Location	Sex	Collector	Date	Notes
CMNH	Carnegie Museum of Natural History							
DMNH	Delaware Valley Museum of Natural History							
FMNH	Field Museum of Natural History, Chicago							
KU	University of Kansas							
LAM	Los Angeles County Museum of Natural History							
LSU	Louisiana State University							
MCZ	Museum of Comparative Zoology, Harvard							
MLZ	Moore Laboratory of Zoology, Occidental College, Los Angeles							
SDNHM	San Diego Natural History Museum							
UA	University of Arizona, Tucson							
UCLA	University of California at Los Angeles							
UMMZ	University of Michigan Museum of Zoology							
UNM	University of New Mexico							
USNM	U. S. National Museum, Smithsonian Institution, Washington, D.C.							
YPM	Yale Peabody Museum							

MASKED BOBWHITE: STATUS OF AN ENDANGERED SUBSPECIES

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ABSTRACT

The masked bobwhite (*Colinus virginianus ridgwayi*), first collected in 1884, soon disappeared and was considered extinct by 1950. Its rediscovery in 1964 precipitated an aggressive effort to restore the masked bobwhite within its range in both the United States and Mexico. The masked bobwhite, despite this effort, has continued to decline with a precipitous decrease in numbers in the last decade. Surveys conducted in 2009 and 2010 resulted in no detections; for all practical purposes the masked bobwhite is now extinct in the wild. Fortunately, a captive population continues to exist and with proper management can produce sufficient masked bobwhite to restore the wild population. The Masked Bobwhite Recovery Program has been developed and is implementing a bi-national recovery strategy with Mexican cooperators that includes: (1) construction of a new captive breeding facility on Buenos Aires National Wildlife Refuge and adoption of new husbandry and rearing protocols; (2) contracting with the San Diego Zoo Conservation Research Center to manage and operate the new facility; (3) construction of a new facility at Africam Safari, Puebla, Mexico; (4) creation of a reintroduction program in Sonora, Mexico; (5) development of a Mexican landowner outreach program; and (6) a habitat improvement and predator management program on Buenos Aires National Wildlife Refuge.

Citation: Mesta, R. 2012. Masked bobwhite: status of an endangered species. Proceedings of the National Quail Symposium 7:329.

Key words: Arizona, *Colinus virginianus ridgwayi,* masked bobwhite, Mexico, recovery strategies

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REVIEW OF THE MASKED BOBWHITE RECOVERY EFFORT

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ABSTRACT

The masked bobwhite (*Colinus virginianus ridgwayi*) was discovered near Sasabe, Sonora in August 1884. Excessive grazing coupled with prolonged drought during the 1890s caused habitat degradation and extirpation of the species in the United States by 1912. The decline of the bobwhite population in Mexico happened later due to similar circumstances. Livestock grazing was not pervasive until the 1940s-1950s in Sonora. The subspecies was thought to be extinct in Mexico by 1960. However, in 1964 a population was discovered between Benjamin Hill and Hermosillo, Sonora. The Buenos Aires National Wildlife Refuge (NWR) was established in 1985 for the re-establishment of the masked bobwhite. There have been four components to the masked bobwhite program on the refuge: captive rearing, release of birds into suitable habitat, habitat manipulation, and cooperation with Mexico. Approximately 98% of the masked bobwhites in the world are in captivity at Buenos Aires NWR and are housed in an indoor facility in Arivaca, Arizona. At that facility the birds are paired by a geneticist and up to 120 pairs are bred each year. Eggs are incubated and hatched and birds are either retained as future breeding stock or prepared for release. Overall, $>$ 31,000 captive-reared bobwhites have been released in the Altar Valley, Arizona with $>$ 21,000 being released on the refuge alone. To date they have not been self- sustaining. Preparation for release includes placing birds in flight pens where they remain for several weeks to a few months to gain exposure to native foods, experience raptor pressure, and become strong flyers. A soft release is normally used with birds being introduced to their new habitat from the confines of a small release pen on-site. A new parent-reared technique is currently being tried and promises improvement in wildness of released birds. This technique limits exposure of bobwhite family groups to humans and other bobwhite family groups until day of release. The bobwhite, as an edge species, needs early successional vegetation, diversity of grasses and forbs, and leguminous shrubs capable of providing cover and winter food. Traditionally, prescribed fire has been the primary management tool used by refuge personnel to improve habitat for masked bobwhites. Currently, Buenos Aires NWR is applying soil aeration treatments in uplands, revegetating with native plant species, constructing brush piles, and converting velvet mesquite (*Prosopis velutina*) woodlands to grasslands to promote bobwhite habitat. Work with Mexico has involved cooperation with the Mexican government, private ranchers, Mexican biologists, and zoological facilities to implement bobwhite surveys, establish conservation easements, and enhance habitat.

Citation: Cohan, D., M. Hunnicutt, S. Gall, and J. Gutierrez. 2012. Review of masked bobwhite recovery effort. Proceedings of the National Quail Symposium 7:330.

Key words: Buenos Aires National Wildlife Refuge, captive rearing and release, *Colinus virginianus ridgwayi,* endangered, masked bobwhite

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GAMBEL'S QUAIL: A HISTORY OF RESEARCH AND MANAGEMENT AT THE ORACLE JUNCTION STUDY AREA IN ARIZONA

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ABSTRACT

We analyzed current as well as historic call-count survey data, check station harvest data, season length, winter precipitation, and daily bag limits in the Oracle Junction Study Area, Arizona to verify factors affecting annual Gambel's quail (*Callipepla gambelii*) harvest. Gambel's quail is the only one of the 9 species of wild gallinaceous game birds found in Arizona endemic to the Sonoran Desert. Oracle Junction has been of particular importance to quail hunters, scientists, researchers, and managers because it has a consistent history of call-count surveys, open hunting seasons, hunter-harvest check stations, and available precipitation data. Oracle Junction provides a valuable 'experiment' of Gambel quail harvest management in Arizona.

Citation: O'Dell, J. C., and S. C. McAdams. 2012. Gambels' quail: a history of research and management at the Oracle Junction study area in Arizona. Proceedings of the National Quail Symposium 7:331.

Key words: Arizona, call-count surveys, *Callipepla gambelii*, Gambel's quail, Oracle Junction

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CAUSES AND CONSEQUENCES OF MIXED-SPECIES COVEYS OF CALIFORNIA AND GAMBEL'S QUAIL AND THEIR HYBRIDS

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ABSTRACT

California (*Callipepla californica*) and Gambel's quail (*C. gambelii*) hybridize where their distributions overlap. Outside of the area of overlap, pairs are known to form within the covey. I observed two mixed-species coveys within the hybrid zone and examined if pairing occurred within the coveys. I compared hatching success and survival of chicks between resident within-covey pairs to immigrant pairs. Isolated coveys could become inbred, given that choice of conspecific mate may be constrained by small population size. I measured relatedness between quail for each individual that paired within the covey, and tested whether it was more or less related to its mate than to other individuals in the covey of the same and opposite sex. The hybrid zone between *C. californica and C. gambelii* appears to be bounded by ecological forces rather than genetic incompatibility. Clinal allelic and plumage trait differences between *C. californica* and *C. gambelii* map closely into the ecotonal area of hybridization. Quail species have fluid geographical distributions but extraordinarily plastic mating systems. This dynamic may help explain why quail have a higher incidence of hybridization than most other bird species.

Citation: Gee, J. 2012. Causes and consequences of mixed-species coveys of California and Gambel's quail and their hybrids. Proceedings of the National Quail Symposium 7:332.

Key words: California quail, *Callipepla californica*, *C. gambelii*, Gambel's quail, hybridization

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USE OF PORTABLE INFRARED CAMERAS TO FACILITATE DETECTION AND CAPTURE SUCCESS OF MONTEZUMA QUAIL

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ABSTRACT

Survey and trapping methods for Montezuma quail (*Cyrtonyx montezumae*) require means not traditionally used for other quail species (e.g., northern bobwhite, *Colinus virginianus*). Trapping Montezuma quail is most effective using pointing dogs at night when coveys can be located and captured by net during roosting. However, reduced visibility at night, cryptic coloration of plumage, and behavioral adaptive stillness reduce detection rates and increase accidental flushing of birds while searching for roost locations. Forward-looking infrared (FLIR) cameras have been used to aid in detection of cryptic wildlife, including avifauna roosting sites. We conducted 25 survey and night-trapping sessions for Montezuma quail in southeast Arizona using a combination of trained pointing dogs and a portable FLIR camera. Detection of coveys on a roost was less successful when ambient climate conditions were freezing (below –3.88 °C), when residual heat signatures from surrounding soils and rocks were greater than 18.33 °C, or when density of grass cover exceeded 40% and the distance to covey was > 2.5 m. The small thermal signatures of quail were often obstructed by vegetative cover or confused with residual thermal signatures reflected by inanimate objects (e.g., rocks, bare ground). Successful detection of coveys combining the use of dogs and FLIR before trapping was 6.06%. Trapping success and detection of coveys with FLIR was improved when used with radiotelemetry and coveys which included radio-marked individuals. Proper tuning of FLIR camera sensitivity to a limited thermal bandwidth, or isotherm range, may effectively narrow covey locations approximated by a pointing dog. The FLIR camera was of limited benefit when actively trapping coveys with dogs and a team of 2–3 people, but may be beneficial for non-invasive monitoring and estimating covey size of marked birds on roosts in landscapes with reduced vegetative cover.

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Key words: Appleton-Whittell Research Ranch, Arizona, Coronado National Forest, *Cyrtonyx montezumae,* FLIR, forward-looking infrared, Mearn's quail, Montezuma quail, roost, survey, trapping

INTRODUCTION

Knowledge gaps in the natural history of wild Montezuma quail populations exist due to difficulties in locating and capturing these birds using traditional methods for similar species in North America (e.g., northern bobwhite) (Leopold and McCabe 1957, Stromberg 1990, Harveson et al. 2007). Cryptic coloration and behavioral adaptive stillness permit limited study opportunities due to lack of detection without use of trained pointing dogs. Pointing dogs provide the most practical means of conducting daytime flush counts for population estimates (Brown 1975, 1976; Hernández et al. 2009) and for locating coveys at night for trapping on roosts. Night-trapping of Montezuma quail, however, is complicated by reduced visibility and accuracy in covey locations by pointing dogs. This decreases covey detection rates and increases accidental flushing of birds while trappers search for exact roost locations.

Use of night-vision and thermal-infrared cameras has facilitated detection of wildlife at night, especially large ungulates and carnivores (Boonstra et al. 1994, Garner et al. 1995, Focardi et al. 2001). These technologies have increasingly been applied in avifauna surveys, particularly for more cryptic and elusive species (Boonstra et al. 1995, Mills et al. 2011), and to aid in detection of avifauna at roosting sites (Locke et al. 2006, Tillman 2009). Use of FLIR cameras has potential to aid in narrowing the probable location of a covey, once an estimated location has been detected, by a pointing dog or triangulated via telemetry of radio-marked birds. Our objectives were to evaluate the efficacy of FLIR cameras in improving detection and capture success of wild Montezuma quail in southeast Arizona when used in combination with dogs.

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We also evaluated its potential for monitoring covey size of marked birds on a roost.

STUDY AREAS

Surveys of Montezuma quail were conducted throughout Arizona Game and Fish Department's (AZGFD) Management Unit 35 in southeastern Arizona within areas administrated by the Coronado National Forest in Santa Cruz County. Most research was concentrated near Stevens Canyon and Smith Canyon in Patagonia, Apache Tank, and Williamson Tank in the San Rafael Valley, Apache Spring, Hog Canyon, and Gardner Canyon near Sonoita, and Appleton-Whittell Research Ranch (AWRR) near Elgin. Trapping and long-term monitoring of radio-marked individuals occurred primarily in Stevens Canyon, Hog Canyon, and AWRR.

AZGFD's Comprehensive Wildlife Conservation Strategy (AZGFD 2006) notes the major vegetation types occupied by Montezuma quail in southeastern Arizona consist of: Plains and Great Basin Grasslands, Subalpine Grasslands, Madrean Evergreen Woodland, and rarely Montane Conifer Forest. Hog Canyon (~31° 40′ N, 110° 42′ W) is dominated by Madrean Evergreen Woodland and Montane Meadow for vegetation and Caralampi gravelly sandy loam (22.2%) soils (NRCS 2012). Steven's Canyon (~31° 35′ N, 110° 45′ W) is also dominated (52.8%) by Caralampi gravelly sandy loam soils (NRCS 2012) and has similar vegetative characteristics to Hog Canyon but with a reduced overstory canopy layer; Madrean Evergreen Woodland is sparser and intermixed with Desert Scrub midstory species (i.e., *Acacia* sp.; mesquite, *Prosopis* sp.). AWRR (~31° 35′ N, 110° 30′ W) consists mainly of Plains and Great Basin Grasslands dominated by Big Sacaton (*Sporobolus wrightii*) bottomlands along Turkey Creek and Madrean Evergreen Woodlands sparsely dispersed among the sloping hills (Stromberg 1990). Dominant soils (52.5%) at AWRR consist of White House gravelly loam (NRCS 2012). Climate data from the nearest long-term weather station (#1231, Canelo 1 NW; Canelo, AZ) indicated mean temperatures of 22.6 °C in June, the hottest month, and mean temperature of 6.3 °C in January, the coldest month, from 1981 to 2010 for this region (WRCC 2012).

METHODS

Initial surveys for Montezuma quail were conducted with trained dogs along survey routes, including some previously established by AZGFD. Covey locations, identified from flush points, were georeferenced using Universal Transverse Mercator (UTM) coordinates in NAD83 datum. Potential roosting sites near flush locations were resurveyed at night during trapping and monitoring events. A Forward-looking Infrared (FLIR) ThermaCAM*t* B-20 handheld camera (FLIR Systems, North Billerica, MA, USA) was used. It is a 1.7-kg long-wave (7.5-13-μm) camera with a 24° lens that allows for a 24 × 18° field of view at a minimum focus distance of 0.3 m. Image resolution is 320 × 240 pixels and can be displayed in real-time on a 10-cm liquid crystal screen. The thermal sensitivity of the camera is 0.06 °C at 30 °C and can be adjusted by the user to show either broad-range or fine-range isotherm bandwidths in color or gray scale. The B-20 FLIR also contains focus and zoom functions that permit monitoring potential targets from distances of $>$ 20 m. Image events captured with the camera in the field can momentarily be 'frozen' on-screen, allowing the user to save an image in its current display setting to the camera's memory card. Image copies of the same event, but which display a broader or finer range of temperatures, or isotherm bandwidths, can consequently be saved if the current image event is still 'frozen' on-screen.

Montezuma quail were captured with hoop nets with the combined of use pointing dogs and FLIR camera. Traditional methods of trapping quail require trained dogs to hold point when quail are located, allowing a short interval of time for 1 or 2 researchers to approach, identify the location of, and capture a bird with a hoop-net (Brown 1975). The FLIR camera was used to narrow the potential location of quail by tracking heat signatures in close proximity to where the dog was 'pointing'. FLIR was used to scan the surrounding landscape where the dog roamed for 5–10 min before the dog went on-point, when the dog's behavior indicated it was nearing a potential roost site. We scanned an area with FLIR for shorter durations the closer a dog was thought to be to a roost, the longer the dog was on-point, and the fewer crew members were present. A 2-person field crew typically had 3–5 min to scan an area with FLIR for the roost site once a dog went on-point while closing-in from a distance of 10 m or more, but only 0.5–1.5 min once the 2-person crew was within 2–5 m. One crew member in a 3-person trap crew was dedicated to restraining the dog, allowing another member to scan potential roost sites for 0.5 to 3.0 min. Detection of birds on a possible roost was attempted from distances of 2, 5, and 10 m. FLIR pictures were taken from these distances, at a 45 ° angle to the ground target with the height, dependent on camera operator, between 1.5 and 2.0 m above ground. We recorded potential identifications and positive identifications of target animals with FLIR and evaluated density of vegetation from event images captured within the FLIR field of view. These were categorized at percent cover intervals of 0–20, 21–40, 41–60, 61–80, and 81–100. We also recorded the number of quail on a roost and temperature at the roost location when targets were positively identified at a scanned location.

Most survey, trapping, and monitoring sessions were conducted after sunset, from 1900 to 0300 hrs, when quail were expected to be on roost and when the darkness and cooler temperatures in the surrounding environment allowed for clearer contrast of thermal signatures. Trapping was discontinued from 0300 hrs until sunrise to: (1) allow dispersed coveys to reassemble overnight, thus reducing potential mortality from trapping effort, and (2) allow sufficient time to process trapped birds to release before dawn the morning following trapping. We hypothesized, when overnight snowfall was present, that the thermal signature of quail was easier to detect when

Table 1. Combinations of the number of personnel, use of dog (D), and telemetry (T) in conjunction with FLIR for trapping Montezuma quail with the outcome of sessions for each combination.

Combination used with FLIR	Number of times tested	Dog points	Possible detection instances with FLIR	Number of birds possibly detected	Number actually detected	Number of coveys flushed	Total number of birds flushed	Average (± SD) covey size	Number of birds captured
1D	1	1	0	0	0	1	6	6.0	0
1D, T	3	3	1	4	0	4	20	5.0 ± 1.4	7
1T	3	–	3	7	6	4	15	3.0 ± 1.6	7
2D	5	12	2	2	0	5	36	7.2 ± 2.7	8
2D, T	4	6	1	2	0	7	22	3.1 ± 2.3	6
2T	1	–	1	2	0	2	4	2.0 ± 0	4
3D	4	11	1	2	2	7	20	2.9 ± 0.9	6
3D, T	4	11	2	3	1	9	33	4.1 ± 3.4	8

contrasted to the colder surroundings; trapping and monitoring sessions in those conditions were conducted between 1900 and 1 hr past sunrise.

RESULTS

We conducted 25 survey and trapping sessions (Table 1) for Montezuma quail, accounting for 128 person-hrs and 75 dog-hrs, between January 2008 and July 2009. Trapping sessions with dogs averaged (± SD) 2.61 ± 1.14 hrs per session, and telemetry-only sessions averaged 2.63 ± 0.65 hrs per session. Average time scanning for targets using FLIR was 0.782 hrs per session, about 30% of the session. We counted 156 birds flushed from roosts during dog-, telemetry-, and FLIR-assisted trapping sessions but estimate the actual number to be $>$160 birds. Average covey size flushed or potentially detected with FLIR (Table 1) varied depending on the season in which trapping was conducted. We observed larger coveys (6–10 individuals) when trapping only with dogs in late fall–early winter, and smaller coveys (3–7 individuals) or pairs of birds in early spring and late summer, respectively. Nine of the total birds flushed (5.7%) were detected with FLIR. Infrared heat signatures of quail possibly and actually detected with FLIR ranged from 11.11 to 29.44 °C. Detection of coveys on a roost was less successful when ambient climate conditions were freezing (below –3.88 °C) or when residual heat signatures from surrounding soils and rocks were greater than 18.33 °C. We detected quail with FLIR from a distance of 5 and 10 m only once in a recently burned landscape. All other possible and actual detections of quail were observed 2.0–2.5 m from a roost. We occasionally flushed multiple coveys roosting within 5 m of one another but these were not detectable with FLIR when scanning within 2.5 m.

Vegetation densities ranged from 41 to 80% at most roost sites where coveys were possibly detected with FLIR. However, actual detection rate was 0% for all combinations (Table 1) when understory-grass density was $>$ 40% because obstructed line-of-sight prevented detection with FLIR. Instances of positive identifications made prior to netting of unmarked quail when using dogs were low ($n = 2$). The density of understory vegetation in both instances was $<$ 40%: the successful session at Hog Canyon had 20–40% density of understory-grass and succulent species while the understory-grass density at AWRR, in a burned landscape, was 0–20%. Actively trapping with dogs was most effective when the field crew had 1 person dedicated to trapping birds with the net, another to restrain the dog, and a third person to scan potential roost sites with FLIR (Table 2). Use of telemetry further facilitated detection and capture success (Tables 1, 2). Positive detection was 66% when FLIR was used in combination only with telemetry ($n = 4$) in areas with an understory-grass density of 0–40%.

DISCUSSION

A variety of factors including ambient climate conditions, density of grass cover, and distance to covey affected our ability to make positive detections of coveys with FLIR (Table 2). The small thermal signature of quail was often obstructed by dense vegetative grass cover, masked by snow on the ground, or confused with residual thermal signatures reflected by nearby inanimate objects (e.g., rocks, trees, bare ground). An appropriate crew size to assist in trapping made use of FLIR more feasible when trapping with dogs (Table 3). The camera was considered portable, but the weight and bulk of our particular model, ThermaCAM*t* B-20, interfered with concurrent use of the camera and net limited our reaction time to net birds on a roost. The dog on-point would also often break point to retrieve birds once an attempt was made to capture them. Preventing dog-related trap injuries and quail mortality required assistance of additional crew members for restraining the dog and operating the camera.

Additional crew members translated into more time invested in scanning an area with FLIR, thereby increasing chances of making possible and actual detections. Detection of coveys on roost required adjusting FLIR to display isotherm bandwidths that provided sufficient contrast between target animals and nearby inanimate objects. Optimal tuning of FLIR to specific isotherm bandwidths produced more accurate estimates of covey size. However, learning how to tune the FLIR camera to display optimal isotherms required a moderate learning curve and experience in a variety of field conditions. Switching isotherm display settings on

Table 2. Advantages and disadvantages of FLIR in different combinations of crew size, use of dog (D), and telemetry (T).

Combination with FLIR	Advantage	Disadvantage
1D, 2D, 3D	1. Dogs are essential for initially trapping birds and can locate unmarked birds or coveys once flushed from roosts.	1. Dog may accidentally flush birds from roost.
	2. Useful for scanning landscapes with $<$ 20% vegetative cover before actively trapping with dog.	2. Vegetative cover $>$ 40% density, especially understory grass, may obstruct line-of-sight.
	3. May be used to estimate covey size before trapping.	3. Accurate estimation of covey size with FLIR reduced with higher densities of vegetative cover.
	4. When crew size = 2, one person can restrain dog and scan with FLIR for 0.5–1.5 min and while other person handles net.	4. When crew size $<$ 2, the bulky ThermaCAM*t* B-20 model prevents simultaneous handling of large hoop net and restraining dog when birds are captured.
	5. When crew size = 3, one person can scan with FLIR for 0.5–3.0 min duration while others handle dog and net.	5. Time allowed to scan a roost is reduced more when crew size is smaller because dogs cannot be restrained simultaneously while trapping and scanning with FLIR.
	6. Isotherm settings in camera can be adjusted to separate infrared signatures of quail from residual thermal signatures of surrounding inanimate objects.	6. Residual thermal signatures of surrounding inanimate objects may mask infrared signature of quail when camera is not set to an optimal isotherm setting; optimal setting varies with ambient conditions.
		7. Freezing conditions seem to negatively impact camera imaging and snowfall masks heat signature of quail.
1DT, 2DT, 3DT,	1. Same as above, but using telemetry allows trapping crew to better approximate location of a radio-marked bird and its covey, and scan with FLIR for a longer duration before having to use the dog.	1. Same as above, but operation of telemetry equipment reduces ability to simultaneously operate other equipment when actively trapping, including scanning with FLIR, capturing birds with net, and restraining dog.
	2. Telemetry may be used to monitor covey size before trapping.	
1T, 2T	1. The location of a radio-marked bird and its covey can be approximated with telemetry and then scanned with FLIR for a longer duration than when using dogs.	1. Same as for 1D, 2D, and 3D, except for absence of using dog.
	2. Absence of dog to assist in trapping reduces chance of accidentally flushing birds from roost.	2. Absence of dog to assist in trapping extremely limits chances of capturing unmarked birds once they flushed from roost.

the ThermaCAM*t* B-20 in the field was not always instantaneous—leading to short intervals of lag time in the software that proved to be most inconvenient when actively trapping with dogs.

Detection of quail with the FLIR camera was especially problematic 2–3 hrs after sunset when the surrounding environment still reflected heat absorbed from daytime solar radiation. Trapping later in the night when cooler temperatures are present reduced the amount of residual thermal signatures reflected in the environment. However, trapping too late at night may increase risks to Montezuma quail survival when displaced from their covey at a roost. Montezuma quail survival may depend on thermal insulation, safety, or awareness provided by the covey and there are limited data in the literature that examines to what extent this species regroups once they are displaced from a roost at night.

The total number of detected targets on roost was not certain when positive identifications were made, but the FLIR was useful, when set to an optimal isotherm, for narrowing the possible roost location within the field of view. False-positives detected with FLIR outnumbered positive identifications and attempts to trap at locations misinterpreted with FLIR as targets on a roost at times lead to accidental flushes. However, roosts could generally be found within 0.25–3.5 m of where a dog went on-point and coveys could be approached within 2.5 m with FLIR before they were accidentally flushed.

The FLIR camera in our study was most beneficial for increasing chances of detecting and trapping a covey when assisted by triangulation via telemetry. There was less risk to accidentally flushing birds from a roost than when assisted with a dog when telemetry was used to locate radio-marked birds and, consequently, the unmarked birds in their covey. It was then possible for a single researcher to conduct trapping and monitoring with the aid of telemetry and FLIR once at least 1 bird in the covey was radiomarked. The FLIR was particularly useful with telemetry for non-intrusive monitoring of covey size on a roost when the surrounding vegetation did not considerably insulate or mask a target's small heat signature or obstruct its line-of-sight. We were able to non-obtrusively monitor a breeding pair of Montezuma quail roosting in a burned landscape and observe movements of radio-marked individuals released on roosts the same night. We also considered using FLIR to monitor mated pair behavior and hatch success during the nesting season. Use of FLIR technology that is lightweight and mountable as head-gear would improve

Table 3. Suggested use of FLIR for trapping and monitoring Montezuma quail.

Before trapping	1. Scan the landscape and note the range of residual thermal infrared signatures from inanimate objects, especially soil and rocks; this will vary with ambient conditions (i.e., temperature). 2. Adjust FLIR to isotherm settings that do not closely resemble the infrared signature of a live animal; use the dog or another captive bird (e.g., pigeon) for reference.
Trapping and monitoring	1. Avoid using FLIR when actively trapping with dogs and crew size is $<$ 2 people. 2. Use a crew of 3 people and a dog to initially locate coveys throughout the landscape. Have 1 person operate the FLIR, 1 person handle and restrain the dog, and 1 person to handle net. If crew size is 2, the dog handler also operates the FLIR. 3. The FLIR operator scans the surrounding landscape when the dog's behavior indicates it is close to a roost location; pictures of a location should be taken from 10, 5, and 2.5 m as soon as the dog goes on-point. 4. Quickly adjust the FLIR to an isotherm setting that best distinguishes the infrared signature of the dog and the surrounding rocks, then scan the ground where the dog is on-point for possible detections of quail. 5. The FLIR operator evaluates images in-field to narrow probable location of a covey and dog handler restrains the dog with a leash. If crew size is 2, FLIR operator reduces maximum scan time to 1.5 min and restrains dog. If the person with the net cannot visually detect the covey, an attempt is made to drop the net on the probable roost location suggested by FLIR operator. When capture attempt is successful, the FLIR operator leaves the camera and assists in handling and capture of quail. 6. Radiomark at least 1 bird from each covey. Release marked birds and trap remaining unmarked members of each covey in consequent attempts using radiotelemetry and FLIR but without use of dogs.

its integration in future studies for trapping and monitoring Montezuma quail.

MANAGEMENT IMPLICATIONS

Management of Montezuma quail has historically relied on use of dogs to conduct daytime flush counts to assess covey sizes, habitat use, and estimate population abundance. However, use of radiotelemetry in conjunction with flush counts, produces more accurate estimates. Trapping wild Montezuma quail remains a challenging endeavor that can be overcome using a combination of field methods described in our study. Tools such as night vision or FLIR complement use of dogs when used in trapping. Trapping efficiency is improved as is detection of quail, and more individuals can be radiomarked and monitored in the wild. Improved implementation of radiotelemetry reduces or eliminates the need to conduct daytime flush counts for evaluating covey sizes, habitat use, and estimating population abundance. There is increased potential for non-intrusive monitoring of Montezuma quail at night using FLIR. Knowledge of covey dynamics, covey size, nesting and roosting behavior at night remain poorly documented for this species. Further application of less expensive and more portable FLIR-like technologies, when used with radiotelemetry, can help to resolve these knowledge gaps and contribute to the conservation of this species.

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LITERATURE CITED

Arizona Game and Fish Department (AZGFD). 2006. Comprehensive wildlife conservation strategy: 2005–2015. Phoenix, USA.

Boonstra, R., C. J. Krebs, S. Boutin, and J. M. Eadie. 1994. Finding mammals using far-infrared thermal imaging. Journal of Mammalogy 75:1063–1068.

Boonstra, R., J. M. Eadie, C. J. Krebs, and S. Boutin. 1995. Limitations of far infrared thermal imaging in locating birds. Journal of Field Ornithology 66:192–198.

Brown, R. L. 1975. Mearns' quail capture method. Final Report. Federal Aid Project W-78-R-15, Work Plan 1, Job 2. Arizona Game and Fish Department, Phoenix, USA.

Brown, R. L. 1976. Mearns' quail census technique. Federal Aid in Wildlife Restoration Project W-78-R-15, Work Plan 1, Job 1. Arizona Game and Fish Department, Phoenix, USA.

Focardi, S., A. M. DeMarinis, M. Rizzotto, and A. Pucci. 2001. Comparative evaluation of thermal infrared imaging and spotlighting to survey wildlife. Wildlife Society Bulletin 29:133–139.

Garner, D. L., H. B. Underwood, and W. F. Porter. 1995. Use of modern infrared thermography for wildlife population survey. Environmental Management 19:233–238.

Harveson, L. A., T. H. Allen, F. Hernández, D. A. Holdermann, J. M. Mueller, and M. S. Whitley. 2007. Montezuma quail ecology and life history. Pages 23–29 in L. A. Brennan, ed. Texas quails. Texas A&M University, College Station, USA.

Hernández, F., E. Garza, L. A. Harveson, and C. E. Brewer. 2009. Fate and survival of radio-marked Montezuma quail. Gamebird 2006: Quail VI and Perdix XII: 426–431.

Leopold, A. S., and R. A. McCabe. 1957. Natural history of the Montezuma quail in Mexico. Condor 59:3–26.

Locke, S. L., R. R. Lopez, M. J. Peterson, N. J. Silvy, and T. W. Schwertner. 2006. Evaluation of portable infrared cameras for detecting Rio Grande Wild Turkeys. Wildlife Society Bulletin 34:839–844.

Mills, W. E., D. E, Harrigal, S. F. Owen, W. F. Dukes, D. A. Barrineau, and E. P. Wigger. 2011. Capturing clapper rails using thermal imaging technology. Journal of Wildlife Management 75:1218–1221.

Natural Resources Conservation Service (NRCS). Web soil survey. USDA, Natural Resources Conservation Service, Washington, D.C., USA. websoilsurvey.nrcs.usda.gov/

Stromberg, M. R. 1990. Habitat, movements and roost characteristics of Montezuma quail in southeastern Arizona. Condor 45: 57–65.

Tillman, J. E. 2009. Fear of the dark: night-time roosting and anti-predation behaviour in the grey partridge (*Perdix perdix* L.). Behaviour 146: 999–1023.

Western Regional Climate Center. 2004. Arizona climate summaries. Western Regional Climate Center, National Oceanic and Atmospheric Administration, Reno, Nevada, USA. www.wrcc.dri.edu

POST-FIRE SUCCESSION AND MONTEZUMA QUAIL IN A SEMI-DESERT GRASSLAND OF SOUTHEAST ARIZONA

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ABSTRACT

A 1,011.7-ha wildfire occurred in southeast Arizona in May 2009 and provided an opportunity to evaluate pre- and post-fire abundance of and habitat use by Montezuma quail (*Cyrtonyx montezumae*) through use of flush surveys and radiotelemetry. We evaluated movements of radio-marked quail from 2 months prior to the burn to 12 months post-burn. We observed strong site fidelity with coveys persisting in small patches of unburned areas and micro-topography, despite extensive reduction in cover in the surrounding landscape. We documented 46.7% reduction in abundance using flush counts within the first 2 weeks post-fire, and 66.7% reduction within 3 weeks post-fire. We also documented roosting within a fire-affected area and successful nesting by Montezuma quail a few months following a wildfire.

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Key words: Appleton-Whittell Research Ranch, *Cyrtonyx montezumae*, dog survey, flush count, Montezuma quail, National Audubon Society, nesting, post-fire succession, radiotelemetry, roosting, wildfire

INTRODUCTION

Opportunities for studying the impact of natural wildfires on vertebrate populations are limited in wildlife field studies. There is substantial scientific literature on how wildlife populations respond to post-fire conditions but few studies evaluate those impacts for species that have been marked and radiotracked before a fire occurs (Bond et al. 2002, Cram et al. 2002, Craig et al. 2010, Martin et al. 2010). Experiments using controlled burns have evaluated how some North American quail respond to fire (Renwald et al. 1978, Wilson and Crawford 1979, Ransom and Schulz 2007), but more can be inferred from how wild vertebrate populations respond to fire when an event is stochastic with the range and intensity of a fire varying naturally rather than manipulated experimentally. This is especially true for protected species, species of conservation concern (e.g., masked bobwhite [*Colinus virginianus ridgwayi*]), or those with limited distribution or narrow habitat requirements (e.g., Montezuma quail) where controlled burns may not be permitted or feasible.

Fire is a naturally occurring phenomenon in the semi-desert grasslands of Arizona and has potential to severely reduce available ground cover upon which scaled quail (*Callipepla squamata*) and Montezuma quail are dependent for use in escaping danger, providing shelter and insulation from ambient climate conditions, and nesting (Leopold and McCabe 1957, Brown 1979, Guthery et al. 2001, Bristow and Ockenfels 2004, White et al. 2011). The effect of fire at the population level for Montezuma quail is a priority management issue for conservation of this species (Arizona Partners in Flight 1999). Past difficulties in adapting adequate methods for studying wild Montezuma quail (Hernández et al. 2009) have led to knowledge gaps about this species. Some observations on the relative abundance of Montezuma quail post-fire have been reported (Bock and Bock 1978), but methods used lacked accuracy compared to flush-counts conducted with

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dogs or by tracking marked quail with radiotelemetry. Few studies have been successful in monitoring movements and survival of Montezuma quail with radiotelemetry (Stromberg 1990), but recent adaptations of traditional methods have allowed tracking populations with greater success.

The Canelo fire was a human-caused incident that impacted some areas of the Appleton-Whittell Research Ranch (AWRR) where research on Montezuma quail was conducted prior to the burn. The fire's point of origin was outside AWRR at ~ 31° 55′ N, 110° 51′ W. It was reported to have started on 5 May 2009 at 1300 hrs and was contained and controlled by 9 May 2009 at 1800 hrs. It qualified as fire intensity level 5 and burned 1,702.9 ha, of which 1,011.7 were within the south and eastern parts of AWRR. The wildfire provided an opportunity to examine its impact on resident quail that had been radiomarked and their population abundance monitored via pointing-dog flush-counts. Our objective was to evaluate abundance, behavior, and habitat use of Montezuma quail from 2 months prior to and 12 months after the wildfire.

STUDY AREA

We monitored Montezuma quail at AWRR near Elgin, Arizona (~ 31° 35′ N, 110° 30′ W) and in the Coronado National Forest, administrated by the U.S. Forest Service (USFS), which directly bordered the boundaries of AWRR. The Research Ranch encompasses ~ 3,237 ha in the western foothills of the Huachuca Mountains at an elevation of 1,417-1,570 m. AWRR is designated as a sanctuary and is owned and managed by the National Audubon Society. Livestock grazing is not permitted and hunting of game species is prohibited.

The dominant vegetation at AWRR consists of species common to Plains and Great Basin grasslands, including perennial grama grasses such as sideoats grama (*Bouteloua curtipendula*), hairy grama (*B. hirsuta*), and indigenous plains lovegrass (*Eragrostis intermedia*). Sacaton (*Sporobolus wrightii*) grasslands are well-represented along the bottomlands of Turkey Creek. Drainages and nearby riparian habitat are dotted with sycamore (*Platanus wrightii*), willows (*Salix* spp.), and cottonwood (*Populus fremontii*). Madrean Evergreen Woodlands, dominated by Emory oak (*Quercus emoryi*) and Arizona white oak (*Q. arizonica*) are sparsely dispersed among the sloping hills of the Ranch but are generally found in greater densities along AWRR's southern and eastern borders in the adjacent Coronado National Forest. McLaughlin et al. (2001) noted grass species are most abundant on AWRR with < 3% succulents (Cactaceae, Agavaceae, Nolinaceae) and < 15% woody species.

Large wildfires (> 10 ha) have been infrequent at AWRR within the past 20 years because of suppression efforts. Limited prescribed burns have been conducted to study the effects of fire on ungrazed semi-desert grasslands in Arizona (Bock and Bock 1992b), including its impact on two exotic African grass species, Lehmann lovegrass (*E. lehmanniana*) and Boer lovegrass (*E. curvula*), which have persisted since the 1940's (Bock and Bock 1992c). Plans to integrate prescribed burning as a method for restoring natural fire frequency and native ecosystem processes have been superseded by the occurrence of recent fires including the Ryan Wildfire on 30 April 2002 which burned 2,913.75 ha within AWRR. The general species composition of AWRR has not changed in response to recent fires with exception of non-native grasses which have persisted and tend to colonize rapidly immediately following a burn (Bock and Bock 1992c).

We studied the northern and northeastern boundaries of the area affected by the Canelo fire within the AWRR boundary and defined this region into 4 zones (Fig. 1). Zone A was not affected by the fire (0% burn), part of zone B burned (~ 50% burned), most of zone C burned (> 80% burned), and most of zone D burned (> 95%). Fire suppression effort within AWRR was greater near the housing (zone C) and administrative structures (zone B), which were not affected by the fire. Zone A was largely dominated by native bunchgrasses with interspersed oak trees lining the washes, but was the area where exotic lovegrass species were highest in abundance. Zones B and C had greater representation of sacaton within the bottomlands and contained sycamores, willows, oaks, and mesquite. Zone D had high abundance of sacaton in the bottomlands but greater representation of native grasses, agave, yucca, and oaks along the ridges.

METHODS

We initially used trained pointing dogs to locate Montezuma quail (Brown 1976) at AWRR during surveys conducted between 0500 and 1700 hrs from February 2009 to July 2010. Daytime flush counts using dogs (Brown 1976) served as the most practical means of obtaining population estimates of this species. Quail flush points from daytime surveys were georeferenced using Universal Transverse Mercator (UTM) coordinates in NAD83 datum and were used to locate possible roosts for trapping at night. Surveys with trained dogs were conducted from ~ 1900 to 0300 hrs and served as the primary means of locating and trapping unmarked quail with large hoop-nets in unburned areas (Brown 1975). Efficiency of night-trapping was, at times, facilitated through use of a Forward-looking Infrared (FLIR) camera which was used to narrow the probable location of a covey from thermal signatures detected by the camera. Standard wire-cage funnel traps baited with seed and, at times with a taxidermy quail mount as a lure, were also used to capture quail.

Captured birds were marked with aluminum leg bands and backpack radio transmitters (~ 5–8 g, < 5% of body mass; Wildlife Materials, Murphysboro, IL, USA) using enhanced methods adapted from Stromberg (1990) and Hernández et al. (2009). Morphological characteristics of captured quail (i.e., gender, age, body condition, wing length) were recorded and birds were released before dawn. Radiotelemetry was used to locate unmarked birds within a covey for capture once several

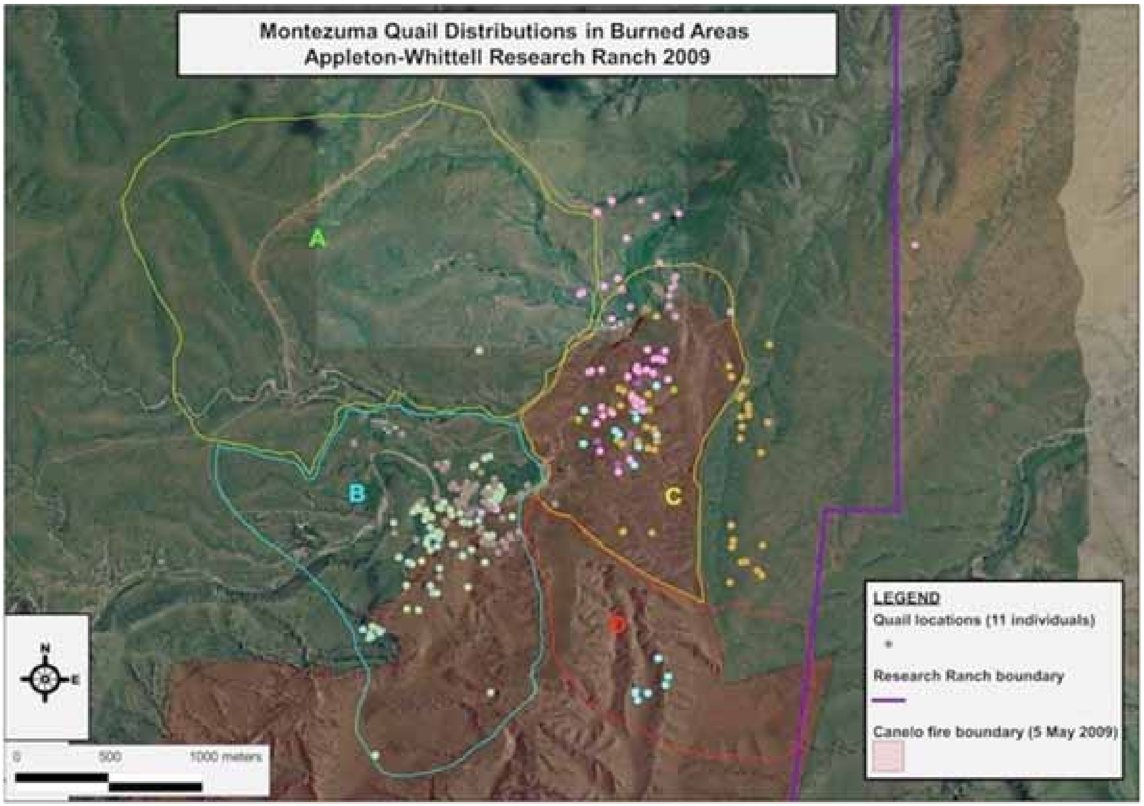

Fig. 1. Distribution of radio-marked Montezuma quail using burned areas in 2009 on the Appleton-Whittell Research Ranch following the Canelo fire (5 May 2009). Surveys conducted in zones A–D ranged from February to October 2009.

birds in a covey were radiomarked. Radio-marked birds were monitored 2–5 times a week during random hours stratified by day (0700–1900 hrs), when quail were most active, or night (1901–0659 hrs), when quail were primarily roosting.

Flush counts with dogs were periodically conducted, ~ 2–4 times a month, during the day to record changes in covey size and gender demographics throughout zones A–D at AWRR (Fig. 1). Flush-count surveys with pointing dogs in zones A and B were conducted from February to May, followed by initial trapping efforts. Surveys in zone C began in early April and monitoring at zone D began once quail were reported by AWRR biologists post-fire. The frequency of flush counts conducted per month, for both 2009 and 2010, was greater when surveying during November–April when research activities would have less impact on pair formation, breeding, and nesting which occur from May to October. Abundance of quail in each zone was calculated as the sum of those radiomarked in each zone plus those not marked and flushed with dogs. Estimates of abundance from flush counts using dogs within each zone were evaluated 2 weeks pre-fire and 2 weeks post-fire for up to 3 weeks.

Flush counts using dogs potentially posed a greater risk to quail survival due to reduction in available escape cover, and we used radiotelemetry as the primary method to monitor covey size and abundance in burned areas. Habitat use, home range, and topography were recorded for radio-marked quail. Roost and nest sites were also georeferenced and compared between burned and unburned areas for each individual. We evaluated quail movements in burn and unburned areas using Quantum GIS (QGIS) 1.7.0 (QGIS 2011) including only movements after 5 May 2009. We recorded locations where quail were observed within the burned area for each individual to estimate use of burned habitats. Preliminary analysis of home range-size was assessed using 25, 50, and 95% fixed kernel range estimates, or utilization distributions (Worton 1989), derived with the Home Range Extension in ArcView 3.2a (ESRI 2000). Survival of radio-marked birds using the burned areas, along with their status at last location (i.e., cause of mortality) was evaluated from the week the burn occurred to October 2009.

RESULTS

We estimated the pre- and post-fire population in zones A+B, C, and D at 2 weeks pre-, 2 weeks post-, and 3 weeks post-fire (Table 1). These estimates included quail reported by AWRR biologists (Table 1). We observed a 35.3% decrease in abundance within 2 weeks post-fire in zones A+B. We observed a 46.7% decrease in abundance within 2 weeks post-fire in zone C. We had no records of radio-marked or flushed birds in zone D 2 weeks before the fire, but observed 1 covey of 5 birds there 2 weeks post-fire. We believed the covey in zone D was different from coveys previously observed in zones

Table 1. Abundance of Montezuma quail up to 3 weeks post-fire estimated from pointing dog flush-counts, including number of quail radiomarked within the population, at Appleton-Whittell Research Ranch, Elgin, Arizona. Zones A–D correspond to regions surveyed within AWRR: A (0% burned), B ($\sim$ 50% burned), C ($>$ 80% burned), and D ($>$ 95% burned). Unk = unknown.

	Zones A + B			Zone C			Zone D	
Montezuma quail	2 weeks pre-fire	2 weeks post-fire	3 weeks post-fire	2 weeks pre-fire	2 weeks post-fire	3 weeks post-fire	2 weeks post-fire	3 weeks post-fire
# Radiomarked	9	5	9	2	0	2	0	0
# Flushed by dogs	25	17	16	28	16	8	5	0
# Reported by staff	5–7	5–7	5–7	unk	unk	unk	4–6	unk
Estimated totals	34	22	25	30	16	10	5	0

A+B or C. We estimated a 13.6% increase in abundance of quail in zones A+B from week 2 to week 3 post-fire, but an overall 26.5% reduction in abundance from 2 weeks pre-fire to 3 weeks post-fire (Table 1). We observed a 37.5% decrease from week 2 to week 3 post-fire, but an overall 66.7% reduction in abundance from 2 weeks pre-fire to 3 weeks post-fire in zone C. No quail were observed 3 weeks post-fire in zone D, a 100% reduction in local abundance (Table 1).

Thirty-two Montezuma quail were trapped in 2009 at AWRR of which 15 were tracked after 5 May 2009 and 11 were observed using the burned area (Table 2). One additional bird (female #777) was not radiomarked or banded but relocated from observing her at a nest. Four of the 11 radio-marked birds observed using burned areas originated in coveys from zone B and 7 originated from coveys in zone C. We made few observations prior to the fire of radio-marked birds using areas that would later burn. One juvenile female (#226) in zone B had at least 3 locations within the edge of zone C, 2 weeks prior to the fire. Adult female (#221) was observed with an unmarked male on 3 May in a large sacaton bottomland in zone C that burned within 2 days. The next visual relocation for #221, on 7 May 2009, was 708 m from the burned area in another large sacaton bottom in the unburned northwest edge of zone B.

The number of telemetry relocations for the 11 radio-marked birds in 2009 ranged from 7 to 49 and varied based on when they were initially trapped, how long they were observed before their death, and if transmitter loss or failure prevented further data collection (Table 2). The mean of radiotelemetry relocations in the burn was 60.9% and ranged from 21.4 to 100% (Table 2). Several ($n = 11$) radio-marked Montezuma quail in this study had 50% fixed kernel range core use areas in the burned area and 9 of these also had 25% fixed kernel core use areas within the burn (Table 2). We suspected most depredations were caused by raptors; this included radio-marked quail with the highest number of locations in the burn, females #221 and male #233 (Table 2). We observed several quail (#221) roosting (Table 2) at the edge of the burn in the unburned area, including 1 individual (#233) that roosted within 32 m of the edge of the burn. Some individuals (#226 and #233) did not have any known roosts in the burn. Quail were observed foraging during the day in the burned sacaton bottomlands using the remaining base of sacaton grasses or any nearby fallen debris and snags as cover. All radio-marked birds in zone C roosted within the burn, and roosts detected per individual in the burn, compared to unburned, ranged from 33.3 to 100%. Females attempted to nest in burned areas during vegetation recovery post-burn. Two radio-marked females and 1 unmarked female nested in the burn, while 3 radio-marked females nested in unburned areas. One female (#226) had 2 nest attempts that were within 50 m of the burn edge.

Table 2. Demographics of radio-marked Montezuma quail in 2009 using the burned area following the 5 May 2009 Canelo fire at Appleton-Whittell Research Ranch, Elgin, Arizona. AHY = after hatch year (Adult), HY = hatch year (Juvenile). Core areas in burn represented by 25 and 50% fixed kernel range estimates (Worton 1989) derived from radiotelemetry data.

Band #	Gender	Age	Dates tracked after the fire	# of locations	% locations in burn	# roosts in burn	Nest in burn?	Core areas in burn 25–50%	Condition at last location
221	F	AHY	7 May–9 Jul	33	60.6	1	Unknown	50	Dead; raptor suspect
226	F	HY	7 May–19 Oct	26	38.2	0	0 of 2	50	Lost transmitter
233	M	AHY	26 May–8 Jun	7	85.7	0	Unknown	25–50	Dead; raptor suspect
234	M	HY	26 May–22 Aug	49	49.0	1	Unknown	25–50	Transmitter failed
238	M	HY	19 Jun–16 July	12	100.0	1	Unknown	25–50	Lost transmitter
239	F	AHY	16 Jun–25 Aug	40	70.0	6 of 8	0 of 1	25–50	Transmitter failed
240	F	HY	19 Jun–19 Oct	42	45.2	2 of 6	0 of 1	25–50	Dead; raptor
241	F	HY	19 Jun–20 Aug	20	100.0	2 of 2	1 of 1	25–50	Transmitter failed
242	M	AHY	19 Jun–16 Jul	12	100.0	2 of 4	1 of 1	25–50	Transmitter failed
243	F	AHY	10 July–23 Oct	29	96.6	5 of 5	1 of 1	25–50	Dead, (Jan 2010)
244	F	AHY	1 Aug–19 Oct	14	21.4	1 of 1	0 of 1	25–50	Lost transmitter
777	F	AHY	16 Jul–8 Aug	10		1	1		Not radiomarked
				Average	60.9				

The majority of Montezuma quail in 2010 were observed in zone C. Flush-count surveys with dogs in January 2010 estimated 38–60 Montezuma quail within zone C and possibly 10–15 in zones A+B. One quail (#243) survived from 2009 and was monitored along with 21 previously unmarked individuals in 2010. We obtained 235 locations for 22 radio-marked Montezuma quail from January to April 2010; 206 (93.6%) of 220 locations were within the recovering burned areas in zone C.

DISCUSSION

Montezuma quail abundance within some burned zones remained high despite a marked reduction in available cover (Table 1). Small islands of unburned bunchgrass present in the hills at the northeast edge of the fire (zone C) provided adequate cover to sustain coveys that had been resident throughout the bottomlands that burned. The pre-fire abundance and density of the islands of bunchgrasses which the quail used for cover post-fire, however, were naturally lower, and considered less ideal, in comparison to areas they would typically inhabit. At least 2–3 coveys in zone C before the fire foraged and roosted in high-density grass flats within 10–50 m of the sacaton bottomlands. These grass flats were more vulnerable to fire in comparison to those which persisted in the rough and rocky canyon banks and sandy wash bottoms. Micro-topography, soil type, and rocky substrate provided some protection from fire in some areas of zone C, allowing cover and quail to persist within these unburned pockets. A few pockets of unburned sacaton remained in the more rugged wash bottoms in zone D but which occurred in low densities and widely interspersed throughout the affected area. Quail that remained in zone D were within these remaining small pockets of sacaton. When flushed, these birds took cover at the fire-charred bases of *Agave* spp. or *Nolina* spp., which did not provide adequate cover and are not ideal habitat for Montezuma quail even when unburned.

Quail abundance decreased in burned areas (zones C+D) 2–3 weeks post-fire but did not correspond to increased abundance in unburned areas (zones A+B) when compared to estimates before the fire (Table 1). Flush-counts with dogs confirmed some unmarked quail from zone C moved to the unburned edge across the road into zone A, but their numbers were small ($3 \leq n \leq 8$) in comparison to pre-fire abundances. High mortality of unmarked quail was observed within 2 weeks post-fire in zones A+B, but it is unknown how many of these corresponded specifically to those that may have been from zone C. Mortality rates from direct susceptibility to fire are unknown for most North American quail. Most literature on the impact of fire on quail suggests, but does not provide direct evidence for, low probability of mortality directly from fire due to innate high mobility and the ability of quail to fly. Recent studies, however, show that prescribed-burns have had low direct impact on mortality of bobwhites (Martin et al. 2010). Montezuma quail behavior during a fire has not been documented. Given their adaptation to remain motionless in response to perceived danger, it is intuitive that some may have moved too late and eventually died from fire-related injuries, or were perhaps surrounded by and could not escape the fire. Unfortunately, the high intensity of the fire, which burned many oaks and sycamores below their bases, left little chance of finding any quail carcasses post-fire.

Strong site fidelity in this species has been documented from radiotelemetry studies (Stromberg 1990) but, until now, there has been no evaluation of response to fire or any other large disturbance events. Our observations provide strong evidence for site fidelity in Montezuma quail in burned areas post-fire. Evidence is provided from individuals within coveys that were radiomarked within 1.5–2 months post-fire (Table 2). Site fidelity remained high in burned areas even when there was little to no cover available immediately post-fire. The covey detected in zone D was observed within a severely burned bottomland up to 20 days post-fire.

Feeding activity in a burned area (zone C) was observed within days post-fire with quail taking cover beside large fallen snags of sycamores or by rocks and rough micro-topography along the banks of Turkey Creek wash. Quail were observed scratching, apparently for seed or tubers that remained underneath the ash and hardened soil. The onset of summer monsoons provided rainfall as early as 21 May and moderate precipitation events followed on 28 May and 10 June. Herbaceous vegetation subsequently carpeted burned areas with apparent eruptions of insect populations, especially grasshoppers. Bock and Bock (1991) observed similar trends for grasshoppers at AWRR post-fire. Montezuma quail were observed feeding in burned areas with new vegetation and in areas with higher concentrations of insects.

The earliest active roosts ($n = 2$) directly within a burned area were recorded at 19 and 24 days post-fire, but others were found earlier in islands of unburned grass within or at the edge of the burn. Several active nests were located within the burned area, including 2 that were found 68 days post-fire and 1 that was found 96 days post-fire. The first 2 nests found were in areas with poor cover. Vegetation in the sacaton bottomlands recovered more quickly than in upland areas and, eventually, provided adequate cover where 2 of the nests were located. One nest was on a burned ridge dominated by *Agave* spp. and initially had sufficient cover within the bunchgrass that had recovered at the base of an agave. The landscape surrounding this nest, however, had poor to no recovery of native bunchgrasses and remained very open 3 months post-fire. The female from this nest was observed making movements of > 100 m to feed on forbs and insects that were in greater abundance at the base of the burned hills.

Productivity in burned areas seemed to not be severely affected the following season. Abundance estimates were higher 8 months post-fire in burned sacaton bottomlands than in those that were not burned. This contrasts with observations of Bock and Bock (1978) who noted decreased abundance of Montezuma quail 1 year post-fire. The methods used by Bock and Bock (1978) to survey birds were likely not effective for detecting Montezuma quail.

There is agreement among some biologists that Montezuma quail have ‘co-evolved’ with grass cover and range fire (Harveson et al. 2007). Thus, populations have recovered in regions where large-scale wildfires have restored native vegetation structure more favorable for their survival (Zornes and Bishop 2009). Montezuma quail may respond differently than other North American quail when exposed to changes in the surrounding landscape brought about by variation in fire intensity, and changes in vegetative structure available for cover. Fire in late spring may impact Montezuma quail breeding behavior and available habitat for nesting. Our research shows that Montezuma quail use burned areas immediately following fire and their resilience includes the ability to roost in burned areas within weeks post-fire and nest within months post-fire when surrounding habitat (e.g., sacaton bottomlands) provide cover during early stages of post-fire succession.

MANAGEMENT IMPLICATIONS

Quail biologists have documented the importance of fire and prescribed burns in conservation and management of North American quail (Cram et al 2002, Brennan and Kuvlesky 2005, Brennan 2007). Our research provides baseline natural history observations of Montezuma quail that are helpful for managers considering implementing prescribed fire in areas where this species is present. Some studies have showed mixed results of application of fire for managing quail populations, particularly in semi-arid grasslands (Ransom and Schulz 2007). Our research indicates fire in open semi-desert grasslands is detrimental to Montezuma quail population recovery for several months post-fire if the surrounding areas do not have nearby unburned sacaton bottomlands for cover.

Fire restructures habitat that can favor nesting of some quail species (Brooker and Rowley 1991) and generally benefits increased abundance of some native grassland birds (Bock and Bock 1992a), especially when exotic vegetation is removed in the process. These aspects have not been explored thoroughly for Montezuma quail and more research is needed concerning site fidelity and movement patterns.

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LITERATURE CITED

Arizona Partners in Flight. 1999. Arizona Partners in Flight bird conservation plan. Technical Report 142. Nongame and Endangered Wildlife Program. Arizona Game and Fish Department, Phoenix, USA.

Bock, C. E., and J. H. Bock. 1978. Response of birds, small mammals, and vegetation to burning sacaton grasslands in southeastern Arizona. Journal of Range Management 31:296–300.

Bock, C. E., and J. H. Bock. 1991. Response of grasshoppers (Orthoptera: Acrididae) to wildfire in a southeastern Arizona grassland. American Midland Naturalist 125: 162–167.

Bock, C. E., and J. H. Bock. 1992a. Response of birds to wildfire in native versus exotic Arizona grassland. Southwestern Naturalist 37: 73–81.

Bock, J. H., and C. E. Bock. 1992b. Short-term reductions in plant densities following prescribed fire in an ungrazed semidesert shrub-grassland. Southwestern Naturalist 37: 49–53.

Bock, J. H., and C. E. Bock. 1992c. Vegetation responses to wildfire in native versus exotic Arizona grassland. Journal of Vegetation Science 3: 439–446.

Bond, B. T., L. W. Burger, B. D. Leopold, K. D. Godwin, and J. C. Jones. 2002. Short-term response of eastern cottontails to prescribed fire in east-central Mississippi. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 56: 187–197.

Brennan, L. A., ed. 2007. Texas quails: ecology and management. First edition. Texas A&M University Press, College Station, USA.

Brennan, L. A., and W. P. Kuvlesky Jr. 2005. North American grassland birds: an unfolding conservation crisis? Journal of Wildlife Management 69: 1–13.

Bristow, K. D., and R. A. Ockenfels. 2004. Pairing season habitat selection by Montezuma quail in southeastern Arizona. Journal of Range Management 57: 532–538.

Brooker, M. G., and I. Rowley. 1991. Impact of wildfire on the nesting behaviour of birds in heathland. Wildlife Research 18: 249–263.

Brown, D. 1979. Factors influencing reproductive success and population densities in Montezuma quail. Journal of Wildlife Management 43: 522–526.

Brown, R. L. 1975. Mearns’ quail capture method. Final Report. Federal Aid Project W-78-R-15, Work Plan 1, Job 2. Arizona Game and Fish Department, Phoenix, USA.

Brown, R. L. 1976. Mearns’ quail census technique. Federal Aid in Wildlife Restoration Project W-78-R-15, Work Plan 1, Job 1. Arizona Game and Fish Department, Phoenix, USA.

Craig, M. D., R. J. Hobbs, A. H. Grigg, M. J. Garkaklis, C. D. Grant, P. A. Fleming, and G. E. St. J. Hardy. 2010. Do thinning and burning sites revegetated after bauxite mining improve habitat for terrestrial vertebrates? Restoration Ecology 18: 300–310.

Cram, D. S., R. E. Masters, F. S. Guthery, D. M. Engle, and W. G. Montague. 2002. Northern bobwhite population and habitat response to pine grassland restoration. Journal of Wildlife Management 66:1031–1039.

Environmental Systems Research Institute (ESRI). 2000. Arcview 3.2a GIS software. Environmental Systems Research Institute, Redlands, California, USA.

Guthery, F. S., N. M. King, W. P. Kuvlesky Jr., S. DeStefano, S. A. Gall, and N. J. Silvy. 2001. Comparative habitat use by three quails in desert grassland. Journal of Wildlife Management 65: 850–860.

Harveson, L. A., T. H. Allen, F. Hernández, D. A. Holdermann, J. M. Mueller, and M. S. Whitley. 2007. Montezuma quail ecology and life history. Pages 23–29 in L. A. Brennan, ed. Texas quails. Texas A&M University Press, College Station, USA.

Hernández, F., E. Garza, L. A. Harveson, and C. E. Brewer. 2009. Fate and survival of radio-marked Montezuma quail. Gamebird 2006: Quail VI and Perdix XII: 426–431.

Leopold, A. S., and R. A. McCabe. 1957. Natural history of the Montezuma quail in Mexico. Condor 59:3–26.

Martin, J. A., W. E. Palmer, D. P. Grimes, and J. P. Carroll. 2010. Mortality of adult *Colinus virginianus* L. (northern bobwhite) from prescribed fire. Southeastern Naturalist 9:181–183.

McLaughlin, S. P., E. L. Geiger, and J. E. Bowers. 2001. A flora of the Appleton-Whittell Research Ranch, northeastern Santa Cruz County, Arizona. Journal of the Arizona-Nevada Academy of Sciences 33: 113–131.

Quantum GIS Development Team (QGIS). 2011. Quantum GIS Geographic Information System, Version 1.7.0. Open Source Geospatial Foundation Project. Vancouver, British Columbia, Canada. qgis.osgeo.org

Ransom Jr., D., and G. G. Schulz. 2007. Northern bobwhites and postfire succession. Journal of Wildlife Management 71:565–570.

Renwald, J. D., H. A. Wright, and J. T. Flinders. 1978. Effects of prescribed fire on bobwhite quail habitat in the Rolling Plains of Texas. Journal of Range Management 31:65–69.

Stromberg, M. R. 1990. Habitat, movements and roost characteristics of Montezuma quail in southeastern Arizona. Condor 45: 57–65.

White, J. D., K. J. Gutzwiller, W. C. Barrow, L. Johson-Randall, L. Zygo, and P. Swint. 2011. Understanding interaction effects of climate change and fire management on bird distributions through combined process and habitat models. Conservation Biology 25: 536–546.

Wilson, M. M., and J. A. Crawford. 1979. Response of bobwhites to controlled burning in South Texas. Wildlife Society Bulletin 7:53–56.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home range studies. Ecology 70:164–168.

Zornes, M., and R. A. Bishop. 2009. Western Quail Conservation Plan. S. J. Williamson, ed. Wildlife Management Institute, Cabot, Vermont, USA.

IMPACT OF INCLEMENT WEATHER ON OVERWINTER MORTALITY OF MONTEZUMA QUAIL IN SOUTHEAST ARIZONA

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ABSTRACT

Inclement weather such as droughts or hard freezes are known to negatively impact quail species and population viability models exist which have evaluated northern bobwhite (*Colinus virginianus*) response to summer and winter catastrophes. Previous research suggests inclement weather may be an important factor that contributes to mortality of Montezuma quail (*Cyrtonyx montezumae*), but few data have been collected to evaluate actual rates of overwinter mortality. We evaluated the overwinter mortality of Montezuma quail in southeast Arizona following an episode of severe winter weather consisting of 27.54 cm of precipitation, which occurred from January to March 2010. Overwinter mortality for radio-marked birds ($n = 23$) was 95.6%. Total abundance using flush counts at a control site estimated an 88% reduction in the population following the episode of above-average precipitation. Post-hunting season flush counts across multiple study sites throughout the Coronado National Forest also support this trend. The 3-year (2007–2009) average (± SD) (41.67 ± 4.73) of birds flushed was ~ 80% higher than number of birds ($n = 8$) flushed in the 2010 post-hunting season.

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Key words: Appleton-Whittell Research Ranch, Coronado National Forest, covey size, *Cyrtonyx montezumae,* dog surveys, flush counts, freezing, Mearn's quail, Montezuma quail, National Audubon Society, overwinter mortality, precipitation, radiotelemetry

INTRODUCTION

Precipitation is a key variable for predicting population fluctuations of quail in North America. Numerous studies have shown the strong influence of summer rainfall on productivity of northern bobwhite (Guthery et al. 2002), Gambel's quail (*Callipepla gambelii*) (Swank and Gallizioli 1954), scaled quail (*C. squamata*) (Lusk et al. 2007), and Montezuma quail (Smith 1917, Bishop 1964, Bishop and Hungerford 1965, Brown 1979), but fewer studies focus on the impact of winter precipitation on these species. Winter climate is known to contribute to over-winter mortality of northern bobwhite and has been evaluated through models of population dynamics (Guthery et al. 2000). Less is known about Montezuma quail, but some evidence suggests severe winter weather can have detrimental impacts on their abundance. Leopold and McCabe (1957: 22) noted that "one cause of sudden decline in Montezuma Quail is periodic winter mortality resulting from abnormally deep snow." Similar observations have been made by Ligon (1927) in New Mexico and O'Connor (1936) in Texas.

Population declines following inclement weather, especially during periods of heavy and persistent snowfall have been reported to be as high as 86.7% (Yeager 1966), but the direct cause of these declines is unknown. Observations reported by ranchers (Yeager 1966) suggest that mortality was directly related to exposure to severe winter storms, but no studies have validated these impacts through monitoring of marked populations. Recent studies using radiotelemetry on Montezuma quail (Stromberg 1990) have overcome past challenges (Hernández et al. 2009) in studying this species, paving the way to better understanding their population dynamics and causes of mortality. This is particularly beneficial for understanding population reductions observed during a severe storm from a winter-storm event from January to March 2010.

We evaluated abundance of Montezuma quail throughout southeast Arizona in the pre- and post-hunt seasons from 2008 to 2010 and compared these estimates to changes in climate observed throughout those periods. Our objective was to evaluate sources or causes of

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overwinter mortality, movements, and covey dynamics for a radio-marked population of Montezuma quail during a period of extreme winter weather in 2010.

STUDY AREAS

Surveys of Montezuma quail were conducted along pointing-dog survey routes previously established by the Arizona Game and Fish Department (AZGFD) as well as 3 study sites where marked populations were studied through radiotelemetry. Areas where only pointing-dog survey routes were conducted were dispersed throughout the San Rafael Valley in areas administrated by the Coronado National Forest in Santa Cruz County. Survey routes that included long-term trapping and telemetry were Stevens Canyon, Hog Canyon, and Appleton-Whittell Research Ranch (AWRR) in Elgin.

Hog Canyon (~ 31° 40′ N, 110° 42′ W) is dominated by Madrean Evergreen Woodland and Montane Meadow (AZGFD 2006). Similar vegetation occurs at Steven's Canyon (~ 31° 35′ N, 110° 45′ W) but there is a reduced overstory canopy layer and the oak (*Quercus* spp.) composition is sparse and intermixed with desert scrub species (i.e., *Acacia* sp., and mesquite, *Prosopis* sp.). Plains and Great Basin Grasslands, dominated by sacaton (*Sporobolus wrightii*) bottomlands along Turkey Creek occur at Appleton-Whittell Research Ranch (~ 31° 35′ N, 110° 30′ W). Madrean Evergreen Woodlands dot the landscape on the long-sloping hills at the ranch. Oaks and other overstory species occur in greater densities along the southern and eastern borders of the ranch that neighbor the Coronado National Forest. Hunting and grazing are permitted at both Stevens Canyon and Hog Canyon. Grazing activities are administrated by the Coronado National Forest and seasonal hunting of Montezuma quail is permitted and regulated by AZGFD from mid-November to mid-February. The National Audubon Society owns and manages AWRR and prohibits both grazing and hunting on their property.

METHODS

Climate Data

Weather data were obtained from the National Oceanic and Atmospheric Administration's (NOAA) climatological data reports (NOAA 2010a, b, c) and National Weather Service (NWS) Forecast Office climate reports for Tucson, Arizona from January to March 2010 (NWS 2010a, b, c). The National Climatic Data Center (NCDC 2010) provided online access to records from weather station #1231, Canelo 1 NW in Santa Cruz County (~ 31° 34′ N, 110° 32′ W) at 1,527 m elevation. Average temperatures and departures from normal (°C) as well as total precipitation and departure from normal (cm) were used for analysis. We evaluated temperature and precipitation collected at AWRR when data from weather station #1231, Canelo 1 NW were missing.

Abundance Surveys

Flush-counts were conducted using trained pointing dogs (Brown 1976) along 9 survey routes, some previously established by AZGFD, throughout southeast Arizona from October 2008 to February 2010. Pre-hunt season surveys occurred the last week of October through the first week of November each year. Post-hunt season surveys occurred the last week of February through the first week of March each year. These were conducted during the day from 0500 to1700 hrs, ending no later than 1800 hrs and generally averaged 1.5 hrs per route. The total number of coveys and total quail were recorded and their locations georeferenced using Universal Transverse Mercator (UTM) coordinates in NAD83 datum. Three separate study sites from those surveyed just with dogs—Stevens Canyon, Hog Canyon, and AWRR—were also evaluated from January 2008 to May 2010. These sites were surveyed with dogs to locate possible roost locations for night trapping. Total number of coveys and total quail were also recorded but birds were also trapped and radiomarked. Flush-counts with dogs were conducted periodically, about 2–4 times a month, during the day to record changes in covey size and gender demographics throughout the 3 study sites. Flush-counts were conducted more frequently from November to April. This was reduced from May to October when research activities could potentially impact pair formation, breeding, and nesting.

Capture and Telemetry

Trapping initially required assistance from trained dogs to locate quail at night. Birds were captured with large hoop-nets (Brown 1975) once a roost was located, and evaluated for morphological characteristics (i.e., sex, age, body condition, wing length). Captured birds were fitted with backpack radio transmitters (about 5–8 g, $<$ 5% of body mass; Wildlife Materials, Murphysboro, IL, USA) and aluminum leg bands using methods adapted from Stromberg (1990) and Hernández et al. (2009), and were released before dawn the following morning. Quail were monitored ~ 2–5 times a week through random hours stratified by day (0700–1900 hrs), when quail were most active. Some telemetry sessions were conducted at night (1901–0659 hrs) for trapping or evaluating roost locations. We monitored covey size and covey dynamics by observing movements of radio-marked quail among coveys of those quail originally trapped in the same group. Aspects of habitat use, including roost selection, were also evaluated. Quail movements were analyzed using Quantum GIS 1.7.0 (QGIS 2011).

Survival and Mortality

We used the Kaplan-Meier staggered entry estimator (Pollock et al. 1989) to calculate survival probability rates ($S \pm$ SE) for radio-marked quail at AWRR from January to April 2010. Survival rates and standard errors were calculated using Program ECOLOGICAL METHODOLOGY (Krebs 2002). The condition at last observation was recorded for each individual tracked including sources of

Table 1. Abundance data of Montezuma quail at 4 study areas from pre-hunt (Oct–Nov) and post-hunt (Feb–Mar) surveys for the 2007–2010 seasons in southeast Arizona. Flush-counts report the total number of coveys and quail. Missing data are indicated where surveys were not conducted. AWRR does not permit hunting—the pre- and post-hunt designations are used only as frame of reference for when the surveys were conducted. SR Valley = San Rafael Valley.

	Flush count abundance					
Year	2007–2008		2008–2009		2009–2010	
Season	Pre-hunt Oct-Nov 2007	Post-hunt Feb-Mar	Pre-hunt Oct-Nov 2008	Post-hunt Feb-Mar	Pre-hunt Oct-Nov 2009	Post-hunt Feb-Mar 2010
Stevens Canyon	–	3 coveys: 11–20	2 coveys: 12	0 coveys: 0	–	0 coveys: 0
Hog Canyon	–	4 coveys: 15–30	3 coveys: 15	2 coveys: 8	2 coveys: 11	0 coveys: 0
AWRR	–	–	–	8 coveys: 64	8 coveys: 60	3 coveys: 10
SR Valley	23 coveys: 182	10 coveys: 38	20 coveys: 175	11 coveys: 47	10 coveys: 65	2 coveys: 8

mortality, if known. We noted the most probable or ‘suspected’ cause of death if cause of death was not directly known.

RESULTS

Pre-hunt flush counts within the traditional pointing-dog survey routes in the San Rafael Valley found similar number of coveys in October–November 2007 when compared to October–November 2008 (Table 1). There was a decline in both number of coveys and total quail in October–November 2009 (Table 1). Post-hunt data had similar trends for February–March 2007 when compared to February–March 2008 (Table 1), but with fewer coveys and slightly more total quail in the later season. The 2009–2010 interval had a decrease in both coveys and total quail in both pre- and post-hunt intervals. The greatest reduction in total coveys and total quail was in the post-hunt period in February–March 2010 with a 87.7% reduction within season. Changes in abundance within season for 2007–2008 (79.1%) and 2008–2009 (73.1%) were considerably lower than in 2009–2010. The 3-year (2007–2009) average (± SD) of birds flushed post-hunting (41.67 ± 4.73) was ~ 80% higher than number of birds ($n = 8$) flushed in the 2010 post-hunting season.

Reductions in number of coveys observed and total quail at Stevens Canyon were similar in post-hunt 2009 and post-hunt 2010, but the amount of quail sign observed in the field (not reported in Table 1) was less than in previous years. No quail sign (i.e., scratching) was observed from surveys at Stevens Canyon in late March 2010. Pre- and post-hunt data for Hog Canyon were comparable to those of the traditional survey routes from the 2008–2009 and 2009–2010 seasons. However, in the 2010 post-hunt season, no quail were flushed and little sign was observed—a 100% reduction in abundance within season. Abundance trends at the AWRR could only be analyzed from 2009, when research was initiated at that site. Surveys in early January 2010 estimated the population to be between 38 and 75 individuals. Estimates obtained from surveys in the post-hunt season indicated a decrease in the population following winter storms in late January. A within-season reduction in abundance of at least 83.3% was observed in 2009–2010. These estimates fail to account for further reductions in abundance observed from March to April 2010.

We had 22 Montezuma quail radiomarked and monitored from January to April 2010. One adult female (#243) remained from the previous season but died from suspected mammal predation on 11 January. Six birds were captured in 1 covey on 13 January and consisted of 1 adult male, 1 adult female, 2 juvenile males, and 2 juvenile females. Male #247 died from suspected raptor predation on 17 January, female #248 died from suspected raptor predation on 24 January, juvenile male #249 died from suspected mammal predation on 22 January, and juvenile female #250 died from suspected mammal predation on 26 January. Juvenile male #702 and juvenile female #701, also trapped in that covey, were found frozen on their roosts on 23 and 24 January, respectively. Female #701 was found frozen on its side and it is unclear if she roosted alone but, at the time of her death, the covey size had been reduced to 3 members. The following day, 2 additional members of the covey died, with 1 (#701) having been frozen in an exposed rocky grass hill within 10 m of oak trees. Most radio-marked birds joined other nearby coveys when numbers in their original coveys were reduced below 4. Those that did not join other coveys, as observed for #701, #248, and #250, died within days. These mortalities coincided within 3 days of the first severe winter storm during 19–23 January. Another quail, juvenile male #706, was found frozen on its roost on 1 February–within 4 days following heavy precipitation. Male #706 was 1 of 4 birds captured in a covey of 6 on 23 January, all of which had full crops at the time. Other members within that covey remained alive post-storm but, by 10 February, at least 3 of the marked birds had died and 1 was missing but assumed depredated.

Radiotelemetry surveys conducted in February noted 2 coveys of 6 and 3 individuals on 2 February during the night but all were observed to be together in a group of 10 during the day. The same 2 coveys monitored on 5 February and 6 February consisted of 5 and 4 individuals. Heavy winter precipitation, followed by extremes of low temperatures persisted in early and late February (Table 2). Reductions in abundance occurred by mid-February, and were confirmed from dead radio-marked birds. Only 1 covey of 6 birds was observed on 15 February and only 1 radio-marked bird remained through 13 March. The Kaplan-Meier estimate for finite survival probability for radio-marked Montezuma quail from January to April 2010 was $S = 0.048 \pm 0.037$.

Table 2. Mean maximum and minimum temperatures, total precipitation, and departures from normal, including coldest recorded dates with data in parentheses measured in °C, and dates of precipitation with data in parenthesis in cm. Data obtained from weather station # 1231, Canelo 1 NW in southeast Arizona from January to March 2010.

	Jan 2010	Feb 2010	Mar 2010
Mean temp (°C)	5.4	5.5	7.8
Departure from normal (°C)	−1.5	−4.1	−3.7
Mean max temp (°C)	13.8	13.0	17.2
Mean min temp (°C)	−3.0	−2.0	−8.2
Coldest days: date (followed by temperature °C in parentheses)	1 (−8.3), 2 (−8.3), 24 (−7.2), 25 (−6.1), 26 (−6.1), 30 (−6.1)	8 (−5.5), 9 (−5.5), 24 (−7.2)	11 (−5.5), 12 (−5.5), 15 (−4.4), 21 (−4.4), 22 (−4.4)
Precipitation days: date (followed by amount in cm in parentheses)	19 (3.51), 20 (1.55), 21 (5.28), 23 (4.27), 28 (4.57)	3 (2.06), 7 (0.33), 10 (2.03), 20 (0.71), 22 (0.84), 28 (1.57)	8 (0.46), 9 (1.52), 10 (0.25), 11 (0.41)
Total precipitation (cm)	19.18	5.72	2.64
Departure from normal (cm)	15.62	2.72	−0.15

DISCUSSION

A series of winter storms occurred during January–February 2010 bringing a combination of sleet, snow, heavy rain, and strong winds throughout southeast Arizona. Mean temperatures were low compared to the previous 2 years with departures from normal of –1.5 °C January, - 4.1 °C in February, and –3.7 °C in March. Total precipitation exceeded previous years with departures from normal of 15.62 cm in January and 2.72 cm in February. Some of the coldest days followed precipitation events, particularly on 24–26 January. The soil was frozen hard at AWRR following the period of heavy rainfall on 22 February. At least 5.08 cm of snow persisted on the ground and standing water and ponds saturated the landscape. Strong winds with gusts to 64 to 97 km/hr were reported in the valleys, and gusts to 129 km/hr in the mountains. The National Weather Service in Tucson reported January 2010 as the 8th wettest January on record and 22 January as the 5th wettest January day on record. The NWS in Tucson reported the continuing storm system made 2010 the 11th wettest February on record and 28 February as the 7th wettest February day on record.

Reductions in abundance of Montezuma quail were observed throughout the pointing-dog survey routes and the 3 study sites examined through radiotelemetry in southeast Arizona in the 2010 post-hunt season. These sharp changes from pre-hunt to post-hunt season and cause of mortalities were evaluated with radiotelemetry at AWRR. Some birds were found frozen on their roosts when the number of individuals within a covey was below 4. Quail that lost members in their covey often joined other nearby coveys. This may have increased chance of survival due to the increased insulation provided from roosting as a group. Weather conditions during January–February 2010, however, may have overcome physiological tolerance of Montezuma quail due to the extreme low temperatures. Many birds were observed to be lethargic and would choose to run rather than flush when approached. This may have increased vulnerability to predation.

Yeager (1966) and Brown (1979) noted the potential negative impacts associated with winter precipitation. Brown (1979) observed a negative correlation coefficient between winter (Oct–Mar) precipitation and the following season's reproductive success ($r = - 0.73$, $P \leq 0.02$). Yeager (1966) reported emaciated dead birds following a severe storm that left parts of southeast Arizona covered with 25.4 to 35.56 cm of snow. Yeager (1966:7) reported conditions where "snow cover lasted from 4 to 6 days on south and west slopes" and that "up to 30.48 cm of undrifted snow still covered many of the east and north slopes through 19 February 1966." Snow cover was not as deep or persistent at AWRR in 2010 compared to conditions described by Yeager (1966), but snow cover persisted on the nearby Patagonia, Santa Rita, and Huachuca slopes through April. Freezing rain rather than snow accounted for most of the precipitation at AWRR in 2010.

Abundance of Montezuma quail at AWRR was lower in February 2010 compared to estimates from 2009. We estimated at least 64 Montezuma quail remaining in May 2009, while in May 2010 we estimated the total population at AWRR to be 10 or less with only 2–4 of these individuals being detectable through intensive surveys. Intensive reductions in abundance also occurred at Stevens Canyon and Hog Canyon—sites that were monitored via flush-surveys but not with radiotelemetry. Flush-count surveys and estimates of survival from radio-marked birds at those 2 sites in previous years suggests hunting does not impact the population by severely reducing the abundance to those levels observed in the 2010 post-hunting season. Surveys at Stevens Canyon in previous years suggest that site is vulnerable to localized extirpation because of intensive hunting and grazing. Hog Canyon has more resilience to both of those pressures because of topography. We expected abundance at Hog Canyon to be higher than observed in our surveys in the post-hunt season through May 2010. It is possible the combination of severe weather and hunting pressure was responsible for marked reductions in abundance observed at both Stevens Canyon and Hog Canyon in the 2010 post-hunt season.

Yeager (1966) and Brown (1979) did not evaluate movements of radio-marked Montezuma quail. Neither Yeager (1966) nor Brown (1979) could account for possible migrations of populations from their study areas.

Brown (1979: 525) suggested the possibility of underestimating a population in surveys, noting that "local populations have been observed to apparently leave an area, presumably because food sources are depleted." Yeager (1966) also suggested the possibility that migration might explain why birds could not be found in areas where they were abundant the month before in his study. However, Yeager (1966: 8) concluded there was no solid evidence to support that claim and, because of the relative sedentary nature of this species, there was evidence to support the assumption that snow cover "can and probably does cause relatively high mortality." Our research with integration of radiotelemetry to supplement dog-assisted flush counts, confirms that: (1) Montezuma quail are relatively sedentary and have small home ranges, and (2) severe winter weather, including freezing temperatures and snow cover, causes high mortality in this species.

MANAGEMENT IMPLICATIONS

Timing and amount of precipitation impact reproduction (Brown 1979, Heffelfinger et al. 1999) of quail and emphasis has been placed on observing summer rather than winter precipitation events. Some quail biologists suggest winter and early spring precipitation may be favorable for early production of vegetation that can benefit quail before the breeding season. Our research shows, however, that timing of precipitation, as well as the severity of the storm system that brings it, are important factors when considering possible benefits to Montezuma quail and developing better estimates of overwinter mortality. Inclement weather impacted the survival of Montezuma quail in our study from the series of record-setting storms with below-average departures from normal in both precipitation and monthly mean temperatures. Montezuma quail have evolved adaptations to survive snowfall and winter storms but the combination of conditions brought by the severe weather in 2010 reduced abundance throughout much of southeast Arizona. Evaluation of shifting weather patterns remains crucial for conservation of quail in the midst of potential climate change (Root 1993). The potential impacts from severe storms can be problematic to Montezuma quail if severe drought conditions follow.

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LITERATURE CITED

Arizona Game and Fish Department (AZGFD). 2006. Comprehensive wildlife conservation strategy: 2005–2015. Phoenix, USA.

Bishop, R. 1964. The Mearns quail (*Cyrtonyx montezumae mearnsi*) in southern Arizona. Thesis. University of Arizona, Tucson, USA.

Bishop, R. A., and C. R. Hungerford. 1965. Seasonal food selection of Arizona Mearns quail. Journal of Wildlife Management 29:814–819.

Brown, D. E. 1979. Factors influencing reproductive success and population densities in Montezuma quail. Journal of Wildlife Management 43: 522–526.

Brown, R. L. 1975. Mearns' quail capture method. Final Report. Federal Aid Project W-78-R-15, Work Plan 1, Job 2. Arizona Game and Fish Department, Phoenix, USA.

Brown, R. L. 1976. Mearns' quail census technique. Federal Aid in Wildlife Restoration Project W-78-R-15, Work Plan 1, Job 1. Arizona Game and Fish Department, Phoenix, USA.

Guthery, F. S., M. J. Peterson, and R. R George. 2000. Viability of northern bobwhite populations. Journal of Wildlife Management 64: 646–662.

Guthery, F. S., J. J. Lusk, D. R. Synatzske, J. Gallagher, S. J. DeMaso, R. R. George, and M. J. Peterson. 2002. Weather and age ratios of northern bobwhites in South Texas. 5: 99–105.

Heffelfinger, J. R., F. S. Guthery, R. J. Olding, C. L. Cochran Jr., and C. M. McMullen. 1999. Influence of precipitation timing and summer temperatures on reproduction of Gambel's quail. Journal of Wildlife Management 63:154–161.

Hernández, F., E. Garza, L. A. Harveson, and C. E. Brewer. 2009. Fate and survival of radio-marked Montezuma quail. Gamebird 2006: Quail VI and Perdix XII: 426–431.

Krebs, C. J. 2002. Ecological methodology. Second edition. Harper and Row, New York, USA.

Leopold, A. S., and R. A. McCabe. 1957. Natural history of the Montezuma quail in Mexico. Condor 59:3–26.

Ligon, J. S. 1927. Wildlife of New Mexico, its conservation and management. New Mexico State Game Commission, Santa Fe, USA.

Lusk, J. J., F. S. Guthery, M. J. Peterson, and S. J. DeMaso. 2007. Evidence for regionally synchronized cycles in Texas quail population dynamics. Journal of Wildlife Management 71: 837–843.

National Climatic Data Center (NCDC). 2010. Climate data online. National Oceanic and Atmospheric Administration, Reno, Nevada, USA. www.ncdc.noaa.gov/cdo-web/

National Oceanic and Atmospheric Administration (NOAA). 2010a. Climatological data, Arizona, January 2010, Volume 114. Number 01 ISSN 0145–038. Rocket Center, West Virginia, USA.

National Oceanic and Atmospheric Administration (NOAA). 2010b. Climatological data, Arizona, February 2010, Volume 114. Number 02 ISSN 0145–038. Rocket Center, West Virginia, USA.

National Oceanic and Atmospheric Administration (NOAA). 2010c. Climatological data, Arizona, March 2010, Volume 114. Number 03 ISSN 0145–038. Rocket Center, West Virginia, USA.

National Weather Service (NWS). 2010a. January 2010 climate report for Tucson. U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Tucson, Arizona, USA. www.wrh.noaa.gov/twc/climate/monthly/jan10.php

National Weather Service (NWS). 2010b. February 2010 climate report for Tucson. U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Tucson, Arizona, USA. www.wrh.noaa.gov/twc/climate/monthly/feb10.php

National Weather Service (NWS). 2010c March 2010 climate report for Tucson. U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Tucson, Arizona, USA. www.wrh.noaa.gov/twc/climate/monthly/mar10.php

O'Connor, J. 1936. Mystery quail. Field and Stream, March 1936: 24, 25, 72–74.

Pollock, K. H., S. R. Winterstein, C. M. Bunick, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry approach. Journal of Wildlife Management 53: 7–14.

Quantum GIS Development Team (OGIS). 2011. Quantum GIS Geographic Information System, Version 1.7.0. Open Source Geospatial Foundation Project. Vancouver, British Columbia, Canada. qgis.osgeo.org

Root, T. L. 1993. Effects of global climate change on North American birds and their communities. Pages 280–292 *in* Biotic interactions and global change, P. Kareiva, J. Kingsolver, and R. Huey, eds. Sinauer Associates, Sunderland, Massachusetts, USA.

Smith, A. P. 1917. Some birds of the Davis Mountains, Texas. Condor 19: 161–165.

Swank, W. G., and S. Gallizioli. 1954. The influence of hunting and of rainfall upon Gambel's quail populations. Transactions of the North American Wildlife Conference 19: 283–297.

Stromberg, M. R. 1990. Habitat, movements and roost characteristics of Montezuma quail in southeastern Arizona. Condor 45: 57–65.

Yeager, W. M. 1966. Mearn's quail management information. Special Report. Federal Aid Project, W-53-R-16. Arizona Game and Fish Department, Phoenix, USA.

MONTEZUMA QUAIL MANAGEMENT IN ARIZONA: ADDRESSING NEEDS OF A CONSISTENT, DEDICATED PUBLIC WITH A VARIABLE, INCONSISTENT RESOURCE

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ABSTRACT

Montezuma quail (*Cyrtonyx montezumae*) are unique among species of quail in habitat, diet, and behavior; these distinctions combined with an exotic appearance, and distribution in warmer climates in the United States have made them a popular game bird among a dedicated cadre of upland bird hunters. Montezuma quail are not, however, unique in population fluctuations which are largely affected by climatic factors. The history of harvest management for Montezuma quail in Arizona has generally been one of increasing season lengths and bag limits since the first 2-day hunt in 1960. There have, however, been several instances when season dates and bag limits have been changed, largely in response to public demand from individuals and groups that believed efforts to reduce harvest would protect populations and reduce fluctuation of bird numbers. Research directed specifically at the influence of harvest on Montezuma quail populations has found quail numbers fluctuate independent of potential harvest levels. Density-dependent survival, compensatory mortality, and self-regulating hunter numbers are often invoked to explain fluctuation of quail numbers independent of harvest regulations. We reviewed current literature relative to these issues and investigated Montezuma quail harvest characteristics to inform management options. Hunter numbers, based on hunter questionnaire data collected between 1987 and 2009, had greater influence ($r^2 = 0.616$) on Montezuma quail harvest than either birds/day ($r^2 = 0.474$), or days/hunter ($r^2 = 0.229$) suggesting restricting hunter numbers would affect harvest more than reducing bag limits or season length. The average Montezuma quail hunters in Arizona harvested < 2 birds/day, < 6 birds/season, and hunted < 4 days/season. Dedicated hunters typical of those seeking harvest restrictions are not 'average' hunters and often have inflated views of the impact of hunting on annual fluctuations in bird numbers. Efforts to control harvest commensurate with perceived bird populations would be ineffective at maintaining reliable bird numbers and would be inconsistent with the current state of knowledge relative to effects of hunting on Montezuma quail numbers. Alternative management options including increasing public information and education efforts may be more effective at satisfying the needs of the dedicated community of Montezuma quail enthusiasts.

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Key words: Arizona, (*Cyrtonyx montezumae*), harvest management, Montezuma quail

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SPATIAL ECOLOGY AND HABITAT SELECTION OF MONTEZUMA QUAIL IN TEXAS

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ABSTRACT

Montezuma quail (*Cyrtonyx montezumae*) occur throughout desert mountain ranges in the southwestern United States and northern Mexico. Considered a popular game bird in Arizona and New Mexico, they are not hunted in Texas. A hunting season was proposed for the species in 1997 but met with strong objections, most citing the dearth of information about the species. Much of the literature on Montezuma quail ecology is anecdotal or outdated. Previous researchers had problems capturing birds for marking and, once captured, keeping radio-marked birds alive. We used trained pointing dogs and conducted a radiotelemetry study on Montezuma quail in the Davis Mountains of Texas from January 2009 through September 2010. We captured 72 birds and recorded 966 locations. Home ranges were calculated for 13 individuals which had at least 25 locations. A 95% fixed kernel was calculated on each individual giving a mean ± SD home range of 2,149.4 ± 4,736.8 ha. Movements varied widely by individuals and the greatest straight-line movement was 12.7 km. We also performed habitat selection analysis. Mountain savannah ecological sites were preferred across all 3 spatial scales. Our results confirm that home range size and movements by Montezuma quail occur at a much larger scale than previously reported. Thus, managing lands on a larger scale and targeting mountain savannah ecological sites should be considered.

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Key words: *Cyrtonyx montezumae*, Montezuma quail, northern Mexico, southwestern United States, spatial ecology, Texas

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AGE, SEX, AND NEST SUCCESS OF TRANSLOCATED MOUNTAIN QUAIL IN OREGON, 2001–2010

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ABSTRACT

We trapped mountain quail (*Oreortyx pictus*) from relatively abundant populations in southwestern Oregon for re-introduction or augmentation in areas of central and eastern Oregon where they were rare or extirpated. We captured 2,596 mountain quail during 2001–2010 using treadle-style traps, of which 1,430 were released in Oregon; the remaining birds were transferred to Idaho, Nevada, and Washington. Yearlings (hatch-year) comprised 69.6% of the total ($n = 2,596$). Analysis of nuclear DNA from 850 captured quail revealed 50.5% were male. We radiomarked 800 (55.9%) of the quail released in Oregon and monitored them to estimate reproductive success. We located 150 nests in Oregon; at least 1 egg hatched in 110 (73.3%) nests. Average (± SE) clutch size was 10.2 ± 0.2 eggs and average number of chicks hatched from successful nests was 8.3 ± 0.3. Sixty-eight nests (45.3%) were incubated exclusively by males, 78 (52.0%) exclusively by females, and 4 (2.7%) by birds of unknown gender. Males incubated slightly larger clutches (11.0 ± 0.3) and hatched more eggs than females (5.5 ± 0.5). Males also regularly contributed to brood-rearing. The reproductive effort and nest success of translocated mountain quail was comparable to native populations in Oregon. Translocations may be an effective means of restoring mountain quail populations that have been extirpated or augmenting populations that have substantially declined.

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Key words: clutch size, mountain quail, nest success, Oregon, *Oreortyx pictus,* translocation

INTRODUCTION

Mountain quail have the most northerly distribution of New World quail with a geographic range that extends from northwestern Mexico to Vancouver Island, British Columbia. They occupy some of the highest elevations and diverse habitats known for quail in North America (Gutiérrez 1980, Brennan et al. 1987, Gutiérrez and Delehanty 1999). Mountain quail populations have declined in the western Great Basin, particularly in western Idaho, southeastern Washington, and south-central and southeastern Oregon (Brennan 1989, Crawford 2000). Concern over the decline of mountain quail in eastern Oregon and apparent habitat recovery due to increased riparian protections prompted the Oregon Department of Fish and Wildlife (ODFW), Oregon State University, and the U.S. Forest Service in 2001 to plan for restoration of mountain quail populations in historic ranges in eastern Oregon by translocating wild quail captured from viable populations in southwestern Oregon. Mountain quail are an excellent candidate for translocations because of abundant source populations in western Oregon, relative ease of capture and handling, and potentially high reproductive capacity.

North American quail evolved reproductive strategies that allow rapid increase in populations during favorable conditions. Most North American quail are monogamous breeders, but they often exhibit flexibility in breeding strategies. Northern bobwhites (*Colinus virginianus*), for example, may use polygyny, whereby a female mates with $>$ 1 male, and the female and $\geq$ 1 male incubate independent nests; this strategy explained successful triple-brooding in this species and was confirmed after decades of doubt (Guthery and Kuvlesky 1998). Mountain quail in contrast appear to be strongly monogamous. A female may lay 2 clutches simultaneously in separate nests with the male and the female each actively incubating a clutch (Delehanty 1995, 1997; Pope and Crawford 2001; Beck et al. 2005). Male mountain quail also brood chicks hatched from their nests, often separately from the brood of the female (Delehanty 1995, Pope and Crawford 2001). The combined nests of associated individuals with simultaneous double-clutching may produce up to 26 mountain quail chicks per adult pair during one breeding season (Pope and Crawford 2001).

Translocations have been used as a conservation technique to re-introduce species or augment populations in areas where their abundance has decreased or where they have been extirpated (Scott and Carpenter 1987). Availability of source populations, high productivity, and ability to withstand repeated handling and transport make mountain quail a good candidate for translocation projects (Pope and Crawford 2004, Stephenson et al. 2011). Monitoring reproductive efforts of translocated species is a crucial step to assess the efficacy of translocation and to inform future management decisions. Monitoring is

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especially important for little known species such as mountain quail (Vogel and Reese 1995, Gutiérrez and Delehanty 1999). Our objectives are to describe sex and age ratios of captured mountain quail, and to describe sex- and age-specific nest success and nesting characteristics (e.g., clutch size) of translocated quail in Oregon. We used long-term (2001–2010) data collected at 6 sites in central and eastern Oregon.

METHODS

Study Area

We conducted our study in central and eastern Oregon in Crook, Grant, Harney, Jefferson, and Malheur counties during 2001–2010. Habitat for mountain quail in the study area primarily included western juniper (*Juniperus occidentalis*) and mountain mahogany (*Cercocparpus ledifolius*) woodlands, ponderosa pine (*Pinus ponderosa*) and eastside white oak (*Quercus garryana*) forest and woodlands, and Ceanothus (*Ceanothus* spp.)-Manzanita (*Arctostaphylos* spp.) shrublands (Johnson and O'Neil 2001). Long-term (1981–2010) climate of the study area included similar mean minimum and maximum temperatures for Grant (John Day = 1.6 and 17.6 °C, respectively), Jefferson (Madras = 2.4 and 16.8 °C), and Harney (Fields = 3.0 and 17.1 °C) counties; mean total annual precipitation was 33.5 cm at John Day (Grant County), 30.8 cm at Madras (Jefferson County), and 23.0 cm at Fields (Harney County) (Western Regional Climate Center 2011).

Capture and Handling

Mountain quail were captured during November–February 2001–2010 in southwestern Oregon using custom-made treadle-style traps baited with grain. Age classification was based on the coloration of greater primary coverts (Leopold 1939). Individuals with coverts of uniform color were classified as adults; those with buffy-colored covert tips were classified as juveniles. We reclassified juveniles as yearlings for analysis of reproduction following the spring translocation.

Gender of mountain quail may be difficult to assign and we used DNA analysis from blood taken from a tarsal vein. Analysis was done either by Wildlife Genetics International, Nelson, BC, Canada or DDC Veterinary, Fairfield, OH, USA. Gender testing by these labs was assumed to be accurate. We did not submit blind test samples, but reference samples were analyzed with samples submitted to DDC Veterinary (Randall Smith, personal communication). Captured mountain quail were held in a facility specifically constructed for this species at the ODFW Southwest Regional Office in Roseburg, Oregon. Quail were typically released in March each year and an attempt was made to release pen-mates in the same area in an effort to preserve any pair bonds that may have formed during captivity. All birds were leg-banded prior to release and a subset was radiomarked with ≤6-g necklace-style transmitters (Model PD-2C, Holohil, Carp, ON, Canada; Model AWE-Q, American Wildlife Enterprises, Monticello, FL, USA).

Monitoring

Nest sites were located during April–July each year by homing on radio-marked birds and visually identifying mountain quail incubating clutches. Nesting quail were flushed to locate nests and to record clutch size. Nests and egg remains were examined to record nest success or failure after the end of incubation. Nests with ≥1 hatched egg were considered successful. Nests were not monitored sufficiently often to reliably examine probabilities for nest survival, as average time between visits was 15.3 ± 1.5 days.

Data Analyses

We used 2-tailed *t* tests to examine differences in clutch size and number of eggs hatched by gender and age class (yearling, adult) of incubating individuals. We assessed nest success by comparing proportions of successful nests based on gender-age class. We constructed 95% confidence limits (CLs) for all analyses, and assumed a difference existed if CLs did not overlap between any 2 groups.

RESULTS

During 2001–2010, 2,596 mountain quail were captured for translocation. Most (69.6%) were juveniles (hatch-year) and on average (± SE) represented 71.2 ± 1.8% of the captured quail in each year (range = 64–78%) (Table 1). We collected blood samples for DNA analysis from 850 mountain quail of all age classes. DNA analysis indicated that 421 (49.5%) were female and 429 (50.5%) were male (Table 2). Females comprised 320 (51.6%) of the juveniles while 300 (48.4%) were male. Adults comprised 27.1% of the sample, of which 101 (43.9%) were female and 129 (56.1%) were male.

Clutch Size

Males incubated 68 (46.6%) and females 78 (53.4%) of 146 nests where the incubating bird was of known gender. Mean (± SE) clutch size for all age and gender classes was 10.2 ± 0.2 ($n = 142$). Males incubated larger clutches ($n = 67$, mean = 11.0 ± 0.3, 95% CL = 10.4–11.7) than females ($n = 75$, mean = 9.5 ± 0.3, 95% CL = 9.0–10.1) when the data were pooled. Clutch size did not differ among adult females ($n = 20$; 95% CL = 8.0–10.8), yearling females ($n = 55$; 95% CL = 9.1–10.1), and yearling males ($n = 52$; 95% CL = 10.0–11.5), but was slightly higher for adult males ($n = 15$; 95% CL = 11.1–13.1) than either age class of females. No difference was found between yearlings ($n = 107$; 95% CL = 9.7–10.6) and adults ($n = 35$; 95% CL = 9.6–11.5) when data were pooled by age class.

Nest Success

Gender of incubating birds and nest fate were known for 142 nests, of which 67 were incubated by males and 75 by females. Apparent nest success was 82% (95% CL = 72–91%) for all males and 69% (95% CL = 59–80%)

for females, but was not different. There was no difference in nest success between yearlings (77%, 95% CL = 68–85%) and adults (71%, 95% CL = 55–86%). There was a difference when comparing the number of eggs hatched by adult females (95% CL = 3.8–8.1), adult males (3.9–9.8), yearling females (4.1–6.2), and yearling males (6.5–8.9); yearling males hatched on average 7.7 eggs (Fig. 1A), whereas yearling females hatched on average 5.3 eggs (Fig. 1B). A slight difference was observed when data were pooled by gender (95% CL = 6.4–8.6 for males, 95% CL = 4.5–6.4 for females), but not by age (95% CL = 5.6–7.3 for yearlings, 95% CL = 4.7–8.0 for adults).

DISCUSSION

Age Ratios

There is some evidence of trapping bias based on age class for California quail (*Callipepla californica*) (Crawford and Oates 1986). We could not ascertain if the much greater proportion of juveniles in our capture sample was an artifact of trapping vulnerability based on age category (juvenile vs. adult). However, our results suggested the proportion of juveniles was relatively constant (range = 64–78%) across the 10-year study period. This represented a relatively consistent age ratio compared to other portions of the species' range, especially arid regions, where water can be a limiting factor. The proportion of juveniles in the Mojave Desert ranged from <1% in a dry year to 93% in a 'moist' year (Delehanty 1997). Disparate age ratios among years with varying precipitation were also reported for mountain quail near Joshua Tree, San Bernardino County, California (Miller 1950).

Sex Ratios

Little is known about sex ratios of mountain quail, but a study of wild-captured quail in southwestern Oregon suggested sex ratios may be slightly female-biased (Pope and Crawford 2001). A sample of mountain quail captured in west-central Idaho was also biased toward females (Beck et al. 2005). Miller (1950), in contrast, suggested a nearly 50:50 sex ratio with some evidence toward more males. Most North American quail have male-biased populations; however, the least sexually dimorphic species (such as mountain quail) appear to have the least skewed sex ratios (Brown and Gutiérrez 1980). We assumed no measurable capture bias associated with gender. Our data suggested the sex ratio pooled across all age classes was close to 50:50. However, our capture sample indicated the adult population was biased toward males, while the juvenile population was slightly biased toward females. A shift toward a male-biased population among older age-classes has long been recognized for other quail species, (e.g., California quail [Emlen 1940] and northern bobwhites [Leopold 1945]).

Other published studies of quail included hypotheses that the energetic cost of egg production and incubation, as well as the vulnerability of females while nesting may contribute to lower survival during spring, thus favoring males in the adult segment of the population. A large proportion of male mountain quail incubate clutches and raise broods, which suggests the energetic cost of egg production, and resulting need to spend more time feeding, may also be an important factor in reducing female survival. Male and female mountain quail are known to have similar nest attentiveness patterns (Pope

Table 1. Age characteristics of mountain quail (n = 2,596) captured in southwestern Oregon, 2001–2010.

Year	Adult (≥1 yr of age)	Juvenile (<1 yr of age)	Juvenile (%)
2001	15	54	78.3
2002	27	66	71.0
2003	89	182	67.2
2004	26	89	77.4
2005	124	249	66.8
2006	136	238	63.6
2007[a]	134	238	64.0
2008	69	239	77.6
2009	81	238	74.6
2010	88	214	70.9
Totals	789	1,807	69.6

[a] Excludes one unknown individual.

Table 2. Gender and age (yearlings = < 1 yr of age, adults = ≥ 1 yr of age) and percent males by age of mountain quail released in central and southeastern Oregon, 2001–2010.

	Yearlings			Adults			All ages		
Year	Males	Females	Males (%)	Males	Females	Males (%)	Males	Females	Males (%)
2001	27	27	50.0	10	5	66.7	37	32	53.6
2002	30	22	57.7	10	10	50.0	40	32	55.6
2003	43	58	42.6	24	15	61.5	67	73	47.9
2004	34	36	48.6	10	8	55.6	44	44	50.0
2005	66	62	51.6	29	24	54.7	95	86	52.5
2006	24	28	46.2	16	13	55.2	40	41	49.4
2007	15	27	35.7	9	10	47.4	24	37	39.3
2008	21	18	53.8	9	5	64.3	30	23	56.6
2009	20	27	42.6	6	3	66.7	26	30	46.4
2010	20	15	57.1	6	8	42.9	26	23	53.1
Total	300	320	48.4	129	101	56.1	429	421	50.5

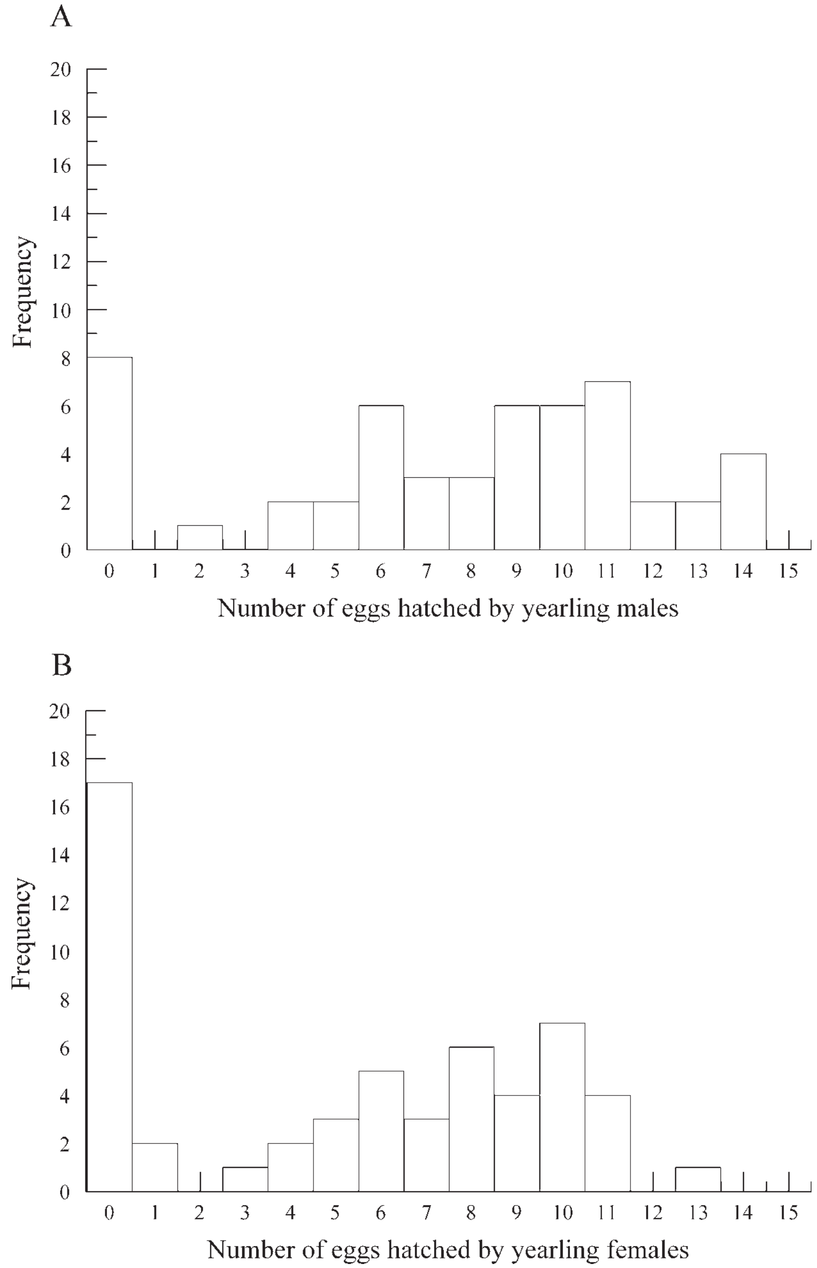

Fig. 1. (A) Frequency of number of eggs hatched by translocated yearling male ($n = 52$) and (B) yearling female ($n = 55$) mountain quail in central and southeastern Oregon during 2001–2010.

2002) and, in one study, female mountain quail had higher survival during the breeding season (Nelson 2007). No gender differences in survival for any season were found for mountain quail in west-central Idaho, and translocated quail in western Idaho and southeastern Washington (Stephenson et al. 2011).

Brown and Gutiérrez (1980) suggested quail with similar sex ratios would have less sexual selection, less intra-male competition, and would be less sexually dimorphic, such as scaled (*C. squamata*) and mountain quail. They lacked data for mountain quail, but cited several papers that reported sex ratios for scaled quail. Data from mountain quail in Oregon show a tendency to be biased toward males, but these ratios more closely approximate ratios reported for scaled quail than highly sexually dimorphic species like Montezuma (*Cyrtonyx montezumae*), Gambel's (*Callipepla gambelii*), and California quail (Brown and Gutiérrez 1980).

Clutch Size

Our finding that males incubated larger clutches than females is consistent with findings from 48 native (not translocated) mountain quail nests in Idaho, where males incubated significantly larger clutches (12.6 ± 0.3) than females (11.4 ± 0.4) (Beck et al. 2005). Clutches incubated by males averaged 11.9 ± 0.4 while those by females averaged 10.9 ± 0.4 in a previous study of 55 nests in Oregon, incubated by both native and translocated birds, but the difference was not statistically significant (Pope and Crawford 2001). Our data and those from other studies indicate the mean clutch size for nests incubated by males was larger than females. Both members of the pair begin incubation within a few days of each other (Pope and Crawford 2001, Beck et al. 2005), suggesting eggs are being contributed to both clutches during the laying period. However, males usually start incubation first (Pope and Crawford 2001, Beck et al. 2005), suggesting the clutch of the male-incubated nest may be completed first. Clutches completed first during the annual reproductive cycle for quail are usually the largest (Johnsgard 1973, Rolland et al. 2011).

The relatively short breeding season, apparent monogamy of paired quail (Pope 2002, Beck et al. 2005), and rarity of renesting attempts (Pope and Crawford 2001, Beck et al. 2005, Abel 2008) limit the possibility of mountain quail using other reproductive strategies with sequential nests (Beck et al. 2005) such as those reported for northern bobwhites (Burger et al. 1995). The selective advantage of the reproductive strategy used by mountain quail would be strengthened if male-incubated nests are more successful and hatch more eggs.

Nest Success

The secretive nature of mountain quail, monomorphism, and remote areas they inhabit make observations of their distinctive breeding behaviors difficult. Consequently, it was relatively recent that male mountain quail were observed to independently incubate clutches and brood chicks with no assistance from females (Gutiérrez 1977, Heekin 1993, Delehanty 1995, Pope and Crawford 2001).

We defined a successful nest as one with ≥1 egg hatching; thus, a successful male-incubated nest would not necessarily result in increased fitness if a smaller proportion of the clutch hatches due to inferior incubation behavior, or other reasons. However, adult males not only incubated larger clutches than other age and sex classes, but males hatched slightly more eggs on average than females of pooled age classes. The successful nesting characteristics associated with males on our study sites supports the continuance of male participation in simultaneous double clutches as a reproductive strategy.

Most nests were discovered after several eggs had been laid or after initiation of incubation, and it is difficult to estimate the total time spent on nesting activity (egg-laying and incubation). Beck et al. (2005) used an average of 1.2 days per egg laid, and estimated the period of nesting activity averaged 59 days (range = 54–64 days). A single egg was found by chance in Oregon in a nest cup on 23 April and later hatched by the male of a marked pair as part of a 14-egg clutch on 29 June (≥68 days of nesting activity) (Abel 2008). Individual eggs of mountain quail are exposed to the environment for a longer period of time than observed for other quail species given the long period of nesting activity required for simultaneous double clutches.

MANAGEMENT IMPLICATIONS

Mountain quail may be good candidates for translocations because of their ability to withstand capture and handling, ability to persist in diverse vegetation types, and abundant source populations in parts of their range. Translocated mountain quail in our study exhibited similar reproductive traits to native quail, which indicated the birds were able to reproduce successfully after translocation. Translocation of mountain quail may be an effective method for restoring this species to suitable habitat within their historic range.

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LITERATURE CITED

Abel, C. 2008. Mountain quail translocations in eastern Oregon. Unpublished Report. Oregon Department of Fish and Wildlife, Salem, USA. www.dfw.state.or.us/resources/hunting/upland_bird/projects/docs/mtn_quail_annualreport_2008.pdf

Beck, J. L., K. P. Reese, P. Zager, and P. E. Heekin. 2005. Simultaneous multiple clutches and female breeding success in mountain quail. Condor 107:891–899.

Brennan, L. A. 1989. Report on a survey of mountain quail habitat in eastern Oregon, southeastern Washington, western Idaho and northern Nevada. Unpublished Report. Chukar Foundation, Winnemucca, Nevada, USA.

Brennan, L. A., W. M. Block, and R. J. Gutiérrez. 1987. Habitat use by mountain quail in northern California. Condor 89:66–74.

Brown, D. E., and R. J. Gutiérrez. 1980. Sex ratios, sexual selection, and sexual dimorphism in quails. Journal of Wildlife Management 44:198–202.

Burger Jr., L. W., M. R. Ryan, T. V. Dailey, and E. W. Kurzejeski. 1995. Reproductive strategies, success, and mating systems of northern bobwhite in Missouri. Journal of Wildlife Management 59:417–426.

Crawford, J. A. 2000. Historic distribution of mountain quail in the Pacific Northwest. Proceedings of the National Quail Symposium 4:194–197.

Crawford, J. A., and R. M. Oates. 1986. Sex and age ratios of shot and trapped California quail. Wildlife Society Bulletin 14:380–382.

Delehanty, D. J. 1995. Incubation and brood rearing by a wild male mountain quail. Western Birds 26:46–48.

Delehanty, D. J. 1997. Mountain quail reproduction and restoration in the Great Basin. Dissertation. University of Nevada, Reno, USA.

Emlen, J. T. 1940. Sex and age ratios in survival of the California quail. Journal of Wildlife Management 4:92–99.

Guthery, F. S., and W. P. Kuvlesky. 1998. The effect of multiple-brooding on age ratios of quail. Journal of Wildlife Management 62:540–549.

Gutiérrez, R. J. 1977. Comparative ecology of the mountain and California quail in the Carmel Valley, California. Dissertation. University of California, Berkeley, USA.

Gutiérrez, R. J. 1980. Comparative ecology of the mountain and California quails in the Carmel Valley, California. Living Bird 18:71–93.

Gutiérrez, R. J., and D. J. Delehanty. 1999. Mountain quail (*Oreortyx pictus*). The birds of North America. Number 457.

Heekin, P. E. 1993. Radio-telemetry reveals secrets of mountain quail in Idaho. Quail Unlimited Magazine 12(2):8–11.

Johnsgard, P. A. 1973. Grouse and quails of North America. University of Nebraska Press, Lincoln, USA

Johnson, D. H., and T. A. O'Neil. 2001. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis, USA.

Leopold, A. S. 1939. Age determination in quail. Journal of Wildlife Management 3:261–265.

Leopold, A. S. 1945. Sex and age ratios among bobwhite quail in southern Missouri. Journal of Wildlife Management 9:30–34.

Miller, E. V. 1950. The life history and management of mountain quail in California. Final Progress Report. Project Number 19-R. California Department of Fish and Game, Sacramento, USA.

Nelson, J. N. 2007. Survival and nest site characteristics of translocated mountain quail on Steens Mountain, Oregon. Thesis. Oregon State University, Corvallis, USA.

Pope, M. D. 2002. The ecology of mountain quail in Oregon. Dissertation. Oregon State University, Corvallis, USA.

Pope, M. D., and J. A. Crawford. 2001. Male incubation and biparental care in mountain quail. Condor 103:865–870.

Pope, M. D., and J. A. Crawford. 2004. Survival rates of translocated and native mountain quail in Oregon. Western North American Naturalist 64:331–337.

Rolland, V., J. A. Hostetler, T. C. Hines, H. F. Percival, and M. K. Oli. 2011. Factors influencing reproductive performance of northern bobwhites in South Florida. European Journal of Wildlife Research 57:717–217.

Scott, J. M., and J. W. Carpenter. 1987. Release of captive-reared or translocated endangered birds: what do we need to know? Auk 104:544–545.

Stephenson, J. A., K. P. Reese, P. Zager, P. E. Heekin, P. J. Nelle, and A. Martens. 2011. Factors influencing survival of native and translocated mountain quail in Idaho and Washington. Journal of Wildlife Management 75:1315–1323.

Vogel, C. A., and K. P. Reese. 1995. Habitat conservation assessment for mountain quail (*Oreortyx pictus*). Unpublished Report. Idaho Fish and Game, Boise, USA.

Western Regional Climate Center. 2011. Western U.S. climate historical summaries, climatological data summaries (temperature and precipitation), John Day, Madras, and Fields, Oregon. Western Regional Climate Center, Reno, Nevada, USA. www.wrcc.dri.edu/summary/Climsmor.html

SCALED QUAIL REPRODUCTION IN THE TRANS-PECOS REGION OF TEXAS

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ABSTRACT

Scaled quail (*Callipepla squamata*) populations have declined markedly throughout their range. We monitored hatch rates and nest placement of radio-marked female scaled quail ($n = 210$) in Pecos County, Texas relative to the availability and location of 'spreader dams' (i.e., shallow water catchments) through the nesting seasons of 1999 and 2000. Hatch rates were high both years (i.e., 67 and 84% for 1999 and 2000, respectively). The predominant nesting microhabitat was tobosa (*Pleuraphis mutica*), which accounted for 85% of the nests located. We failed to document any direct impacts of spreader dams on nesting ecology of scaled quail.

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Key words: *Callipepla squamata*, Chihuahuan desert, reproduction, scaled quail, Trans-Pecos, Texas

INTRODUCTION

Scaled quail declined ~ 4% annually from 1966 to 2010 throughout their range (Church et al. 1993, Sauer et al. 2011), and experienced a precipitous decline (annual rate of decline > 8%) since about 1989 over most of their range in Oklahoma and north Texas (Rollins 2000). Scaled quail populations declined markedly across most of their range in Texas from 1988–2001 (Fig. 1), but notable exceptions occur where populations remained relatively high. One exception was a private ranch in Pecos County, Texas during 1997. The relatively greater abundance of scaled quail at this site was attributed by the landowner to a network of 'spreader dams' (shallow water catchments) that provided better quality microhabitats for scaled quail (i.e., foci of enriched herbaceous diversity and cooler microclimates).

Scaled quail have been the focus of numerous studies over the past 70 years (Bent 1932, Wallmo 1957, Schemnitz 1961, Campbell et al. 1973), but have lagged behind northern bobwhites (*Colinus virginianus*), especially since the advent of radiotelemetry (Rollins 2000, Rollins et al. 2009). Reports by Bent (1932), Wallmo (1957), Schemnitz (1964), and Campbell et al. (1973) were primarily natural history studies based on field observations that provided general ecological information about scaled quail, but little information on nesting ecology, movements, or population dynamics. These data are critical for scaled quail management given extensive declines since the 1960s. We initiated a project in 1999 to: (1) study population dynamics of scaled quail, and (2) document nest site placement relative to spreader dams.

STUDY AREA

This study was conducted on 12,000 ha of private land in southeastern Pecos County, ~ 32 km southwest of Fort Stockton, Texas in the Trans-Pecos ecoregion (Fig. 2). The vegetation was dominated by desert scrub and consisted mainly of creosote (*Larrea tridentata*), tarbush (*Flourensia cernua*), and honey mesquite (*Prosopis glandulosa*). Incidental species included allthorn (*Koeberlinia spinosa*) and catclaw mimosa (*Mimosa biuncifera*). Common grasses included tobosa (*Pleuraphis mutica*) and bush muhly (*Muhlenbergia porteri*). Major land uses included cattle ranching; grazing on study sites consisted of a cow-calf enterprise on a rotational basis at a light to moderate stocking rate (e.g., 30 ha/animal unit).

We compared nesting ecology of scaled quail across 3 sites. Site 1 (treatment) consisted of ~ 6,000 ha east of

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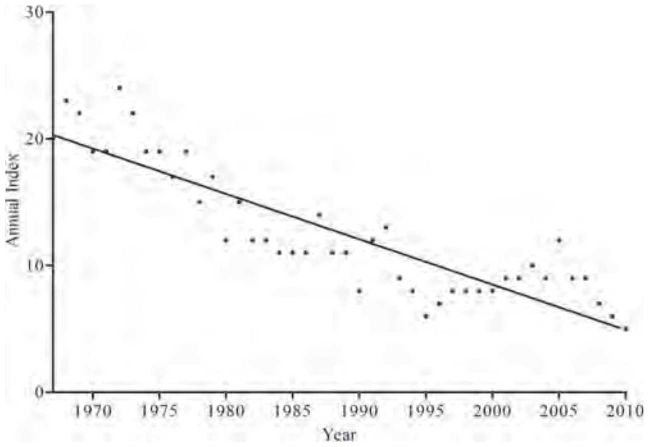

Fig. 1. Scaled quail population trends in Texas from 1967 to 2010 as estimated from Breeding Bird Survey data (Sauer et al. 2011).

the ranch headquarters characterized by numerous spreader dams. Site 2 (positive control) was ~ 800 ha within a larger 2,500-ha area north of the ranch headquarters where quail had access to water and/or green vegetation year-round (via the irrigated lawn and surrounding areas). The positive control (4,500 ha) also included spreader dams. Site 3 (negative control) was ~ 4,500 ha east of site 1. Site 3 did not have spreader dams, although livestock watering points (concrete troughs) were available about every 2.5 km. All sites had similar vegetation and topography with the exception of the microhabitats provided by spreader dams and the area immediately adjacent to the ranch headquarters.

METHODS

We captured scaled quail during March 1999 and 2000 using standard funnel traps baited with milo, and banded them with aluminum, individually-numbered leg bands. Female quail were radiomarked with a ~ 7-g mortality-sensitive neck-loop transmitter (Telemetry Solutions, Concord, CA, USA). Radio-marked quail were monitored twice weekly during spring and summer (e.g., Mar–Aug) 1999 and 2000. Birds were located twice weekly until behavioral indications suggested nest initiation. Nests were located to estimate clutch size and identify nest substrate, and subsequently monitored until hatching or nest loss. Nest initiation was calculated by back-dating based on laying 1 egg every 1.5 days. Nest site availability was estimated by counting the number of

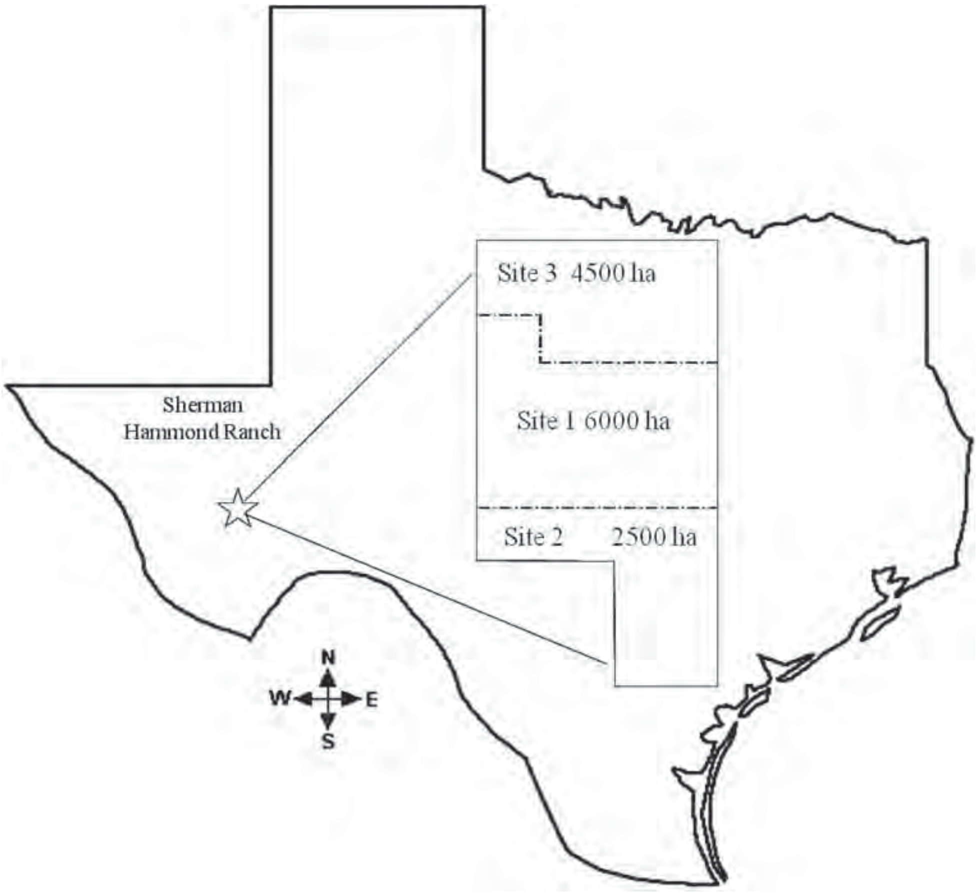

Fig. 2. Location of study areas on the Hammond Ranch, Pecos County, Texas, 1999–2000. Sites 1 (treatment) and 2 (positive control) had spreader dams whereas site 3 (negative control) did not.

suitable clumps of grass that occurred within a 2.0-m belt transect (Slater et al. 2001).

Arthropod sampling was conducted prior to vegetation sampling to minimize disturbance. Twenty-five random points were chosen and a global positioning system (GPS) was used to navigate to the nearest spreader dam. Sweep nets were used for sample collection. Seven sweeps were conducted inside the spreader dam as well as along an adjacent transect > 25 m from the spreader dam. Arthropods were dried and weighed to compare mass inside and outside the spreader dam.

We measured herbaceous biomass at 25 spreader dams in July 1999. A random numbers table was used to define coordinates within the boundaries of the site. Sample points were located using a handheld GPS unit. An additional 25 100-m transects were established at least 50 m from spreader dams in a randomly assigned heading. Vegetation sampling was conducted using a 0.25-m^2 sampling frame. Three quadrats were clipped to ground level inside the spreader dam as were 3 random quadrats along a transect outside the area. Vegetation samples were air-dried to a constant mass and then weighed. Samples were not sorted to species and the data respresent total herbage biomass.

RESULTS

Trapping

We captured 497 scaled quail (290 females, 207 males), 269 in 1999 (154 females [57%], 115 males [43%]) and 228 in 2000 (136 females [59%], 92 males [41%]). Most birds captured were adults in 1999 ($n = 193$ [72%]) and 76 were juveniles (28%). The majority of birds trapped in 2000 were juveniles ($n = 186$ [82%]) with 42 adults (18%). We radiomarked 120 females (40 per site) in 1999 and 90 (30 per site) in 2000. Adults comprised 75% of the females marked on each site in 1999, where 75% of females marked on each site were juveniles in 2000.

Nesting

Sixty-nine of 210 (33%) females established 74 nests over both years of the study with an average clutch size of 11.0 eggs. There was no difference in hatch rates on sites with (sites 1, 77%, and 2, 73%) or without spreader dams (site 3, 62%). Only 1 of 74 nests was in a spreader dam, and it was depredated. The next closest nest was ~ 1 m from the nearest spreader dam.

Thirty-seven (31%) birds established 43 nests during 1999 with the first nest observed on 11 April. We estimated the nest was initiated on 5 April based on backdating, and defined this date as the beginning of the 1999 nesting season. Twenty-nine of 43 nests (67%) hatched across all sites of which 6 were renests by 5 hens. Five nests represented second nests, and 1 represented a third nesting attempt. Five of the 6 multiple nesting attempts were successful.

Thirty-one of 90 (34%) hens established 31 nests during 2000. Nesting was delayed by 30 days relative to the 1999 season, presumably because of a dry winter and spring. The first nest was observed on 11 May. We estimated the nesting season began on 7 May based on back-dating. Twenty-six of 31 nests hatched (84%) across all sites. Hatch rates were similar across all sites in 2000 (site 1, 82%; site 2, 82%; and site 3, 88%). No nests were in or adjacent to spreader dams with the nearest nest 15 m from a spreader dam. No multiple nesting attempts were observed.

Nest Site Availability

Tobosa and bush muhly were the nesting substrates most available across all sites. Thirty-eight of 43 nests in 1999 were established in tobosa with the remainder in bush muhly. We estimated 422 suitable nest sites per ha, 97% of which were in tobosa. Nest site results were similar in 2000 with tobosa and bush muhly the dominant nesting substrate. Twenty-eight of 31 nests were established in tobosa in 2000. We estimated 312 suitable nest sites per ha in 2000, 95% of which were in tobosa.

Vegetation and Arthropod Analysis

Spreader dams significantly influenced overall plant biomass and arthropod abundance. Plant biomass inside the area influenced by spreader dams (mean ± SD = 98.8 ± 8.06 g) was 23 times greater than corresponding areas outside spreader dams (4.3 ± 2.94 g). Arthropod abundance inside the area influenced by spreader dams (0.9 ± 0.14 g) was 4.5 times greater than corresponding areas outside spreader dams (0.2 ± 0.08 g).

DISCUSSION

Spreader dams produced more mesic microhabitats that responded with greater plant and arthropod diversity and biomass. However, these mesic environments were not used as nest sites, as only 2 of 74 nests were in or adjacent to spreader dams. Lerich (2002), in a similar study 90 km southwest of our study area, also was unable to show any contribution or use of spreader dams by radio-marked quail and concluded spreader dams had no effect on scaled quail. Rollins et al. (2009) failed to detect any difference in survival of breeding females across the 3 treatment sites used for our study.

Spreader dams were not used for nest sites, but they may provide benefits beyond the scope of our study. Greater arthropod abundance may have improved brood habitat and increased chick survival and recruitment, but we did not monitor these aspects of reproduction. Benefits of spreader dams to quail, if any, may accrue during the fall and winter in the form of cover or by providing a reliable seed source. Spreader dams likely green up earlier in the year (i.e., late winter, early spring) than surrounding areas and could provide green vegetation for scaled quail. We did not investigate scaled quail ecology in fall or winter in our study, but such studies are warranted.

We observed high hatch rates (67 and 84% for 1999 and 2000, respectively) for quail nests suggesting cover conditions (screening and nesting) were more important for scaled quail hatch rate than the mesic microhabitats provided by spreader dams. Pleasant et al. (2006) also concluded that improved cover conditions caused by precipitation resulted in higher hatch rates (44 and 64% for 1999 and 2000, respectively). Our study sites were conservatively stocked with livestock relative to most ranches in this region. This likely resulted in more abundant nesting cover (e.g., tobosa) across the landscape (as opposed to small islands of nesting habitat provided by spreader dams).

MANAGEMENT IMPLICATIONS

Spreader dams are an attempt to manipulate the influence of rainfall upon habitat conditions. Increased vegetative cover, while not demonstrating positive influences to scaled quail during this study, may be beneficial in Chihuahuan Desert rangelands. Appropriate grazing strategies combined with spreader dams may provide increased vegetative and arthropod biomass.

ACKNOWLEDGMENTS

We thank a group of local landowners and quail hunters, namely Sherman Hammond (deceased), Harlan Lambert, Jimmie Childs, Ernest Woodward, John May, Bentley King, and Dan Law for their willingness to support this project as well as provide part of the funding. A number of other interested sportsmen contributed funds through the 'Adopt-a-Quail' program and their contributions are appreciated. We thank Lannom Industries for donation of the 'ranch buggy' to the Texas Agricultural Experiment Station system.

LITERATURE CITED

Bent, A. C. 1932. Life histories of North American gallinaceous birds. U.S. National Museum Bulletin 162.

Campbell, H., D. K. Martin, P. E. Ferkovich, and B. K. Harris. 1973. Effects of hunting and some other environmental factors on scaled quail in New Mexico. Wildlife Monographs 34.

Church, K. E., J. R. Sauer, and S. Droege. 1993. Population trends of quail in North America. Proceedings of the National Quail Symposium 3:44–54.

Lerich, S. P. 2002. Nesting ecology of scaled quail at Elephant Mountain Wildlife Management Area, Brewster County, Texas. Thesis. Sul Ross State University, Alpine, USA.

Pleasant, G. D., C. B. Dabbert, and R. B. Mitchell. 2006. Nesting ecology and survival of scaled quail in the Southern High Plains of Texas. Journal of Wildlife Management 70:632–640.

Rollins, D. 2000. Status, ecology and management of scaled quail in west Texas. Proceedings of the National Quail Symposium 4:165–172.

Rollins, D., B. D. Taylor, T. D. Sparks, R. J. Buntyn, S. E. Lerich, L. A. Harveson, T. E. Wadell, and C. B. Scott. 2009. Survival of female scaled quail during the breeding season at three sites in the Chihuahuan Desert. Proceedings of the National Quail Symposium 6:279–289.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski Jr., and W. A. Link. 2011. The North American Breeding Bird Survey, results and analysis 1966–2009. Version 3.23.2011. USGS, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Schemnitz, S. D. 1961. Ecology of the scaled quail in the Oklahoma panhandle. Wildlife Monographs 8.

Schemnitz, S. D. 1964. Comparative ecology of bobwhite and scaled quail in the Oklahoma Panhandle. American Midland Naturalist 71: 429–433.

Slater, S. C., D. Rollins, R. C. Dowler, and C. B. Scott. 2001. *Opuntia*: a prickly paradigm for quail management in west-central Texas. Wildlife Society Bulletin 29:713–719.

Wallmo, O. C. 1957. Ecology of scaled quail in west Texas. Dissertation. Texas A&M University, College Station, USA.

EVALUATION OF SURVEY INDICES FOR SCALED QUAIL IN WEST TEXAS

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ABSTRACT

Wildlife biologists and land managers require information on population demographics to effectively plan harvest schedules and evaluate habitat modifications. Population indices can potentially provide an efficient way to gather reliable information on wildlife populations as long as they reflect population behavior. We evaluated the relationships among standard survey indices used to monitor scaled quail (*Callipepla squamata*) across 6 sites in west Texas from 2007 to 2010. We collected data on spring cock call counts, simulated nest survival, roadside counts, and helicopter counts. The mean difference between methods was 2.4 quail/1.6 km on the Andrews County sites, and 4 quail/1.6 km at the Upton/Reagan County sites. Roadside counts and helicopter counts had similar numerical trends in relative abundance with a correlation coefficient of (0.67). Simulated nest fate (i.e., dummy nests) tended to track trends in population abundance. Our survey indices also followed annual fluctuations in scaled quail abundance as estimated from Texas Parks and Wildlife Department's annual roadside surveys.

Citation: Koennecke, B. A., D. Rollins, C. Snow, and J. White. 2012. Evaluation of survey indices for scaled quail in west Texas. Proceedings of the National Quail Symposium 7:364.

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THE FORGOTTEN QUAIL DECLINE: THE PLIGHT OF SCALED QUAIL IN TEXAS

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ABSTRACT

Several quail species are experiencing range-wide declines in the United States. The northern bobwhite (*Colinus virginianus*) has garnered the most attention, both from a research and conservation perspective. The bobwhite decline in Texas, has resulted in considerable time and effort being devoted to research and management on the species due to its status as a highly popular and economically important game bird. This attention has been beneficial to bobwhite conservation and management but, an unfortunate consequence of this focus has been neglect of the scaled quail (*Callipepla squamata*) that has been declining at even a more alarming rate. Scaled quail, according to Breeding Bird Survey (BBS) data, have declined at a rate of 5.1% per year in the Tamaulipan Biotic Province (southern Texas), the greatest of any region surveyed in its geographic range. Anecdotal reports of landowners have long noted the gradual disappearance of scaled quail and concomitant replacement with northern bobwhite throughout southern Texas, beginning since about the 1990s. Analysis of BBS data provides evidence for this replacement. Percent of quail detections in the core of the scaled quail range in the Tamaulipan Biotic Province were 80:20 (scaled quail: bobwhite) during the 1960s but currently represent about 5:95. In addition, the range of scaled quail has been contracting, moving progressively west with time. The species is no longer detected on the easternmost BBS routes in southern Texas.

Citation: Hernández, F., C. J. Parent, I. C. Trewella, and E. D. Grahmann. 2012. The forgotten quail decline: the plight of scaled quail in Texas. Proceedings of the National Quail Symposium 7:365.

Key words: Breeding Bird Survey data, *Callipepla squamata*, *Colinus virginianus*, northern bobwhite, scaled quail

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PHYLOGEOGRAPHY OF SCALED QUAIL

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ABSTRACT

Scaled quail (*Callipepla squamata*) are distributed over much of the Chihuahuan Desert in the United States and south into central Mexico. Four subspecies have been described based on slight variations in coloration and body size, but the distinctiveness of the subspecies is unknown. We conducted a range-wide phylogeographic analysis of scaled quail based on the mitochondrial control region (D-loop). Our objectives were to: (1) ascertain the overall genetic diversity, (2) examine the phylogeographic structure of the scaled quail, and (3) examine the genetic distinctiveness of its 4 subspecies. We obtained D-loop sequences from 190 hunter-harvested wings and 38 museum specimens. Haplotype diversity ($Hd = 0.386$) and nucleotide diversity ($\pi = 0.002$) were relatively low. We found 16 D-loop haplotypes, 5 of which were shared by 2 or more subspecies. Haplotype A (carried by 178 individuals) was most widespread and occurred in nearly every population. Analysis of molecular variance revealed that most of the genetic variation in scaled quail occurred within populations rather than among subspecies. The low levels of genetic diversity probably reflect a historically restricted distribution within the Chihuahuan Desert, and wide geographic distribution of some haplotypes implies expansion from a single refugium. Our data indicate the scaled quail subspecies probably do not represent historically independent units. Phenotypic-based subspecies should not be used as proxies for management units if preserving genetic diversity and evolutionary potential is a goal of management, unless molecular data demonstrate the subspecies represent genetically distinct entities. Our data support viewing the entire species as a single management unit.

Citation: Williford, D. L., R. W. DeYoung, L. A. Brennan, F. Hernández, and R. L. Honeycutt. 2012. Phylogeography of scaled quail. Proceedings of the National Quail Symposium 7:366.

Key words: *Callipepla squamata*, Chihuahuan desert, genetics, scaled quail

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CLOSING REMARKS: ARE WE WHISTLING PAST THE GRAVEYARD?

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Citation: Brennan. L. A. 2012. Closing remarks: are we whistling past the graveyard? Proceedings of the National Quail Symposium 7:367–369.

Key words: case histories, hunting, management, northern bobwhites, quail, research, success

INTRODUCTION

"Whistling past the graveyard" is an idiomatic phrase unique to the English language. It came to mind one evening when I was thinking about how to organize the closing remarks for this conference. The wiktionary.org definition of the phrase "to whistle past the graveyard" is really more of a 4-part explanation than a definition: "*To attempt to stay cheerful in a dire situation; to proceed with a task, ignoring an upcoming hazard, hoping for a good outcome.*" At first pass, it might seem strange to make connections among the 4 parts of this definition-explanation and any lessons about quail science and conservation that might be learned from Quail VII. However, as I continued to think about it, the 4 phrases that combine to define this idiom have a direct connection with the current situation with quail in the United States.

ATTEMPT TO STAY CHEERFUL IN A DIRE SITUATION

The current situation with quail habitat and populations in the United States is dire, indeed. The recent report (Dailey et al. 2011. State of the Bobwhite: Grassland Conservation at a Crossroads, National Bobwhite Technical Committee, Knoxville, TN, USA) outlines a set of circumstances for northern bobwhites (*Colinus virginianus*) that is especially troubling. Each of the past 5 National Quail Symposia, going back to Quail III, documents a continuing and worsening situation for bobwhites. Scaled quail (*Callipepla squamata*) are also experiencing widespread declines, the endangered masked bobwhite (*Colinus v. ridgewayi*) is virtually gone from a refuge that was originally purchased for the sole purpose of recovering this species in the U.S., and the status of the rest of the western quail remains uncertain.

Despite this rather awful situation, I am amazed at the attempts my colleagues have made with respect to putting massive amounts of positive energy towards stopping the quail declines. In other words, people have stayed cheerful in this dire situation. The 2 most obvious ways that people have stayed cheerful is by development of the National Bobwhite Conservation Initiative Version 2.0 (NBCI 2.0) and the Western Quail Management Plan (WQMP).

NBCI 2.0 represents a major overhaul from the original Northern Bobwhite Conservation Initiative. Perhaps most importantly, it contains a spatially-linked set of resources that allows managers and biologists to assess the potential of areas for habitat improvement and restoration across nearly the entire geographic range of bobwhites, and it predicts outcomes for bobwhite population density. Like all predictions it begs to be tested, and this is part of NBCI 2.0. This is unprecedented. Thus, it is critically important for moving bobwhite conservation forward.

The WQMP represents a major step forward for wildlife agencies in the American West. If nothing else, the WQMP brings western quail to the forefront of management attention and priority after languishing in the background for decades. The key to the success of both the NBCI and WQMP will be buy-in and support from state wildlife agency administrators.

The third thing that quail scientists and managers have done to stay cheerful in a dire situation is to conduct a rather impressive amount of research since the last National Quail Symposium 5 years ago. With 80+ presentations (both oral and poster), Quail VII represents a high water mark with respect to the quantity of research findings communicated at a National Quail Symposium. For example, the past 5 National Quail Symposia averaged $\sim$ 46 presentations per conference (Quail III $=$ 29 presentations, Quail IV $=$ 64, Quail V $=$ 54, and Quail VI $=$ 38, respectively).

Of course, National Quail Symposia are not the only outlet for quail research. There has been a recent spate of books as well as stream of articles in the peer-reviewed literature that continue to communicate new research findings about quail. While the vast majority of this effort is directed at bobwhites, this is nothing new. Material on bobwhites has dominated the past 5 National Quail Symposia.

TO PROCEED WITH A TASK

Implementing NBCI 2.0 and the WQMP are clearly 2 tasks with which quail conservationists must proceed as they whistle past the graveyard. This brief essay is not the place to drill into the details of implementing these

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landmark initiatives. However, I think it is safe to say that our next generation of wildlife scientists and managers (the ones who are just entering university wildlife programs today) will have major roles in implementing NBCI 2.0 and the WQMP.

Of course, there is that old bromide: "More research is needed." In 2011 the quail world experienced something unprecedented, populations were doing poorly everywhere, from east to west and north to south, as a result of drought in the west and southeast, and severe winter or too much rain in the east. Will quail populations once again rebound 100%, or will the continuing decline in habitat suitability translate to a step-down in long-term quail recovery? Thus, whether bobwhites and other species of quail operate as metapopulations needs to be addressed, along with the implications related to dispersal, landscape permeability, and amount of habitat area needed to maintain population persistence, etc.

IGNORE AN UPCOMING HAZARD

Nearly every prevailing land use in the continental United States is hostile to sustaining and elevating populations of wild quail. The iron triangle of intensive-farming, industrial forestry that grows and harvests trees like corn, and the inexorable sprawl of suburbia have been the death knell for wild quail over many 10s and even 100s of millions of hectares. Grazing and rangeland management is also problematic especially where exotic grasses, so-called "improved" pastures, and excessive stocking rates predominate. However, rangelands that contain mostly native vegetation, and are not overgrazed, represent one of the best, and last, economical opportunities for quail conservation today.

NBCI 2.0 and the WQMP are not ignoring these land-use hazards when it comes to quail conservation. In fact, they are addressing many of these issues either head-on, or through influencing policy through the political process. Researchers are not ignoring these hazards either. For example, studies of the effects of exotic grasses on quail habitat use and production are something of a growth industry in places like Texas and the Southeastern states. Knowing, for example, that some of these introduced grasses, such as buffelgrass (*Pennisetum ciliare*), provide adequate nesting cover but inadequate foraging cover for quail has been an important step forward with respect to understanding the hazards they present to quail.

HOPE FOR A GOOD OUTCOME

In the 21st century, the places where we will have wild quail, and the opportunities to hunt them, will be the places where people implement purposeful management that provides habitat on the appropriate scale which will support their annual life cycle needs. We see the effects of purposeful management on quail today. For example, Conservation Reserve Program initiatives in the Southeast and Midwest states failed to provide any kind of purposeful management for bobwhites for >20 years until the longleaf pine (*Pinus palustris*) initiative and the buffers for bobwhites (field borders) programs took hold.

In places such as the Red Hills of Georgia and Florida or the vast rangelands of South Texas, people have made a conscious decision, based on various sets of strategies, tactics and motives, to keep quail habitat intact. It should come as no surprise, that areas like these contain sustainable and huntable populations of bobwhites. Cultural management, however, seems to be all the rage these days. Cultural management include actions such as supplemental feeding, releasing pen-raised birds, controlling predators, translocating wild birds, or political maneuvering to shorten hunting seasons and/or reduce bag limits. Cultural management does not sustain or restore wild quail in and of itself. Purposeful management does. Purposeful management is the essential component if hope for a good quail conservation outcome is to be realized.

AN ALTERNATIVE DEFINITION

There is a second, alternative definition of "to whistle past the graveyard" in wiktionary.org that is much more foreboding than the first one that I mentioned at the beginning of this essay. This alternative definition is: "*To enter a situation with little or no understanding of the possible consequences*." The current situation for quail in the U.S. clearly represent a situation where we may have only a foggy view of the possible consequences of our quail conservation efforts. Indeed, drought, severe winter, massive wildfires, climate change, and anthropogenic-caused extinctions are all possible consequences in this world. However, not knowing the possible negative consequences of attempting to provide positive solutions to challenges such as quail conservation is not a legitimate reason to shy away from such pursuits. By ignoring the ongoing quail conservation crisis, we can be certain that quail numbers will have even less chance of being sustained and elevated than they would by implementing NBCI, WQMP, and other efforts.

A NEED FOR SUCCESS STORIES

One of the glaring omissions from the Quail VII program is case histories of management successes. Of the more than 70 papers presented, only 1 (on mountain quail [*Oreortyx pictus*]) documented there were more birds on the study areas at the end of the project than there were at the beginning, which represents a combination of purposeful management (riparian vegetation restored for Salmonids also restored quail habitat) and cultural efforts (translocation of wild birds). Success stories are out there, and we need to create more of them. Back in October 2011, I was stunned at a paragraph in an e-mail from my colleague Dick Potts (Box 1). I never thought that recovery of the partridge populations on his Sussex study area would have been possible in our lifetimes. I sincerely hope that when Quail VIII takes place in Tennessee in 2017, there will be a prominent, and well-populated with presentations, session on the program dedicated to case histories of quail management success stories.

Box 1. Excerpt from an e-mail from G. R. Dick Potts, Director Emeritus of the Game Conservancy Trust, regarding recent gray partridge (*Perdix perdix*) restoration efforts in Sussex. This area in the United Kingdom experienced a 90%+ decline in partridges from the 1960s to the early 21st century

Dear Lenny,
Things have just got better and better here.
Biodiversity has been almost completely restored on a 1,200-ha part of my Sussex study area. Partridge numbers are up 100-fold without any rearing with 400–500 now shot per year, and all achieved since I last saw you in 2006!
Dick Potts
Fordingbridge, UK
24 October 2011

TO ANSWER THE QUESTION

So, are we really "Whistling Past the Graveyard" when it comes to quail science and conservation? In many ways, we are. However, I will argue that we are whistling past the graveyard in the best possible way, knowing full well that we are doing everything we can to make sure the graveyard of past quail conservation failures does not get any bigger. The success of NBCI Version 2.0 and the WQMP will be judged on the success stories that emerge from management efforts related to these initiatives. The successful application of the body of research information presented at this conference, as well as in peer-reviewed journals and scholarly books over the past century will be key to the purposeful management actions required to sustain and elevate populations of wild quail.

ACKNOWLEDGMENTS

I sincerely appreciate the invitation from the Quail VII Program Committee to contribute these thoughts and comments. I also appreciate the editorial guidance provided by T. V. Dailey and C. E. Braun that improved this paper.

APPENDICES

Executive Summary, National Bobwhite Conservation Initiative, March 2011

NBCI 2.0…the unified strategy to restore wild quail

William E. Palmer,[1] Theron M. Terhune, Tom V. Dailey, Don F. McKenzie, and John Doty

Citation: National Bobwhite Technical Committee. 2012. W. E. Palmer, T. M. Terhune, T. V. Dailey, D. F. McKenzie, and J. Doty, eds. Executive Summary: National Bobwhite Conservation Initiative, NBCI 2.0…the unified strategy to restore wild quail. Proceedings of the National Quail Symposium 7:370–380.

Key words: *Colinus virginianus*, conservation, management, NBCI, northern bobwhite

The Problem For Bobwhites

Northern bobwhites (*Colinus virginianus*) were once common, even abundant, on farms, rangelands, and forests across more than 30 states. Bobwhites have declined an average of 3% per year since 1966, and have virtually disappeared from some northern states. The last strongholds are portions of the western states with significant native habitats and quail-friendly land-use patterns, or other locales where bobwhite management is a priority on agricultural or plantation lands. Over most of the species' range, the decline of wild bobwhite populations has relegated quail hunting to memories. The next few decades may be our last opportunity to halt the declines, stem widespread localized extinctions of bobwhites, and restore populations sufficient to create new memories for many.

Not Just Bobwhites

An entire suite of species that live alongside bobwhites in native grasslands and shrublands also is in long-term decline, for example grasshopper, Bachman's, and Henslow's sparrows (Fig. 1). Across the bobwhite's vast range and among the various types of grassland habitats, its bird neighbors change, but not the shared theme of widespread, long-term population declines. Declining species that share habitats bobwhites use include lesser and greater prairie-chickens, loggerhead shrike, yellow-breasted chat, field sparrow, vesper sparrow, Bell's vireo, dickcissel, prairie warbler, red-cockaded woodpecker, brown-headed nuthatch, eastern meadowlark, eastern kingbird, Bewick's wren, golden-winged warbler, blue-winged warbler, painted bunting, orchard oriole, and eastern towhee, among many other species of concern.

Why These Declines?

The causes of these declines are the same: long-term habitat loss or degradation at the national scale. Bobwhites thrive in habitats with a diversity of primarily native grasses, forbs, legumes, and brush, along with some bare ground. In arid environments such as western Texas, Oklahoma, and Kansas, mature grassland/shrubland plant communities provide optimal conditions for bobwhites. But ideal bobwhite habitat conditions are classified as 'early successional' in the lifespan of a plant community in 'rich' environments, i.e., those with high rainfall, fertile soils, and long growing seasons.

For most of the 19th and 20th centuries, typical land uses created habitats that favored bobwhites. But with the advent of modern agricultural and silvicultural practices following World War II, along with the elimination of the cultural use of fire to manage forests and fields, the diverse herbaceous ground cover these species need has mostly vanished. Grazing lands throughout the East were converted from native, clump-grass forages to aggressive, sod-forming, exotic forages on pastures that provided poor quail habitat. Rowcrop agriculture intensified to bigger fields with fewer fencerows and weeds … and poorer habitat. Modern silviculture practices transformed millions of hectares (acres) of southern forests into dense pine plantations, and nearly eradicated fire. Societal sentiments against logging impeded forest management on millions of other hectares (acres) which, when combined with the elimination of fire, erased quail habitats. The cumulative result across dozens of states is that changing land management practices have degraded habitats for grassland birds across three of the largest land-use types.

Consider, for example, the near complete functional demise of the pine-barrens of the mid-Atlantic, the vast longleaf pine savannah ecosystem of the deep Southeast, the oak savannahs of the Midsouth, the shortleaf pine-bluestem ecosystem of the Midwest, and the tall- and mixed-grass prairies across the bobwhite's entire range. These disparate ecosystems that once provided vast, high-quality habitat that supported abundant bobwhite populations share a functional dependence on frequent fire and/or animal grazing, which set back vegetative succession to sustain a ground cover of vegetation with the appropriate

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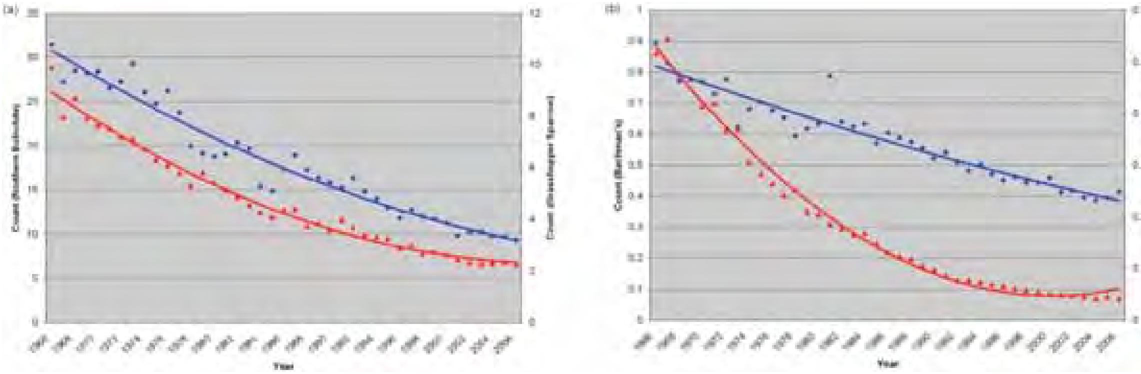

Fig. 1. (a) Population trends (mean annual BBS counts) for the northern bobwhite (blue) and grasshopper sparrow (red), and (b) population trends (mean annual BBS counts) for Bachman's sparrow (red) and Henslow's sparrow (blue) indicating a common habitat cause for declines.

structure and composition for bobwhites. To halt the decline of bobwhites and return recreational opportunities to 1980-era levels, as called for in the original 2002 Northern Bobwhite Conservation Initiative (NBCI 2002), landscape-scale habitat restoration is needed on farms, forests, and other private and public lands along with the return of natural disturbance cycles, such as prescribed fire, at the appropriate scale and frequency.

Reasons for Hope

While declines have been precipitous and sustained, there are reasons to be optimistic. First, bobwhite populations still exist across significant portions of their range in sufficient numbers so they can respond, in time, to sound and targeted habitat initiatives. Second, where bobwhites are locally extinct but habitat is sufficiently restored, translocation of wild bobwhites has become a viable option for recovering populations locally. Third, habitats managed to be suitable for bobwhites overlap with myriad species in decline so that increasing bobwhite habitat engenders wide support and collaboration across the conservation community. Native grassland habitats managed for other popular species such as grassland songbirds, cottontail rabbits, ring-necked pheasants, elk, and wild turkey can also benefit bobwhites.

The First Step: the 2002 Northern Bobwhite Conservation Initiative

Sometimes a crisis is necessary for a change. Even as conservationists were proudly heralding myriad other wildlife restoration success stories throughout the mid- and late-20th century, a half-century of land-use changes had quietly reduced bobwhite populations to non-huntable levels in many parts of their range. By the end of the 20th century, this 'unfinished business' of wildlife conservation resulted in the fading of an American culture and a treasured rural heritage. In 1998, following a half century of failed *laissez faire* quail management, the directors of the 16 southeastern state fish and wildlife agencies took a definitive step – to go it together, instead of alone – by issuing a charge to develop a regional recovery strategy.

Bobwhite conservation found hope in March 2002. That month, the Southeast Quail Study Group (SEQSG), on behalf of the Southeastern Association of Fish and Wildlife Agencies (SEAFWA) published the 'Northern Bobwhite Conservation Initiative' (NBCI 2002). Nearly 60 biologists had collaborated to describe the problems of bobwhites, prescribe habitat management solutions, and lay out a blueprint of restored acreages needed to meet desired population recovery goals for bobwhite restoration. The overall vision was to restore bobwhite populations to at least 1980-era levels.

The 9 years since completion of NBCI 2002 have fundamentally changed quail conservation. NBCI 2002 garnered regional and national attention, causing bobwhite restoration to become a national priority and a common topic of the national conservation dialogue. Results included close collaboration with Partners in Flight songbird conservationists; Congressional support of bobwhites in the 2002 Farm Bill; creation of the Conservation Reserve Program's (CRP) CP33 'Habitat Buffers for Upland Birds' practice, the CP36 Longleaf Pine Initiative, and the CP38 'State Acres for Wildlife Enhancement' practice by the USDA Farm Service Agency; the 9-state, $1.5 million bobwhite restoration research project by the USDA Natural Resource Conservation Service; and an increase in state quail initiatives from 2 to 18.

On the ground, several state wildlife agencies began linking their quail restoration plans to NBCI 2002, resulting in notable examples of NBCI 2002 fulfilled, such as in Scott and Cass counties, Missouri. Success in these counties was measured by an increase in habitat, anecdotes and data about population response by quail, and ultimately, a marked increase in quality quail hunting that made the Sikeston, Missouri Chamber of Commerce news.

Positive results created additional opportunities, demands, and expectations for collective action that in turn required state-centered infrastructure and capacity that did not exist. The states and the bobwhite community forged ahead with another round of 'firsts,' such as selecting the University of Tennessee as the national operational center for NBCI. Meanwhile, all components of the Initiative were expanded range-wide in scope. The SEQSG now is the National Bobwhite Technical Com-

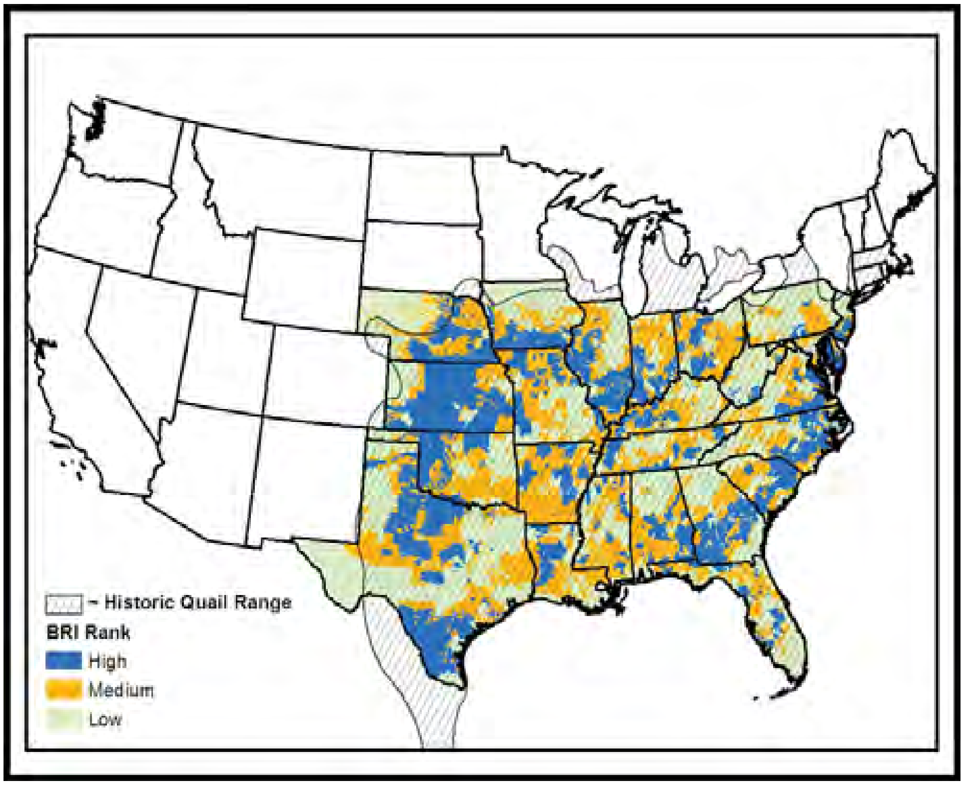

Fig. 2. The National Bobwhite Conservation Initiative's BRI indicating the potential for habitat restoration benefiting bobwhites and grassland songbirds. Across 17 Bird Conservation Regions (BCRs), 29.1% of the landscape was identified as having high potential for bobwhite management.

mittee (NBTC), expanded from the 16 SEAFWA states to include 25 states across the bobwhite's core range, and the jurisdictions of the Midwest, Northeastern, and Western Associations of Fish and Wildlife Agencies. The original SEAFWA Directors' NBCI 2002 Committee has grown into the national NBCI Management Board, and the regional 2002 'Northern Bobwhite Conservation Initiative' now is the 'National Bobwhite Conservation Initiative'.

At the same time, enhanced collaboration is occurring among bobwhite conservationists and other conservation groups, including Southeastern Partners in Flight, Joint Ventures, the Midwest Pheasant Working Group, the National Wild Turkey Federation, Landscape Conservation Cooperatives, and the Western Quail Working Group.

The Next Step: NBCI 2.0

From the beginning, all involved in producing NBCI 2002 knew that it would need continual refinement and updating to stay relevant and remain a force for progress. Revising NBCI 2002 was a massive undertaking, involving 5 years of planning efforts across 25 states, dozens of agencies, more than 600 professionals, and incorporating the latest geospatial and data management technologies. The purpose of this summary report is to introduce conservation leaders, the public, and policy decision-makers to the scope, utility, and power of the new NBCI 2.0. The full report of the NBCI 2.0 is available on-line (http://www.bringbackbobwhites.org).

NBCI 2.0 is primarily an information framework (the Biologist Ranking Information or 'BRI') and a mechanism (the Conservation Planning Tool or 'CPT') for states to use to develop or refine quail habitat management and restoration plans, thus saving time and money. The BRI is state biologists' collective expert judgment of exactly where and how much they should focus resources for bobwhite conservation. The CPT is a massive data base of the latest geospatial and interactive data management technologies and planning tools. Those are 2 of the 3 major features not found in the original NBCI. The third major feature is Adaptive Resource Management (ARM), the use of estimated current and potential bobwhite population densities in a structured decision making framework to provide feedback on the effectiveness of restoration efforts. Together these improvements move the state-based NBCI 2.0 to the forefront of wildlife conservation strategies.

The original NBCI 2002 changed bobwhite conservation. This revision, NBCI 2.0, will improve our efforts. We largely know what to do; we largely know how to do it; NBCI 2.0 shows us, better than ever, *where* to do it, and gives us the tools to test our effectiveness.

The Process

The NBCI 2.0 process uses a novel combination of computer-based geospatial technology and human professional judgment to produce a 25-state geographic model of quail recovery priorities, opportunities and constraints

(Fig. 2). More than 600 professional contributors to NBCI 2.0 (10 times more experts than contributed to NBCI 2002) participated in 2-dozen state workshops. Most participants were state biologists with local field experience, ensuring that NBCI 2.0, through the BRI, is relevant to the on-the-ground habitat restoration challenges of the 21st century. Field biologists provided informed expertise unattainable by satellite imagery or geospatial data layers, such as current distributions of quail, and the economic or sociological potential for habitat management by the people who control the land, whether private or public.

The CPT also relies heavily on analysis of standard geospatial habitat data, including distribution of vegetation types, soils, land ownerships, and Farm Bill program acreage, to prioritize areas for habitat recovery. This component of NBCI 2.0 allows bobwhite data to be integrated with other complementary conservation efforts.

Biologists at 23 structured workshops evaluated over 600,000,000 acres of landscape across the core bobwhite range. The landscape was divided into 2,590-ha (6,400-ac) cells, which biologists evaluated against a list of key quail restoration criteria, including landscape features, habitat types, management opportunities, and management constraints. The High-Medium-Low rankings illuminate regionally-specific areas where opportunities to recover bobwhites have greatest potential and the least constraints.

The Plan

NBCI 2.0 is presented in 2 parts—a written report, and a GIS-based BRI and the CPT. The written report contains 5 sections.

(1). Introduction and background information.
(2). An overview of bobwhite ecology and management.
(3). A description of the BRI and CPT with the major results – findings are presented primarily by bird conservation regions (BCRs), consistent with other bird conservation plans. State and county-level data are available on the web and the GIS web mapping applications. Habitat rankings and management prescriptions are available for customized reports, data analysis or planning, using CPT interactive tools.
(4). Regional assessments of primary bobwhite conservation needs and challenges – to discuss how policy and management must adapt to local and regional conditions, opportunities and constraints for successful conservation.
(5). Monitoring and evaluation – provide recommendations on how to improve monitoring and make it integral with NBCI 2.0, to evaluate the plan's effectiveness, and continually improve it.

Spatial Estimates of Habitat Management Opportunities

In the BRI process, biologists provided recommendations as to what habitat management practices are needed by habitat type. Opportunities to manage for bobwhites and other early-successional species varied across and within regions. As such, what works in one region may have little utility in another region. For example, practices such as CP33 field borders were very important in certain regions of the country, but not in others. However, prescribed fire is the most often cited need for habitat management across the bobwhite range. With the CPT, biologists can rapidly prepare detailed reports on regionally-specific management information, and provide guidance on habitat restoration policy. Spatially-explicit habitat management recommendations also can be used to evaluate benefits to other wildlife species.

Spatial Estimates of Constraints

For every management need, certain factors impede its effective application to the landscape. For instance, land ownership patterns may be a major constraint to application of habitat management across large landscapes. Therefore, in addition to ranking areas and recommending habitat management needs by habitat type, biologists provided spatial prescriptions of constraints. Recognition of these constraints is necessary to successfully design habitat restoration plans and policies, by guiding administrators to where needed management should be applied while avoiding regions where likelihood of success is lower.

Spatially-specific Current and Managed Bobwhite Densities

The ultimate goal of NBCI is to use habitat management to increase bobwhite population density to huntable levels across much of its former range. To do this, state quail biologists created a spatial layer of current estimated 'unmanaged' and future potential, 'managed,' densities of bobwhites, if given proper management implementation. Using these estimated data, NBCI 2.0 predicts we could add 2.36 million bobwhite coveys (12 birds/covey, average) to landscapes rated with High BRI potential and 2.31 million coveys in areas rated with Medium BRI potential *if* ALL the prescribed management occurred (Table 1).

Table 1 is intended to provide states a big picture view of the potential increase in quail abundance in their state if biologists' prescriptions are followed and implemented. It is more likely, however, that habitat management must begin with focused effort on smaller portions of the landscape as part of integrating NBCI 2.0 habitat and quail population goals into state focal areas. In 2010, NBCI states reported a vast range of sizes of bobwhite focal areas: from 121 to 942,837 ha (300-2,329,800 ac). In general, larger focal areas have greater potential to sustain quail hunting over the long term. Smaller focal areas have tremendous value in demonstrating what is possible, particularly in landscapes where suitable habitat is rare. A priority for NBCI 2.0 and beyond is identifying relationships among different levels of habitat restoration and subsequent improvements in bobwhite populations, quail hunting activity, rural economies, and quality of life.

Table 1 provides state-by-state BRI summarized by habitat type for areas ranked High or Medium, and corresponding number of coveys predicted to be added to the landscape. Coveys added are considered potentials

Table 1. State summary of Biologist Ranking Information (BRI) summarized by habitat type (Acres × 1,000) for areas ranked High and Moderate with associated number of coveys predicted to be added (Coveys Added) to current populations levels. Coveys added are considered potentials without a time scale, where potential is dependent on realizing the habitat management goals as stipulated in the NBCI. Coveys added depict crude estimates of population targets for states and can viewed properly as hypotheses to be tested (i.e., models) in an adaptive framework.

State	Rank	Row Crop	Range	Hardwood	Mixed Forest	Pasture	Upland Pine	Coveys Added
Alabama	High	250	1,053	1,770	366	856	2,281	63,643
	Medium	175	1,632	3,026	841	1,240	3,903	98,857
Arkansas	High	1,658	151	2,590	201	1,587	784	118,405
	Medium	2,827	966	5,159	422	2,667	5,072	222,692
Delaware	High	115	0.8	115	4.8	13	17	570
	Medium	236	1.6	154	8.2	22	12	1,039
Florida	High	320	633	266	59	687	1,471	59,312
	Medium	672	1,535	855	80	1,825	3,186	80,206
Georgia	High	1,806	1,919	1,534	255	559	3,420	118,877
	Medium	594	1,241	2,122	130	180	3,154	52,284
Illinois	High	6,196	73	3,358	2.3	2,332	6.2	22,416
	Medium	6,872	25	1,741	1.0	1,286	26	25,895
Indiana	High	2,624	74	2,227	0.8	1,026	29	64,368
	Medium	5,614	150	2,207	2.7	1,141	21	70,604
Iowa	High	2,957	230	1,222	3.9	2,944	1.6	103,494
	Medium	4,688	295	608	0.8	1,243	0.5	49,204
Kansas	High	13,176	13,354	966	25	2,074	3.3	609,170
	Medium	3,538	2,653	575	10	1,794	3.6	183,613
Kentucky	High	566	94	2,614	2.4	716	66	30,178
	Medium	1,527	298	5,115	39	1,286	103	83,633
Louisiana	High	117	980	49	104	378	2,524	30,870
	Medium	1,439	1,208	112	119	1,890	2,310	69,947
Maryland	High	586	5.6	455	18	77	130	26,545
	Medium	401	10.0	766	4.7	258	41	9,424
Mississippi	High	515	424	389	218	874	813	76,280
	Medium	795	2,019	2,130	996	2,402	2,806	211,832

Table 1. Continued.

State	Rank	Row Crop	Range	Hardwood	Mixed Forest	Pasture	Upland Pine	Coveys Added
Missouri	High	2,109	13.8	1,841	1.4	4,778	5.2	76,861
	Medium	3,789	66.4	5,662	27	6,951	133	296,591
Nebraska	High	5,662	6,114	458	4.8	152	5.9	67,099
	Medium	6,908	6,434	211	16	68	28	97,412
NewJersey	High	141	15.6	259	5.3	10	310	979
	Medium	91	20.2	150	2.0	4	38	458
NorthCarolina	High	1,981	559	1,194	169	444	1,970	73,057
	Medium	1,202	377	2,818	104	802	1,342	47,018
Ohio	High	2,800	57	1,266	3.8	923	13	2,023
	Medium	3,770	118	5,180	1.4	2,354	70	9,501
Oklahoma	High	1,975	8,759	775	63	132	237	252,262
	Medium	2,744	7,186	4,507	147	1,807	1,158	176,734
Pennsylvania	High	498	14	274	16	93	9.1	1,330
	Medium	1,592	83	3,259	98	350	116	5,433
SouthCarolina	High	1,101	568	439	358	280	1,725	34,801
	Medium	635	329	1,215	183	303	2,020	26,573
Tennessee	High	1,127	278	2,017	60	560	140	45,344
	Medium	636	712	5,492	213	943	280	120,192
Texas	High	2,457	33,566	1,129	16	2,924	996	464,552
	Medium	3,271	24,347	2,016	279	5,521	4,129	334,491
Virginia	High	1,184	190	2,472	33	99	1,209	18,667
	Medium	1,927	221	3,921	55	295	785	34,693
WestVirginia	High	211	38	1,067	1.5	99	8.8	3,066
	Medium	138	9.7	1,438	4.4	115	16	3,536
TOTAL	High	52,134	69,462	30,747	1,992	24,619	18,184	2,364,169
	Medium	56,081	51,935	60,436	3,783	36,746	30,754	2,311,862

without a time scale, where potential is dependent on fulfilling habitat management as prescribed in NBCI. Taking Alabama as an example, for land rated as having High potential for restoration (High BRI), acreage breakdown by habitat type was 101,171 ha (250,000 ac) in row crop landscapes, 426,134 ha (1,053,000 ac) in rangeland, 716,294 ha (1,770,000 ac) in hardwood forests, 148,115 ha (366,000 ac) in mixed forest, 346,411 ha (856,000 ac) in pasture land, and 923,088 ha (2,281,000 ac) in upland pine landscapes. If all these acres were restored and managed per NBCI prescriptions, 63,643 coveys would be added to populations occupying these High BRI areas. If all of Alabama's lands rated as having Medium BRI potential were managed per NBCI prescriptions, 98,857 coveys would be added to the landscape. For Alabama, and many other states (Arkansas and Delaware, for example), coveys added is *greater* in lands with *lower* potential simply because there are many more acres rated as Medium than rated High. Biologists expect lower quail density on Medium BRI lands relative to High BRI lands, and it is only when there are many more acres of Medium land that those populations catch up to the greater potential of the High BRI lands. High BRI lands usually will be a higher priority for restoration because the same amount of effort and money are expected to produce more quail.

Web-based Planning

NBCI 2.0 is spatially-explicit, dynamic, updatable, extensible, and scalable to effectively impact conservation of bobwhites, grassland birds, and grassland and early-succession ecosystems. The plan is web-based and uses a GIS-data base platform so it can be easily shared with other conservation partners to permit layering of conservation efforts. User-friendly graphic user interface (GUI) tools are being created to help users access data for the areas they need, and the data base infrastructure enables states to work with NBTC (and NBCI) to add additional tools (e.g., data entry and archival) to meet other needs and conservation objectives. The updatable framework fosters long-term grassland ecosystem restoration planning that remains adaptable, timely, and useful to multiple conservation partners. Such collaboration will save time and money for state agencies.

TOOL-BOX SECTION

NBCI 2.0 Conservation Planning Tool

A primary goal of NBCI 2.0 was to produce a strategic Conservation Planning Tool (CPT) that was spatially and temporally explicit, while pragmatic, flexible and dynamic, extensible, and usable by various organizations. The strength of the CPT is the biologist ranking information (BRI) data. The CPT was designed with the biologist in mind for adding data and data extraction, but not necessarily, at least at present, for the general layperson audience. However, the CPT can be adapted easily to incorporate components more directly benefiting non-biologists (i.e., private landowners). As such, the CPT is composed of a collection of components, each with different levels of functionality depending on users and objectives: web mapping applications (WMAs); actual data available for download including the biologist ranking information (BRI) and ancillary data (e.g., NRI data, land cover classification); and a planning toolbox for ArcGIS.

Web Mapping Applications.—The WMAs are internet-based maps used for general viewing of habitat ranking informed by the revision-generated BRI as well as viewing of habitat classifications (e.g., land cover data, NRI data), farm bill practice information (e.g., summary contract and acres-by-practice information), and other relevant geospatial data (e.g., urban areas, conservation areas). Additionally, WMAs afford biologists the ability to print maps, perform simple and predefined queries, and perform routine mapping actions (e.g., calculate area or distance, identify layer attributes). All that is needed to use the WMAs is a high-speed Internet connection and browser.

Data Availability.—Most of the data used in the revision, and which are viewable via the online web mapping applications are available for download in various formats.

Planning Toolbox.—The intent of the planning toolbox is to provide biologists or more advanced users with access to ArcGIS, a suite of tools to aid in conservation planning of bobwhites and grassland birds. The toolbox can be downloaded and integrated directly into ArcGIS. It offers the most extensive range of usability and was designed to work with data generated via NBCI 2.0.

These tools will allow you to:

- query data,
- display data,
- perform geospatial analysis,
- create maps, and
- generate reports for conservation planning, agency reports, and grant applications.

BUILDING CONSERVATION AROUND NBCI 2.0

Armed with local expert evaluation of habitat restoration potential (the BRI), conservationists can simultaneously integrate bobwhite habitat restoration potential at the local, state, regional, and national levels, and provide justification for why a boundary line was drawn between adjoining landowner properties.

Example 1 (Fig. 3): Conservationists desire to identify areas where longleaf pine (LLP) and bobwhites can be restored simultaneously and, because of limited funding, areas need to be prioritized by their relative restoration potential.

- Left panel: the entire NBCI 2.0 coverage (olive green) is shown; neon green areas are classified by state biologists (BRI ranking) as having High or Medium potential for simultaneous LLP/bobwhite restoration. Also shown in light green in map inset is historic distribution of the Longleaf Pine ecosystem.
    - ○ Of the roughly 20 million ha (50 million ac) identified as improvable via LLP restoration, roughly one-half (26 million ac) have High

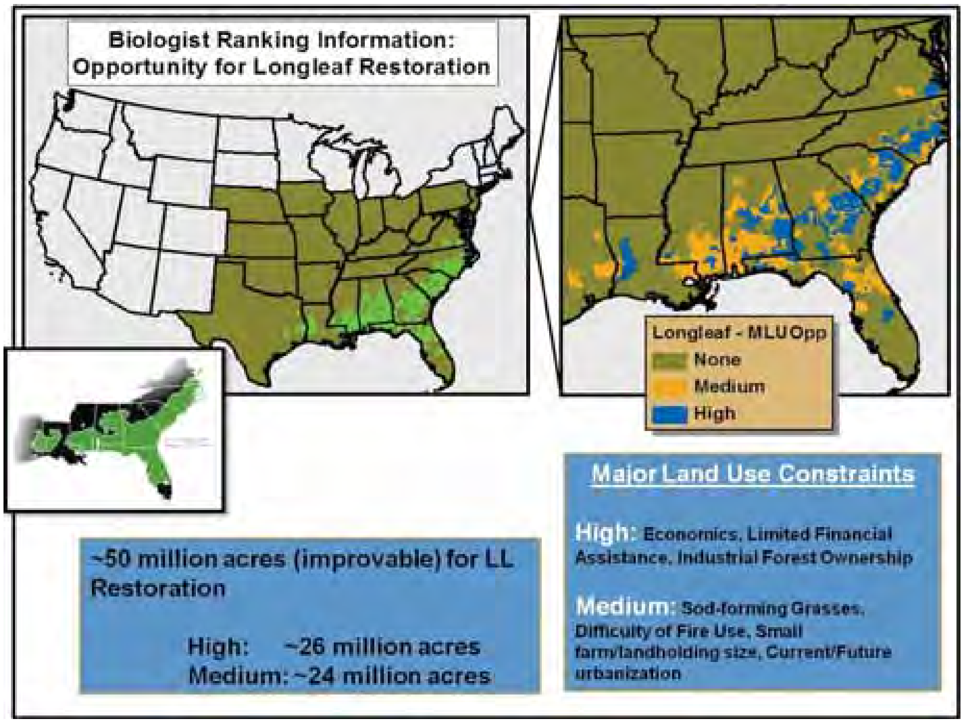

Fig. 3. The intersection of biologist ranking information (BRI) ascribing management opportunity for longleaf pine restoration, longleaf pine historic range, and potential for bobwhite response.

restoration potential and one-half (24 million ac) have Medium potential. High and Medium in BRI language are relative terms. High BRI indicates that the likelihood for successful bobwhite restoration is greater, relative to Medium-ranked areas. The details behind these disparate ratings are shown in the right panel, and described below.

To get the greatest 'bang for the buck,' conservationists must identify areas where restoration potential is relatively high. NBCI 2.0 divides the landscape by restoration potential, and backs up this designation with local, expert information on social as well as resource management opportunities and constraints.

- Right panel: Major Land Use Opportunities (MLU) are classified using the BRI ratings of High (blue), Medium (orange), and No (none) (olive green) illustrating the relative potential of the landscape for restoring bobwhites in the LLP area.
  - To get the greatest bang for the buck, conservationists must identify areas with the greatest potential for restoration, based on numerous factors, such as the condition of existing habitat and the extent to which landowners are willing, technically capable, and financially able to conduct habitat work.
  - The Major Land Use Constraints for High-BRI lands are economics and limited financial assistance (e.g., restoration is expensive and outside funds are limited) and by the presence of industrial forest owners whose primary goal is income. Relative to the constraints in Medium-BRI areas, however, local experts believe restoration is more feasible.
    - Major Land Use constraints often separate High from Medium ranked areas: the greater the constraint the greater the impediment to successful management and subsequent bobwhite response. In this case, the constraints listed in the Medium ranked areas (sod-forming grasses, difficulty of fire use, small farm/landholding size, current/future urbanization) are viewed as serious obstacles to restoration potential. For example, the potential for increased urbanization is one of the greatest sources of wildlife habitat loss.
  - Returning to the original question, conservationists in this case would recommend the High (blue) areas be funded first because they best meet management objectives for restoring longleaf pine communities and bobwhite populations.

Example 2 (Fig. 4): Conservation today attempts to understand how proposed management affects all species of plants and animals, and the environment in general. This desire translates to myriad geospatial data bases for birds, endangered species, watersheds, and urbanization. NBCI 2.0 can be integrated with any spatial data base. The detailed BRI analysis can be scaled down or up to inform large-scale conservation planning initiatives and management/planning units, such as landscape conservation cooperatives and joint ventures.

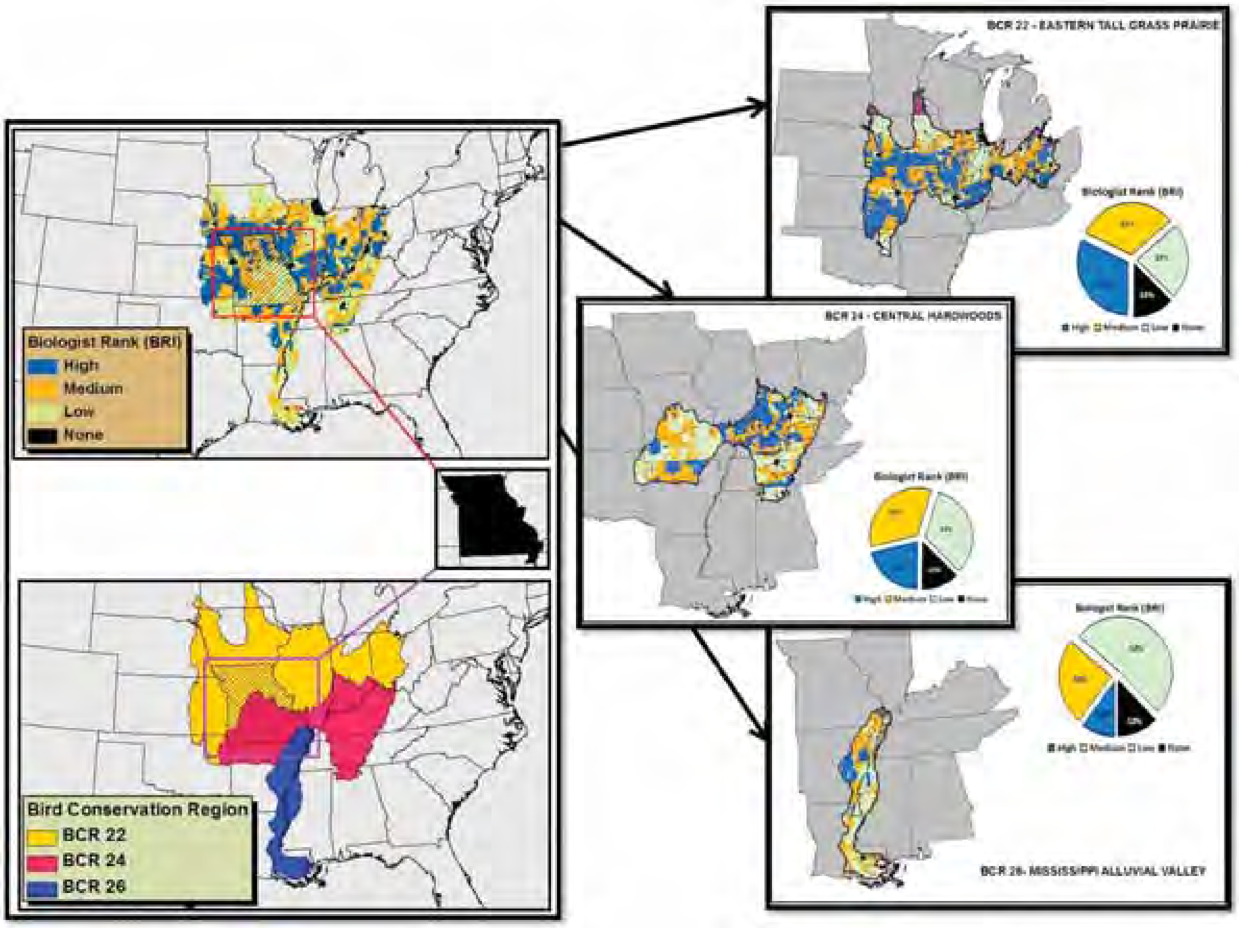

Fig. 4. Representation of the BRI summarized at the Bird Conservation (BCR) level. The conservation planning tool can be easily and seamlessly integrated into multiple conservation planning efforts or overlaid with other geospatial layers to identify priority conservation areas and target species.

Most states are covered by multiple bird conservation regions, and the CPT readily identifies common conservation (e.g., BCRs, Midwest Association of Fish and Wildlife Agencies) and political boundaries (state and county). The CPT (Fig. 5) uses data for Missouri, overlaying state biologist ranking information (BRI) classifications across the state, BCR boundaries, and BRI data for each of the BCRs.

- Upper left panel: Missouri's BRI classifications. From highest bobwhite restoration potential (High BRI) to Low BRI, and None. The None classifications are typically urban areas.
- Lower left panel: Missouri is covered by 3 BCRs.
- Right 3 panels: Considering each BCR separately, these maps show the potential for bobwhite habitat restoration. Comparing among Missouri's 3 BCRs, it is clear that Missouri biologists see the greatest potential in the Eastern Tallgrass Prairie with 32% of the landscape classified as having High potential, less potential in the Central Hardwoods with 23% of the landscape as having High potential, and relatively low potential in the Mississippi Alluvial Valley with 10% High potential.

Bobwhite management provides just one perspective on conservation, with a multitude of other factors affecting conservation priorities. For example, songbird, elk, and wild turkey brood-rearing habitat management are priorities in the Central Hardwood BCR in Missouri, translating to a value-added situation when bobwhite management is added. The NBCI conservation planning tool allows for layering of conservation priorities, improving the chances for bobwhites to be considered in decisions about management of landscapes.

Example 3 (Fig. 5). Each state is charged with crafting conservation based on a multitude of programs – such as Joint Ventures and Landscape Conservation Cooperatives – and a natural question arises. If we achieve the goals of plan X, what is ***our*** contribution to conservation of a particular plant or animal species, ecosystem, or quality of life, in the case of bobwhite hunting? Often people are motivated by such information, whether by pride in a place, or by having a role in some greater good. The NBCI 2.0 CPT allows for calculation of attainment of habitat and quail population goals for any geospatial division.

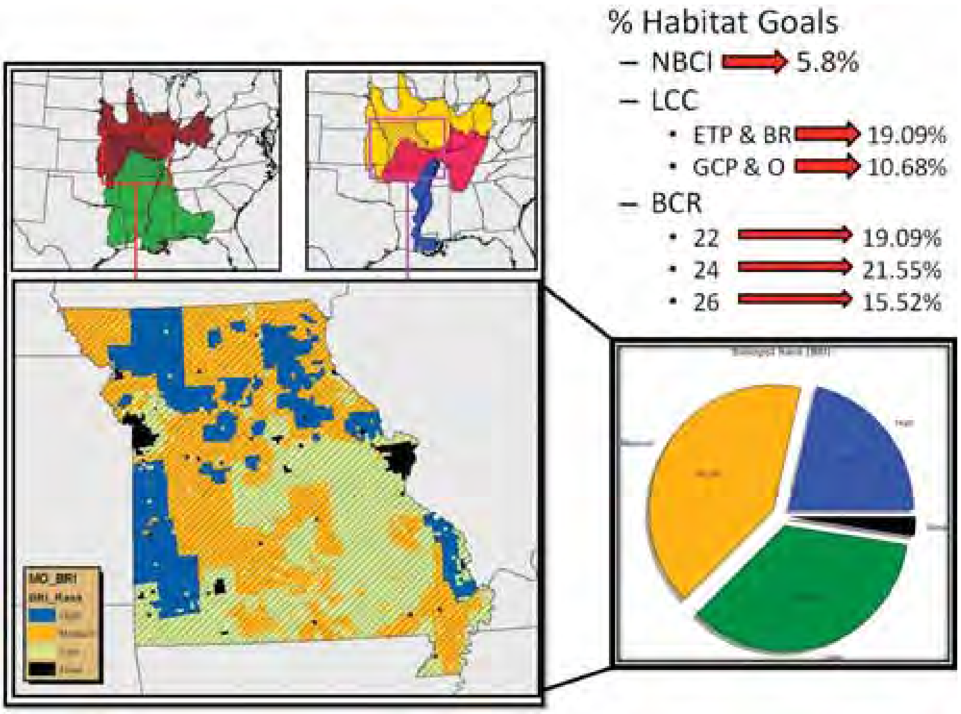

Fig. 5. The BRI summarized at the state level for Missouri and the percent of habitat goals that are reached if NBCI 2.0 management prescriptions are fully achieved by Missouri in the NBCI 2.0 range, landscape conservation cooperative (LCC, upper left map) range, and bird conservation region (BCR, upper right map) range.

According to the CPT, Missouri has the potential to meet a number of the NBCI 2.0 habitat goals.

- Pie chart: Missouri biologists' rating for their state: 21.4% of the landscape has a High potential for bobwhite restoration (BRI), 41.0% has Medium potential, 35.1% has Low potential, and 2.5% None (e.g., urban areas).
  - For the entire NBCI 2.0 range, the portion within Missouri's border contributes 5.8% toward the initiatives habitat goal.
  - For landscape conservation cooperatives (LCCs), the portion within Missouri's border contributes 19.09% toward the habitat goal of the entire area of the Eastern Tallgrass Prairie and Big Rivers LCC (ETP & BR) and 10.68% toward the habitat goal of the entire area of the Gulf Coastal Plains and Ozarks LCC (GCP & O).
  - For BCRs, the portion within Missouri's border contributes 19.09% toward the habitat goal of the entire area of BCR 22 (Eastern Tallgrass Prairie) (same as ETP & BR LCC because Big Rivers contribution is insignificant), 21.66% for the entire area of BCR 24 (Central Hardwoods), and 15.52% for the entire area of BCR 26 (Mississippi Alluvial Valley).

Many states want to know 'their part' in the big picture and how they stack up against other states. NBCI 2.0 has a tool for computing state contributions to habitat and quail population restoration, whether for a county, state, or Bird Conservation Region.

MONITORING AND ADAPTIVE MANAGEMENT

An original goal of NBCI 2002 was to restore bobwhite populations to 1980-era densities on improvable acres, yet due to the lack of reliable bobwhite density data for 1980 an alternative approach was required. Therefore, NBCI 2.0 relies on expert knowledge to develop spatially-explicit estimates of (a) current bobwhite densities on the landscape and (b) managed (potential) target densities. Managed densities are based on the assumption that management recommendations, as highlighted in the BRI and the CPT, are applied to the landscape and have the presumed effect on quail populations. Both current (unmanaged) and managed densities provided by the CPT provide a rough estimate of the additional quail that can be produced by implementation of NBCI at multiple scales. These estimates are provided for each state delineated by habitat type and summarized by BCR in the full plan.

NBCI 2.0 sets a new standard for evaluation of restoration by calling for measurement of quail population density in an adaptive resource management (ARM) framework. This section provides guidance on approaches to measuring bobwhite density on focal areas managed for bobwhites and calls for development of a comprehensive and flexible monitoring strategy to assess plan progress, evaluate specific management actions, and augment future conservation plans and management decisions. This sets the course for evaluation of what is working and what is not working, providing guidance for hunters, field biologists, administrators, and policy-makers.

It is important to view NBCI 2.0 bobwhite population density estimates as management hypotheses – as new density data are collected, current and target densities can be adapted and new hypotheses can be proposed and tested. Therefore, NBCI 2.0 was designed to lend itself to adaptive resource management. With experience implementing NBCI in different regions of the bobwhite range, the density estimates can be tested and improved by appropriate monitoring.

In short, habitat restoration as prescribed in NBCI 2.0 is the fundamental means to increase bobwhite abundance, while bobwhite density is the metric for evaluating the success of and subsequently improving the NBCI program, through an ARM approach.

Future Improvements

NBCI 2.0 is a significant a step forward, but the revision process has only begun. The process developed should alleviate the need for punctuated changes every 5 or 10 years. Instead, by providing a framework for continual improvements, NBCI can remain relevant indefinitely, as new opportunities for habitat creation are developed and functionality of the CPT, itself, is improved as listed below.

- Planning for climate change; improving or creating geospatial layers associated with mined lands, urban growth models, and public lands.
- Refining the CPT to meet state biologists' and other conservationists' needs.
- Incorporating areas where active bobwhite management projects are being undertaken.
- Assessing and incorporating other grasslands species' models to optimize conservation efforts.
- Developing spatially explicit data for Farm Bill practices and coalescing 'true' density estimates for predicting bobwhite population response using objective methods.

For More Information

The full report of NBCI 2.0 is available on-line (www.bringbackbobwhites.org).

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WESTERN QUAIL MANAGEMENT PLAN 2009

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EXECUTIVE SUMMARY

The Western Quail Management Plan was created to provide range-wide and Bird Conservation Region (BCR) assessments of western quail population size, habitat abundance, current threats, management recommendations and research needs. The 6 species of western quail included in the Plan are California quail, scaled quail, Montezuma quail, mountain quail, Gambel's quail, and masked bobwhite. The northern bobwhite is present in the West but is excluded from this Plan because of the recent publication of the National Bobwhite Conservation Initiative. Five of the 6 species of western quail included in the Plan are fairly abundant game birds. The sixth species, masked bobwhite, is a federally listed endangered species and occupies only a fragment of its former range. Western quail occupy habitats from the shrublands of northwestern United States to the deserts of the Southwest. Throughout the ranges of the various species, quail abundance is a product of habitat availability and quality, and by extension, patterns and timing of rainfall. Habitat conditions and population densities were based on available data or the expertise of resource professionals knowledgeable of regional conditions and populations. Because comparable population estimates for each BCR were not available, harvest estimates were used to index population size. No Plan is complete without suggesting how to advance the conservation status of the species and management recommendations are included within each of the BCR descriptions and for the entire region. In general, western quail populations reflect long term changes in habitat condition. In some BCRs, quail populations are in long term decline because of changes in land use. In other BCRs, quail populations are stable, but can be increased with appropriate management of habitats, especially when focused on enhancement of a diversity of native shrubs and herbaceous plants. Management recommendations differ to reflect the different species and different landscapes occupied, but there are commonalities. Public land agencies can embrace the conservation of native quail by stepping down management recommendations from the Plan to establish specific management recommendations for land management unit plans. Habitat improvement in many locations may be obtained by balancing the level of livestock grazing to ensure benefits to quail by enhanced grassland and shrubland condition. Management to provide periodic disturbance is critical to some species. Control of invasive plants and promotion of diverse, native shrublands is essential throughout for all species. Recommendations for management of water distribution include enhancement of riparian areas and restoration of springs and seeps and, in some locales, construction of artificial water sources. Since reports of harvest index population change, improved surveys of harvest to produce comparable statistics between states and regions is critical to further assessments of quail conservation. Recommendations for research topics to improve the manager's knowledge of quail population dynamics are provided. As quail occupy some of the most arid regions of the U.S., responses of western quail to climate change and projected decreases in precipitation and increases in temperature need to be understood better. The Plan provides a benchmark for continued conservation of western quail. Updates to the Plan will be based on consistent assessment of population change and comparable tracking of management recommendations. A full version of the Plan can be accessed at westernquail.org.

INTRODUCTION

The Western Quail Management Plan (Plan) has been developed under the auspices of the Resident Game Bird Working Group of the Association of Fish and Wildlife Agencies. The development of the Plan is part of a continuing effort to establish species-specific or species-group conservation strategies to guide resource planning and on-the-ground habitat management initiatives.

The Plan utilizes the North American Bird Conservation Initiative's bird conservation regions (BCRs) as the geographic assessment unit to ensure consistency with other planning efforts that focus on avian species. BCR boundaries may be viewed at http://www.nabci-us.org/bcrs.html. Assessments are provided for those BCRs which represent the core range of western quail in the United States.

Species included in the list of western quail include California quail, Gambel's quail, scaled quail, Montezuma quail, mountain quail, and masked bobwhite (scientific names of plants and animals mentioned in the text are in Appendix A of the plan). While there are populations of northern bobwhite residing in some of the BCRs included in the Plan, northern bobwhite management needs were not included because of the existence of the National Bobwhite Conservation Initiative.

The geographic coverage of the Plan is limited to the United States portions of the range of western quail. Assessments of western quail populations in Mexico and Canada are not included in the Plan.

The primary objectives of the Plan are to provide indices of population and habitat and to assemble current assessments of threats, management recommendations, and research needs. Habitat conditions and population densities were based on available data or the expertise of resource professionals knowledgeable of regional conditions and

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populations. Comparable population estimates for each BCR were not available, and harvest estimates were used to index population size. In the arid West, both habitat quantity and habitat quality are highly variable because they are largely determined by rainfall. In wet years, habitat quantity may increase as quail are able to use areas they could not use in dry years. Habitat quality likewise changes with rainfall because the amount and distribution of rainfall determines the availability of food, cover, and water.

The Plan is organized to describe the natural history of each of the 6 species of western quail. Assessments and management recommendations are then included within each of the BCR descriptions. Only 4 of the 6 species are described in this summation of the Plan.

BIRD CONSERVATION - REGION 34: SIERRA-MADRE OCCIDENTAL

The Sierra Madre Occidental mountain range runs northwest to southeast parallel to the Pacific Coast, from the Mogollon Rim and isolated mountain ranges in southeastern Arizona and southwestern New Mexico through Sonora to central Mexico. It is characterized by high elevations and a complex topography with the presence of oak/pine, pine, and fir forests along the mountain range and of semiarid scrub habitats on eastern slopes. Most uplands in the United States portion of BCR 34 are publicly owned, but lower-elevation grasslands and riparian habitat are subject to development and conversion. The whole region is an important corridor for migration of many species in the West.

Montezuma Quail

Current Trend.—Current management of the majority of the Montezuma quail habitats in this BCR provide for a stable, overall trend in abundance with annual variation due to precipitation patterns. The majority of Montezuma quail habitats in this BCR fall under the jurisdiction of the Coronado National Forest.

Population Estimate Population Density.—No reliable population estimates exist for this species. Of all the North American quail species, Montezuma quail likely are the most difficult to detect and survey due to their secretive habits.

Desired Population Level.—Hunter effort and harvest will continue to be used as indices of Montezuma quail abundance. Total harvest in BCR 34 represents ~ 90% of the current harvest for this species. The desired population goal for Montezuma quail in BCR 34 is to maintain or improve habitat and abundance so that this population can support an average sustained harvest of at least 30,000 quail annually.

Management Issues Limiting Factors.—Limiting factors for this species in BCR 34 primarily involve precipitation and grass cover height. Livestock grazing has been a significant concern in this area in the past, but has lessened in recent years with the adoption of the Montezuma quail habitat guidelines by the Coronado National Forest.

Habitat Objectives.—The current distribution and abundance of Montezuma quail in BCR 34 will be maintained through continued application of the Montezuma quail habitat guidelines by the Coronado National Forest. Habitat objectives for BCR 34 include:

- continue to apply the Montezuma quail habitat guidelines throughout potential and occupied habitats,
- adjust livestock use downward during drought years, so the grass cover needs of this species are met,
- monitor and map invasive grass distribution,
- develop control strategies and manage invasive grass species to reduce their distribution, and
- convert potential Montezuma quail habitat areas with invasive grasses to native bunchgrass habitats.

Management Recommendations

- Manage grazed lands to maintain > 50% as horizontal canopy cover of grass.
- Manage grazed lands in Montezuma quail habitat to provide greater than 50 percent canopy cover of grass heights from 8 to 20 inches (20.3–50.8 cm) for escape, nesting, brood- rearing and roosting cover.
- Manage grazed lands habitat to maintain or improve species richness.
- Maintain or restore at least 5 native perennial bunchgrass species. Native forb and tree species diversity should be maintained or enhanced.
- Maintain the necessary security and thermal cover and the necessary microclimate for the forbs on which Montezuma quail feed. Manage fire and fuelwood programs to maintain a minimum of 25% tree canopy cover. Areas with tree canopy up to 75% are frequented by Montezuma quail.

Gambel's Quail

Current Trend.—While Gambel's quail do not reach the abundance found in BCR 33, they still are common throughout much of the lower elevations in BCR 34. Recent droughts, particularly during winter months, have reduced overall numbers of Gambel's quail. A return to more normal precipitation will increase abundance, provided habitat is protected from conversion.

The biggest threat to Gambel's quail is the rate at which the desert Southwest is being developed and rapid human population growth. In Arizona, a large portion of occupied Gambel's quail habitat has been facing the threat of urban development. Continued development will have major impacts on the species distribution, abundance, and harvest opportunity.

Population Estimate Population Density.—No reliable population estimates exist for this species in BCR 34. Trends in hunter harvest data and a few formal call-count surveys are the primary indices of abundance for Gambel's quail. Breeding bird survey data have been used as an additional trend index, although the data tend to be collected after the peak calling season for this species. Documented density estimates range from 0.11 bird per acre (0.27/ha) in poor years or habitats to 1.19 birds per acre (2.96/ha) during years of peak abundance. Additional density estimate data are a management need for this species.

Desired Population Level.—Hunter harvest is used as an index of Gambel's quail abundance. Total average annual harvest in BCR 34 is roughly 100,000, the bulk of which is in Arizona. New Mexico contributes a small percentage of annual harvest in this BCR. The desired population level would maintain or enhance the current total Gambel's quail harvest in BCR 34.

Management Issues Limiting Factors.—The biggest threat to Gambel's quail is the rate at which the desert Southwest is being developed and rapid human population growth. In Arizona, a large portion of occupied Gambel's quail habitat is facing the threat of urban development. Continued development will have major impacts on the species distribution, abundance, and harvest opportunity.

Habitat Objectives.—Habitat recommendations, made by Partners in Flight (PIF), for Sonoran desert scrub will benefit Gambel's quail, as will recommendations for general habitat protection and acquisition and noxious weed control. Protection and enhancement of desert wash and riparian habitats are key to survival of this species, as is creation and maintenance of suitable ground cover characteristics. Habitat objectives for BCR 34 include:

- assess current habitat condition,
- identify and maintain minimum distance between water sources in appropriate areas; much of this area will require little additional water,
- protect existing Gambel's quail habitat in this BCR from further urban development,
- accommodate wildlife movement needs when planning developments, and
- develop and implement effective strategies to reduce noxious invasive plant species.

Management Recommendations

- Identify and encourage acquisition—by trade, fee-title purchase or conservation easement—of in-holdings within public lands that are of value to Gambel's quail and in danger of development.
- Work on legislation to protect state or federal lands from sale, trade or development. In Arizona, areas between Phoenix and Tucson are particularly vulnerable to further development at a vast scale, and they represent one of the most rapidly growing segments of the United States. These lands represent a large percentage of core range for Gambel's quail and for other Sonoran Desert species.
- Work with county and city zoning boards to ensure the needs of Gambel's quail and other wildlife species are met, including considerations for habitat connectivity and adequate patch size.
- Work with county and city zoning boards and land-management agencies to ensure lands remain open to quail hunting.
- Work with land-management agencies and other entities to reduce harmful invasive plant species and noxious weeds, with particular emphasis on control and eradication of certain species such as Lehmann's lovegrass and buffelgrass.
- Provide OHV users with areas that are poor wildlife habitat to conduct their activities. In other areas, restrict OHV use to existing roads and designated routes. Increase law enforcement to address resource concerns involving OHV users.

Scaled Quail

Current Trend.—Scaled quail apparently are declining throughout their range in response to habitat type conversions. Scaled quail abundance and distribution in Arizona is greatest in BCR 34. These birds are associated with Chihuahuan Desert grasslands of southeastern Arizona, particularly in the Sulphur Springs and San Bernardino valleys. Scaled quail also remain relatively common in suitable habitats east of Tucson, near the towns of Sonoita and Tombstone, and Buenos Aires National Wildlife Refuge. The population of scaled quail north of Oracle has declined dramatically due to habitat conversion. This population will likely be extirpated relatively soon due to planned developments in the area.

Population Estimate Population Density.—There are no reliable population estimates for scaled quail in BCR 34. Harvest statistics and breeding bird survey data are the only current population indices available. Calling of males is greatly influenced by spring and summer precipitation levels and is so variable that these data may be of little value. Density estimates for scaled quail vary from 0.016 to 1.01 per acre (0.04 to 2.50/ha). Additional density estimate data are a management need for this species in BCR 34.

Desired Population Level.—Hunter harvest will continue to be used as an index of scaled quail abundance in this BCR, although an independent index is a management need. This BCR represents the bulk of scaled quail harvest in Arizona, probably $> 95\%$. Average annual harvest since 1991 is $\sim$ 47,000, but has averaged significantly lower ($\sim$ 30,000) in recent years. The desired population goal for this BCR is to increase habitat suitability and abundance, so an annual average harvest of 45,000 can be supported.

Human development is increasingly reducing habitat availability for scaled quail but at a lower rate than for Gambel's quail. Invasive grass species and reduction of native perennial bunchgrass also negatively impacts the species.

Management Issues Limiting Factors.—The major limiting factors for this species involve drought and overuse of Chihuahuan grasslands by livestock and corresponding type conversion (grassland to shrublands). Human development is increasingly reducing habitat availability for scaled quail but at a lower rate than for Gambel's quail. Invasive grass species and reduction of native perennial bunchgrass also negatively impacts the species.

Habitat Objectives.—Habitat recommendations to benefit scaled quail and other desert grassland species in BCR 34 are provided in Latta et al. (1999). Protection and enhancement of desert grassland habitats are key to survival of this species, as are creation and maintenance of suitable ground cover characteristics. Provision of water developments continues to be debated but may benefit this species in more arid portions of its range. Habitat objectives for BCR 34 include:

- assess current habitat condition,
- continue to assess and address shrub encroachment in the Sulphur Springs and San Bernardino valleys,
- re-establish native bunchgrass habitats where possible,
- identify and maintain minimum distance between water sources in appropriate areas,
- protect existing scaled quail habitat in this BCR from further urban development,
- accommodate wildlife movement needs when planning developments,
- develop and implement effective strategies to reduce noxious invasive plant species, and
- manage livestock levels to accommodate scaled quail

Management Recommendations

- Manage shrub and grassland components at appropriate levels to maintain existing suitable habitat.
- Modify existing livestock grazing to promote habitat conditions. Implement annual vegetation monitoring throughout the area to assess condition.
- Convert shrub-invaded grassland to proper condition. Shrub-reduction programs should be conducted in a manner that does not increase non-native invasive grasses.
- Work with land-management agencies and with other entities to reduce harmful invasive plant species and noxious weeds, with particular emphasis on control and eradication of species such as Lehmann's lovegrass and buffelgrass.
- Assess and address identified water-development needs.
- Identify and encourage acquisition—by trade, fee-title purchase or conservation easement—of private lands that are of value to scaled quail and in danger of development.
- Work on legislation to protect state or federal lands in the Southwest from sale, trade or development.
- Work with county and city zoning boards to ensure the needs of this and other wildlife species are met, including considerations for habitat connectivity and adequate patch size.
- Work with county and city zoning boards and with land-management agencies to ensure lands remain open to quail hunting.

Masked Bobwhite

Current Trend.—While no range-wide survey information exists, masked bobwhite populations have declined in central Sonora and on the Buenos Aires National Wildlife Refuge.

Population Estimate Population Density.—There is no good estimate of population numbers. However, population levels appear to be extremely low, perhaps nearing extinction.

Desired Population Level.—The Masked Bobwhite Recovery Plan (U.S. Fish and Wildlife Service 1995) considers the subspecies to be re-established when a population of at least 500 masked bobwhites inhabit the Buenos Aires National Wildlife Refuge. At that point, a second site would be selected for the reintroduction of a second population.

In Sonora, the emphasis is on preserving and restoring two or more viable populations. Downlisting from endangered to threatened status would be considered when 4 separate, viable populations are established (2 in the United States and 2 in Mexico). They also would have to be maintained for 10 consecutive years.

Management Issues Limiting Factors.—Issues pertinent to the establishment of viable populations in Arizona include prolonged drought, invasion of velvet mesquite, prevalence and invasiveness of nonnative grasses (particularly Lehmann's lovegrass), lack of diversity of leguminous shrubs, and lack of winter rain. In addition, extremely high densities of predators (avian, mammalian, and reptilian) may be contributing to low population densities.

Sonoran issues are integrally related to extreme drought coupled with continued cattle grazing and the planting of buffelgrass for cattle forage. This has resulted in loss of plant diversity and, ultimately, bobwhite habitat.

Habitat Objectives.—Objectives for BCR 34 include:

- assess habitat conditions,
- reduce mesquite encroachment in desert grasslands,
- reduce nonnative grasses,
- re-establish native perennial bunchgrasses,
- establish native food plants, such as leguminous shrubs and native forbs,
- provide adequate hiding, thermal and nesting cover, either through native plants or artificial means, such as brush piles,
- assess water distribution and provide for water needs as necessary,
- assure adequate interspersion of food, cover and water needed,
- create or maintain stands of vegetation consisting of 15 to 30% woody vegetation, at least 15% forb cover, at least 15% native grass cover, and between 0 to 25% unobstructed bare ground,
- create or maintain diverse stands of native vegetation consisting of a minimum of 8 native perennial grass species, a minimum of 12 perennial forb species and a minimum of 3 midstory shrub or tree species, and
- manage livestock stocking rates and grazing regimes to permit co-existence of livestock and masked bobwhite.

Management Recommendations

Arizona

- Utilize prescribed fire to stimulate growth of forbs and seed-producing plants.
- Plant appropriate food or cover plants.
- Implement traditional habitat management techniques, such as disking, mowing and aeration to improve production of food plants.
- Create brush-piles or implement half-tree cutting to improve cover where needed.
- Provide and maintain water catchments and spreader dams wherever needed.
- Reduce cover of nonnative grasses and noxious weeds.

- Assess the predator base and implement reduction, if needed.

Mexico

- Establish conservation easements or purchase ranches in core bobwhite areas.
- Provide for movement corridors between populations.
- Reduce buffelgrass and re-establish native grass.
- Provide for water catchments in extremely arid areas.
- Reduce or eliminate grazing and develop rotational grazing systems for livestock in core bobwhite areas.
- Plant appropriate food or cover plants where needed.
- Implement disking, mowing, aeration and, possibly, prescribed fire to improve production of food plants.
- Support continued predator reductions if needed.

RECOMMENDED MANAGEMENT PRACTICES (for all species of quail)

Land Management Planning

- Step down management recommendations to establish specific targets within public land- management plan.

Land Management Practices

- Assess and recommend grazing management that benefits quail, such as deferment, rotation or rest.
- Maintain appropriate animal unit months (AUMs) on occupied quail range.
- Manage shrub and grassland component appropriate for scaled quail.
- Manage for early seral brush component for California quail and Montezuma quail.
- Maintain savanna characteristics in Madrean Archipelago for Montezuma quail.
- Increase dense roost site habitats for California quail.
- Restore native vegetation to riparian corridors by (a) controlling invasive plant species, e.g., saltcedar, leafy spurge, (b) managing forage removal, and (c) planting native species.
- Manage dense brush stands for diversity of stand density and edge effect to benefit California quail and Montezuma quail by establishing fire lanes in chaparral and scrub oak habitats.
- For all quail species, maintain and encourage native plants that provide critical invertebrate food sources for developing chicks.
- Develop Best Management Practices for "quail friendly" habitat treatment and incorporate them into land -use plans of public land managers, and farm bill conservation programs.

Invasive Species Management

- Control and prevent invasive annual grasses and noxious weeds.
- In appropriate habitats, encourage the use of prescribed fire or create let-burn policies, especially in mountain quail habitats. Managers should not use fire as a habitat-management tool when there is a risk of invasive species out-competing desired native vegetation unless active measures, such as spraying, are planned to control invasive plants.
- Feral hog control may be an important management practice in some quail ranges.

Conservation Programs

- Develop education programs and materials for the public regarding quail and the protection and enhancement of quail habitat.
- Take advantage of existing federal (e.g., farm bill) programs.
- Seek partnerships with landowners, land- management agencies and nongovernment organizations (such as Quail Unlimited, Quail Forever, and watershed councils) to improve quail habitat.
- Encourage community efforts to consider natural resource needs.
- Complete spatially mapping current distribution (occupied habitat) of each western quail species.
- Assess indices to population abundance that can replace harvest trends in those locations without regulated hunting seasons.
- Work with USDA native plant material centers to collect, store and develop new native plant stock for quail habitat. Identify remaining patches of quail habitat to serve as areas for collection of native seeds.
- Identify remaining patches of excellent quail habitat to serve as benchmarks for comparing and measuring success of habitat treatments.

Water Distribution and Allocation Policy

- Restore riparian areas.
- Restore seeps and springs.
- Develop and maintain natural ponds and artificial water sources (such as guzzlers and catchments) where needed.
- Provide both access ramps and escape ramps to existing watering facilities.
- Mitigate for over allocation of water resources.

Development Policy

- Encourage backyard habitat in urban settings.
- Ensure zoning and planning considers needs of wildlife.
- Encourage protection of farm and ranch lands.

Fragmentation Policy

- Create riparian corridors with associated vegetation.
- Improve connectivity of existing riparian corridors and shrub communities.

Harvest Policy

- Identify quail hunters to increase accuracy of harvest surveys.
- Structure hunting regulations to account for differences in distribution and population size
- Collect hunter-harvest information (e.g., wing collection).

Disturbance

- Manage dog training and trials, so impacts to reproducing quail are eliminated or reduced.

- Work with land-management agencies to manage OHV use to limit damage to habitat. Educate OHV users about impacts to quail and quail habitat.
- Restrict OHV use to designated trails.

Translocations

- Support intra- and interstate efforts to restore quail populations to suitable habitats.

Predators

- Reduce or eliminate feral mammals.

RESEARCH NEEDS (for all quail species)

Monitoring Protocol Development

- Continue to develop and refine reliable population indices that are independent of harvest data (e.g., call counts, pointing dog surveys, brood counts).

Population Dynamics

- Determine the benefit of free-standing water to quail throughout the year. Discover whether the addition of artificial water sources benefits quail populations.
- Investigate how Montezuma quail survive in the high elevation habitats of BCR 16 and 34.
- Learn whether seasonal migration occurs and, if so, what distances are traveled.
- Continue to update basic life-history knowledge for all western quail species.
- Assess quail density potential by habitat type and BCR.

Harvest Policy

- Refine harvest- survey techniques and apply them consistently throughout a species' range.
- Ascertain how late-season hunting affects breeding populations.
- Determine how hunting seasons affect bird abundance.

Predation Policy

- Conduct research into the effects of predation.

Habitat Policy

- Develop a habitat-assessment model in xeric landscapes for mountain quail.
- Conduct research regarding the effects of fire for various habitat types by species.
- Conduct research regarding the effects of timber production and harvest on quail species.
- Conduct research regarding the effects of grazing in various habitat types.

Translocation Policy

- Evaluate release techniques.
- Evaluate source population survival in various habitats.
- Evaluate various trapping techniques by species.

Recreational Use of Habitat

- Quantify effects of OHV use.

Development of Habitat

- Quantify the impacts of both urban and semi-urban developments.

Climate Change

- Responses of western quail to decreases in precipitation and increases in temperature need to be understood better.

Implementation

- Development of priority actions for funding (e.g., scaled quail and mountain quail habitats, consistent harvest data collection, implementation of individual state plans, etc).
- Develop metrics and methods to track accomplishments of the Plan.

Review and Update Process

- Recommend this plan be continuously reviewed and updated, with scheduled five year reviews.

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