Fall 2011

Great Plains Research, Volume 21, Number 2, Fall 2011 (complete issue)

GREAT PLAINS RESEARCH

A Journal of Natural and Social Sciences

Volume 21, Number 2 Fall 2011

CENTER FOR GREAT PLAINS STUDIES
UNIVERSITY OF NEBRASKA–LINCOLN

Center for Great Plains Studies

THE CENTER FOR GREAT PLAINS STUDIES was established in 1976 by the University of Nebraska Board of Regents to promote a greater understanding of the people, culture, history, and environment of the Great Plains through a variety of teaching, research, and outreach programs. Under the administration of the College of Arts and Sciences at the University of Nebraska-Lincoln, the Center encompasses nine divisions: the Great Plains Art Museum, three academic journals (*Great Plains Quarterly, Great Plains Research*, and *Plains Song Review*), Plains Humanities Alliance, undergraduate and graduate programs, editing projects, research support, outreach programs, interdisciplinary symposia, and Fellows and Associate Fellows.

Great Plains Research

Cover image: Photo of American burying beetle, *Nicrophorus americanus* Olivier (Coleoptera: Silphidae) was taken in August 2007 in Tripp County, South Dakota, by Doug Backlund, retired wildlife biologist from the South Dakota Department of Game, Fish and Parks. The beetle was captured in a baited pitfall trap. Copyright by dougback@wildphotosphotography.com.

GREAT PLAINS RESEARCH (ISSN 1052-5165) is published biannually in Spring and Fall by the Center for Great Plains Studies, University of Nebraska-Lincoln.

Articles from Volume 1 through Volume 18 may be found on the UNL Digital Commons website: http://digitalcommons.unl.edu/greatplainsresearch/

Subscriptions per year:
U.S. Individual $25.00; Institutional $50.00
Canada Individual $30.00; Institutional $55.00
other foreign Individual $35.00; Institutional $60.00
Make checks payable to **GREAT PLAINS RESEARCH**
Tel.: (402) 472-3082; FAX: (402) 472-0463
E-mail: cgps@unl.edu
Web page: **www.unl.edu/plains**

Nonprofit standard postage paid at Hanover, PA. **Postmaster: send address changes to** Center for Great Plains Studies, University of Nebraska-Lincoln, P.O. Box 880214, Lincoln, NE 68588-0214. Return postage is guaranteed.

GREAT PLAINS RESEARCH is a peer-reviewed, biannual, multidisciplinary science journal, which publishes original research and scholarly reviews of important advances in the natural and social sciences with relevance to the Great Plains region and with special emphases on environmental, economic, and social issues. It includes reviews of books.

Articles include:

- **original research findings**, such as have been published in *GPR* since 1991;
- **synopses** of the "state of the science" on topics relevant to the Great Plains;
- **overviews** of critical environmental, economic, and social issues for the plains;
- **reviews** of knowledge on important questions and their regional application; and
- **syntheses and cross-disciplinary analyses** relevant to the Great Plains.

Great Plains Research is indexed or abstracted in *America: History and Life, BIOSIS Previews, Biological Abstracts, Environment Abstracts, Historical Abstracts, Geographical Abstracts* and *GEOBASE, Meteorological and Geoastrophysical Abstracts*, and CSA *Sociological Abstracts, Inc.*

The editor encourages those submissions in particular that report general findings in the sciences relevant to this vast region. Articles should include thoughtful reviews of critical scientific findings and issues relevant to the Great Plains, whether the research was done in the Great Plains or not. The key to acceptance will be how well the findings are related to the region, and how well the science is communicated to other scientists outside the specific discipline, in the style of *Scientific American*, for example. The Board of Governors' Publication Committee will select annually the best paper in natural sciences and the best paper in social sciences. The author/s of the winning papers will be presented cash prizes for the **Charles E. Bessey Award** (natural sciences) or the **Leslie Hewes Award** (social sciences).

Scientists doing interesting work with important implications for this region are invited to synthesize their significant research results and present them to our readers. The overall goals are to develop *Great Plains Research* as a centralized outlet for science of regional importance, to communicate important scientific findings to as wide an educated audience as possible, and to help keep scientists, interested citizens, and leaders of this region up-to-date on scientific progress relevant to the Great Plains.

This publication is printed on acid-free 10% SFI certified recycled paper by The Sheridan Press, Hanover, PA.

TABLE OF CONTENTS

BOOK REVIEWS

Great Plains Research 21 (Fall 2011):131–43

NEW RECORDS OF CARRION BEETLES IN NEBRASKA REVEAL INCREASED PRESENCE OF THE AMERICAN BURYING BEETLE, *NICROPHORUS AMERICANUS* OLIVIER (COLEOPTERA: SILPHIDAE)

Jessica Jurzenski

Department of Entomology
202 Entomology Hall
University of Nebraska–Lincoln
Lincoln, NE 68583-0816
jurzenskij@alumni.unk.edu

Daniel G. Snethen

Science Department
Little Wound High School
P.O. Box 500
Kyle, SD 57752

Mathew L. Brust

Department of Biology
Chadron State College
1000 Main Street
Chadron, NE 69337

and

W. Wyatt Hoback

Department of Biology
905 West 25th Street
University of Nebraska at Kearney
Kearney, NE 68849
hobackww@unk.edu

ABSTRACT—Surveys for the American burying beetle, *Nicrophorus americanus* Olivier (Silphidae), between 2001 and 2010 in Nebraska resulted in 11 new county records for this endangered species and 465 new county records for 14 other silphid species. A total of 5,212 American burying beetles were captured in more than 1,500 different locations. Using mark-recapture data, we estimated the population size of the American burying beetle (ABB) for six counties in the Sandhills. Blaine County (2003) had the largest population, with an estimated 56 ABBs per km^2 (1,338 ± 272 ABBs). The remaining estimates were between 2 and 36 ABBs per km^2, which were calculated for Loup (2010) and Holt (2010) Counties, respectively. We calculated movement distances, finding that some American burying beetles moved as far as 7.24 km in a single night. This new information greatly contributes to efforts to conserve the American burying beetle in the Great Plains and provides knowledge about other silphid species distributions, which may play a role in recovery of the American burying beetle.

Key Words: American burying beetle, carrion beetles, conservation, endangered species, Nebraska, Silphidae

Manuscript received for review, December 2010; accepted for publication, March 2011.

INTRODUCTION

Carrion beetles (Coleoptera: Silphidae) are important saprophagous and predaceous insects because they recycle carcasses and compete with or consume many pest fly species (Pukowski 1933; Ratcliffe 1972; Scott 1998). Although Silphidae is a small family having only about 200 species, they are distributed worldwide, except for in Antarctica, and occur across numerous temporal and spatial niches (Ratcliffe 1996; Bishop et al. 2002; Sikes et al. 2006). North America (north of Mexico) contains 31 species of carrion beetles, four of which are shared with Europe (Peck and Kaulbars 1987). Over half of the North American silphid species have been recorded in Nebraska (18 species), with seven species in the subfamily Silphinae and 11 species (all in genus *Nicrophorus*) in the subfamily Nicrophorinae (Ratcliffe 1996). Members of the genus *Nicrophorus*, characterized by their burial of small carcasses for reproduction, are better known as burying beetles (Pukowski 1933; Scott 1998). Comprehensive descriptions and identification keys for the carrion beetles in Nebraska can be found in Ratcliffe (1996).

Nicrophorus americanus Olivier, the American burying beetle (ABB), once occurred throughout temperate eastern North America and was found in 35 states of the United States and in three of the Canadian provinces (U.S. Fish and Wildlife Service 1991). This species is the largest silphid in the Western Hemisphere (Anderson 1982). Its absence became apparent in the 1980s, and by 1989 the American burying beetle was thought to occur only on Block Island, Rhode Island, and on a military installation in Oklahoma (Davis 1980; Kozol et al. 1988; U.S. Fish and Wildlife Service 1991). It was listed as federally endangered in 1989 (*Federal Register* 54 [133]: 29652–55). At present, the American burying beetle is found in less than 10% of its historic range, with localized, extant populations now found in seven states (Lomolino et al. 1995; Miller and McDonald 1997; U.S. Fish and Wildlife Service 2008a). Although the specific reasons for its rapid decline are still undetermined, human impacts are suspected to have played a role (Sikes and Raithel 2002). Reclassification criteria (endangered to threatened) for the American burying beetle consists of the discovery or reestablishment of three populations with 500 or more individuals within each of the four geographic regions designated by the recovery plan (U.S. Fish and Wildlife Service 1991). As of 2008, these criteria have been met by the Midwest region (U.S. Fish and Wildlife Service 2008a).

ABB specimens were recorded from two Nebraska counties prior to 1950 (Antelope and Lancaster) and one county (Custer) in 1970 (Ratcliffe 1996). The American burying beetle was rediscovered in Nebraska by Ratcliffe and Jameson (1992) and was later captured from seven additional counties (Cherry, Dawson, Frontier, Gosper, Keya Paha, Lincoln, and Thomas), which formed a broken band through central Nebraska and included a sizable population of ABB in the Loess Canyon region (Ratcliffe 1996; Bedick et al. 1999; Peyton 2003). Bedick et al. (1999) and Peyton (2003) established population estimates for the Loess Canyon region. In 1996, June and August population estimates calculated for an assumed area of 1,943 km^2 (Bedick et al. 1999) resulted in 1,174 and 3,046 ABB estimated, respectively. A larger sample area of 4,500 km^2 was reported to have over 3,000 ABB individuals in June 1998 (Peyton 2003). Most sampling efforts for ABB prior to 1996 were limited to the south-central, northern, and eastern portions of Nebraska; there was relatively little effort in the north-central region. As of 1999, ABB distribution records indicated two disjunct ABB populations (Bedick et al. 1999).

The purpose of this paper is to update all silphid county records in Nebraska, with a special focus on the American burying beetle. The estimated number of ABBs occurring in the Sandhills is presented along with additional survey information, including recapture distances.

MATERIALS AND METHODS

From 2001 to 2010, various surveys involving carrion beetles were conducted across the state of Nebraska. A majority of the surveys were concentrated in central Nebraska (north to south), and other traps were scattered in the eastern and western portions of the state. Many of the traps were placed to identify ABB presence or absence. Also, voucher specimens in the University of Nebraska at Kearney (UNK) insect collection are included for county records.

Trapping in 2001 followed the Fish and Wildlife Service (1991) protocol for ABB as modified by Bedick et al. (1999). Baited pitfall traps were constructed using a 9.5 L plastic bucket with a diameter of 28.5 cm. These buckets were placed at selected sample sites and buried so that the lip of the bucket was approximately 2 cm above the ground surface. The bottom of the bucket was filled with about 10 cm of damp soil to reduce mortality from desiccation and from inter- and intraspecific competition or predation. The carrion bait consisted of 300 ± 50 g of

rat, which was allowed to decompose at environmental temperatures of 35°–40°C for four days prior to trapping. During trapping, the bait was placed in a plastic screw-cap container covered with a 0.5 cm screen top, which prohibited beetles or flies from contacting the carrion. A 2.8 cm screen (chicken wire) was placed over the top of the bucket and was staked in place to deter scavenging vertebrates from disturbing the trap. A rain cover consisting of a piece of plywood approximately 30 cm by 30 cm was suspended 2.5 cm above the trap by 5 cm stakes. Traps were placed a minimum of 0.8 km apart and were checked once per day. The traps were baited by 6:00 p.m. and were checked the following morning by 10:00 a.m. Many trap sites were chosen by driving into a county and visually seeking habitat that was minimally disturbed. Most traps were checked for three or five consecutive days before being removed. At each trap location, GPS coordinates were recorded. During extended trapping periods, bait continued to degenerate through time, and bait was changed after three, six, and eight nights of trapping.

Unless otherwise stated, surveys conducted from 2002 to 2010 followed the American burying beetle Nebraska sampling protocol (U.S. Fish and Wildlife Service 2008b), which is similar to the protocol in Bedick et al. (2004), except the bait was kept exposed. Traps were checked every 24 hours, except during a 31-county survey in 2004, in which traps were checked at 48 to 72 hours after baiting. Occasionally, bait deterioration required earlier bait change, and on these occasions, pitfall traps were rebaited with roadkill or decomposed rats between the scheduled changing of the bait.

Trapped silphid beetles were identified to species, then counted and released. Most ABB specimens were sexed, marked with a small spot of automobile touch-up paint (different sequences of colored dots placed on the beetle's pronotum or elytra) or with a 2 mm disk (colored-coded numbered disks superglued to the elytra or pronotum) (The Bee Works, Ontario, Canada) to monitor recaptures, and released. American burying beetles captured in August were usually identified as senescent, which indicated they had already overwintered the year before, had reproduced, and had very darkened pronotal markings, or were teneral, which indicated they had recently eclosed and had very bright orange-red pronotal markings. In our 2004 survey, two vouchers of each silphid species, except for the American burying beetle, were killed with ethyl acetate, pinned, and deposited in the collections at the University of Nebraska at Kearney.

Mark-recapture surveys for ABB were conducted in four Nebraska Sandhills counties in 2003 for two ten-day survey periods. A late June survey consisted of 12 baited pitfall trap locations at least 0.8 km apart in Loup and Rock Counties (six traps per county). A mid-August survey also consisted of 12 baited pitfall trap locations at least 0.8 km apart, six each in Blaine and Brown Counties. The baited pitfall traps for these surveys used 11.4 L buckets and guinea pigs as bait, but all other aspects were the same. The age (i.e., senescent or teneral) was not recorded for captured ABBs in August for these surveys to avoid variability and errors in the evaluation of age between multiple research crews.

Subsamples of surveys in 2009 and 2010 were used for additional population estimates in the Sandhills region. All trap locations were a minimum of 1.6 km apart. Holt County was sampled in June 2009, June 2010, and August 2010 in various locations using six traps for 10 trap nights, four traps for five trap nights, and four traps for 10 trap nights, respectively. Rock County and a small portion of Brown County were sampled in August 2009 using two transects with 11–12 traps for five trap nights. In 2010, Cherry and Loup Counties were sampled over five trap nights using 19–25 traps in each transect. Two areas in Cherry County were sampled in June, and the Loup County transect was sampled in August. All August ABBs were recorded as senescent or teneral. Teneral ABB data were used for all August population estimates unless otherwise noted.

All mark-recapture data used for population estimates were analyzed using ECO-STAT software (Young and Young 1998) following the same procedure as Bedick et al. (1999). The trapping radius used to calculate total area for the population estimates was 1 km^2 per trap, as used by Bedick et al. (1999). The estimated number of ABBs per km^2 was calculated to compare ABB numbers between years and seasons and should not be assumed to represent an equal distribution of the American burying beetle in the sampled areas.

RESULTS AND CONCLUSIONS

Seventy-six of the 93 Nebraska counties (Fig. 1) were sampled between 2001 and 2010 at more than 1,500 sampling locations. ABB numbers were recorded from 537 different trap locations in 18 counties, with 11 counties being new county records (Fig. 2). Our earliest capture of ABB was May 26 (of five ABBs), and the latest capture (of one ABB) was October 11 (September 28 was the second-latest capture); however, the majority of ABBs were captured in June and August. A total of 5,212 ABBs were captured and recorded, with 321 recaptured once,

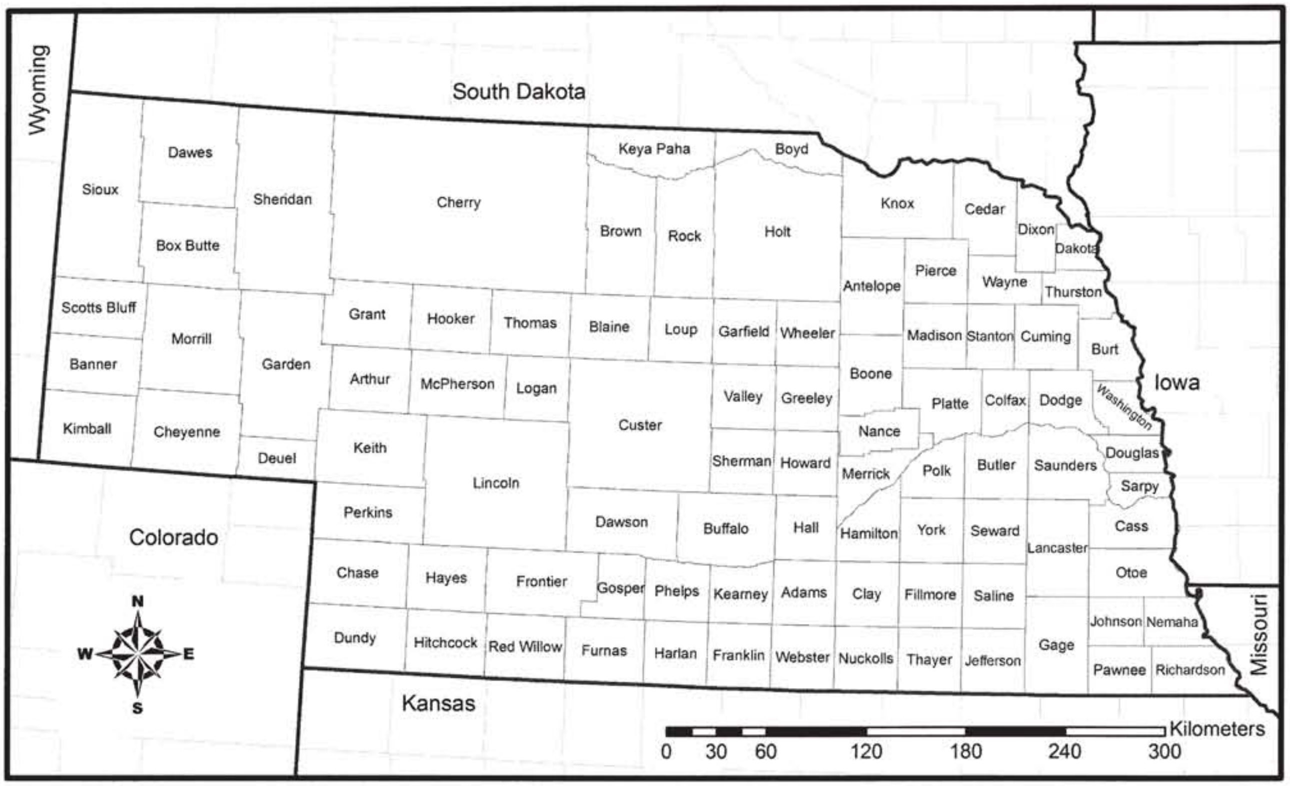


Figure 1. Map of Nebraska's counties.

38 twice, 8 three times, and 2 four times. The known occurrence of the American burying beetle in Nebraska counties was increased from 10 to 21 counties, but only 18 of the 21 counties have had the presence of American burying beetle recorded in the last 15 years. The presence of the American burying beetle in Lancaster and Antelope Counties before 1950, and in Gosper County before 1995, has not been reconfirmed. The captures from 2001 to 2010 substantially expand the distribution of the American burying beetle in Nebraska, connecting the known populations occurring in Keya Paha and Custer Counties and extending the range almost 300 km farther west than that recorded before 1999. A large gap of approximately 90 km remains between the northern Sandhills population (4,082 ABBs captured) and the southern Loess Canyons population (1,130 ABBs captured).

Mark-Recapture Population Estimation

In the 2003 mark-recapture surveys, a total of 378 (219 ♀, 156 ♂, and 3 undetermined) American burying beetles were trapped a total of 416 times over a period of 240 trap nights for an average of 1.73 ABBs per trap night. A total of 64 captures of American burying beetles occurred over a period of 120 trap nights during the early survey from Loup and Rock Counties, for an average trapping ratio of 0.53 ABBs per trap night. In Blaine and Brown Counties, American burying beetles were captured a total of 352 times over a period of 120 trap nights during the late survey, for an average trapping ratio of 2.93 ABBs per trap night. Overall, 9.1% of the ABBs were recaptured in the 10-day surveys.

These data were used to estimate the population size of the American burying beetle in Blaine, Brown, and Rock Counties (Figs. 3 and 4); however, the absence of recaptures in Loup County prevented the estimate of population (Table 1). Each estimate was calculated from a sample area of 18.84 km^2. The population estimate was largest for Blaine County (1338 ± 272 sd), followed by Brown County (277 ± 68 sd), and then Rock County (157 ± 70 sd) (Table 1). Given the same sample area size that was used for the estimates, the ABB per km^2 follows a similar trend of 56, 12, and 7 for Blaine, Brown, and Rock Counties, respectively.

In 2009, 1,097 (561 ♀, 529 ♂, and 7 undetermined) American burying beetles were captured in Brown, Holt, and Rock Counties, in which 59 recaptures traveled a mean distance of 0.41 (± 1.41 sd) km per night; however,

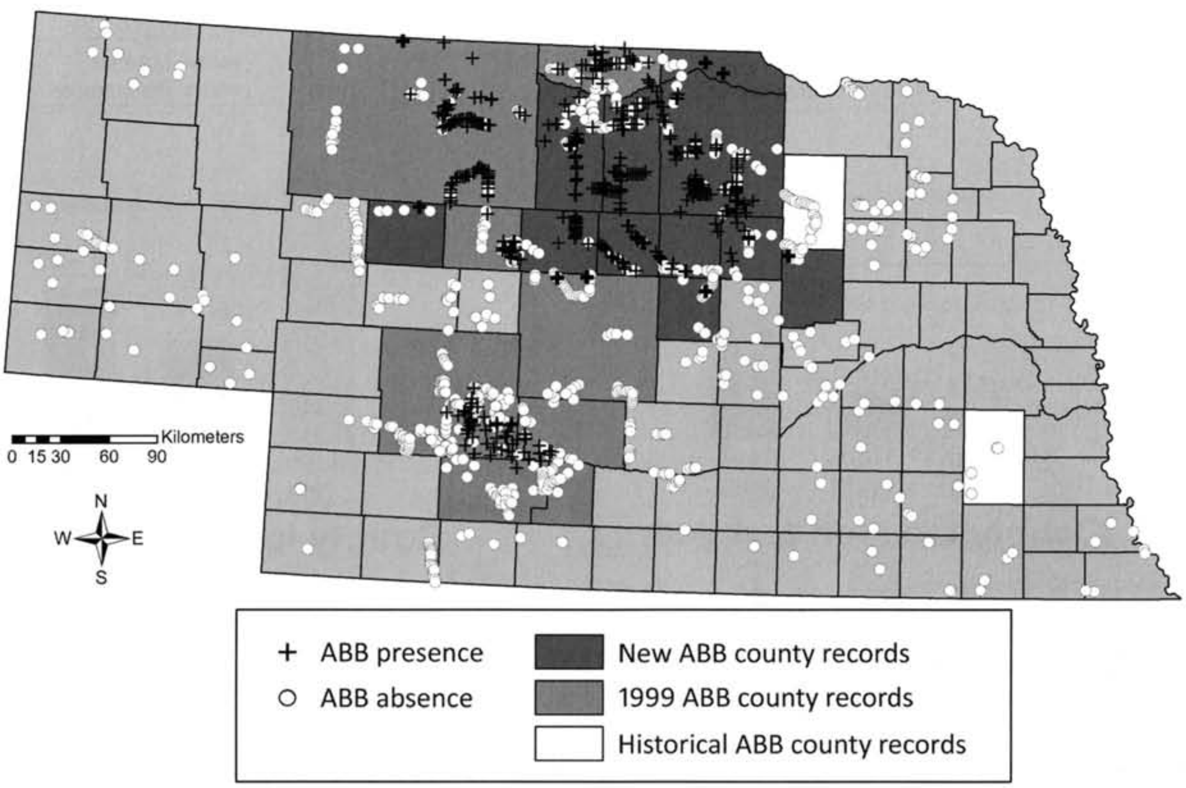


Figure 2. Baited bucket pitfall trap results from 2001 to 2010, showing the presence and absence of the American burying beetle (*Nicrophorus americanus*) in Nebraska. Absence is defined as three or more survey nights without ABB capture. County records illustrated as either 1999 or historical ABB county records are as reported in Bedick et al. (1999). Boyd county records were provided by Doug Backlund and Gary Marrone.

85% of the American burying beetles did not move to a different trap (distance equaled zero), and 90% traveled 1.6 km or less. In June, one American burying beetle traveled 7.41 km in a single night and another was recaptured 29.19 km east-southeast from the original trap in which it was captured and marked the day before (this distance was excluded from average distance calculations). The latter American burying beetle individual traveled unusually far, and during the night the winds ranged from calm to 13.04 kph, with a majority of the wind blowing southeast to east-southeast. In comparison, an Oklahoma study found that recaptured American burying beetles moved an average of 1.23 (± 0.73 sd) km per night with the maximum distance moved over one night being 2.9 km (Creighton and Schnell 1998). A beetle recaptured twice in the Oklahoma study traveled a total of 10 km over the six nights between the first and last capture.

In 1995, Peyton (2003) recaptured 11 specimens out of 201 marked in the Loess Canyons in Nebraska, with all but one recaptured within the same trap. In 1996, a single American burying beetle was recaptured 30 days after initial marking and had traveled 11 km (Peyton 2003). A total of 21 American burying beetles (out of 379 initial captures) recaptured by Peyton (2003) in 1998 were caught within five days in the same trap in which they were originally marked. Bedick et al. (1999) also trapped American burying beetles in 1995 and 1996 in the Loess Canyons and found that most recaptures occurred over distances of less than 1 km. More recently, Walker (2005) recaptured 56 out of 202 marked ABBs in a 2004 and 2005 study located in the same area as the studies by Peyton (2003) and Bedick et al. (1999). These beetles were found to travel between 0 km (39% of marked beetles) and 6.2 km (single ABB over four nights), with a mean distance of 0.54 km.

The 2009 mark-recapture survey in Holt County had zero recaptures, thus preventing an estimate of population size, but the 213 ABBs captured or 11 ABB per km^2 serves as a conservative population estimate (Table 1). In June 2010, the Holt County pitfall traps yielded approximately eight ABB per km^2, and in August 2010, traps were more widely separated in distance in Holt County resulting in a larger estimate of 36 ABB per km^2. From our experience sampling in these areas, the estimated

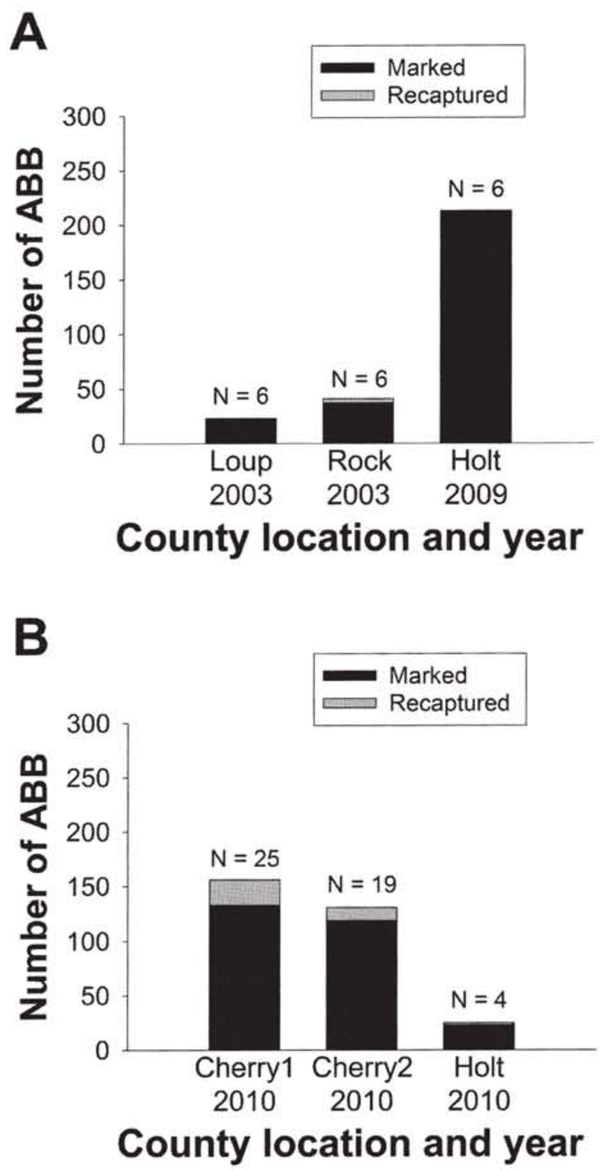


Figure 3. The number of ABB marked and recaptured in six survey areas during June. Surveys conducted over 10 survey nights (A) and 5 survey nights (B) are reported. The number of pitfall traps used are indicated by N = *x*. These data were used to calculate population estimates (Table 1).

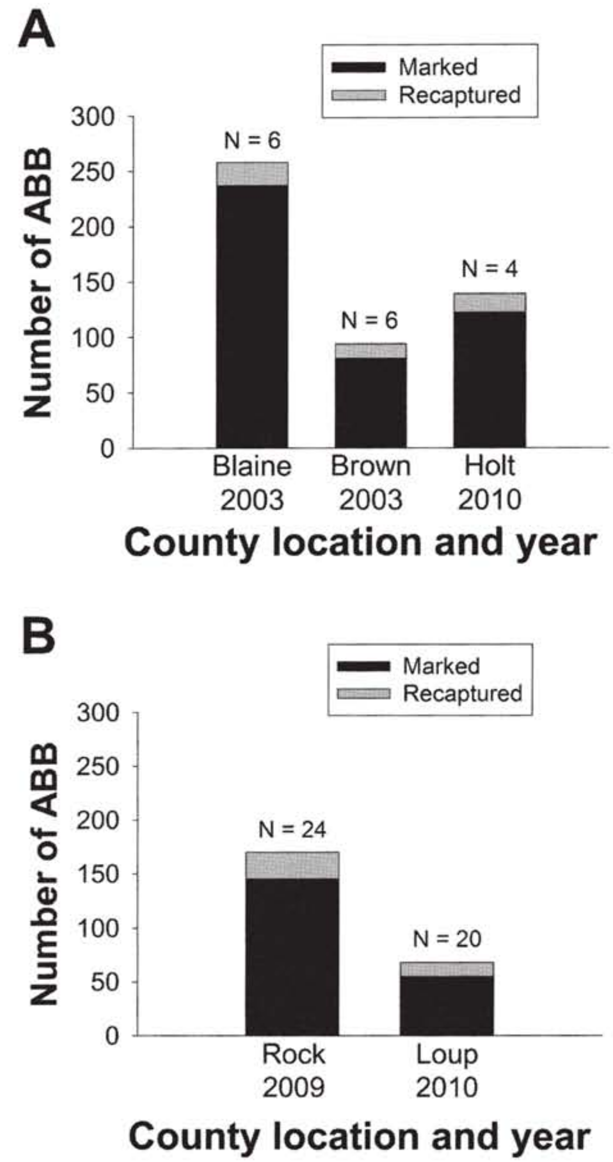


Figure 4. The number of ABB marked and recaptured in five survey areas during August. Surveys conducted over 10 survey nights (A) and 5 survey nights (B) are reported. The number of pitfall traps used are indicated by N = *x*. These data were used to calculate population estimates (Table 1).

population of 451 ± 97 (sd) ABBs, or 36 ABB per km^2, better reflects the number of ABBs in Holt County. An area sampled in August 2009 in Rock County and part of Brown County had an estimated six ABBs per km^2. The remaining mark-recapture samples in 2010 provided estimates of six, nine, and two ABBs per km^2 for two areas in Cherry County and one area in Loup County, respectively. Three of the six counties sampled using mark-recapture methods showed estimates greater than 10 ABBs per km^2 and overall did not show any distinct decreases or increases in ABB population over time.

Population estimates using June sampling data should not directly be compared to the August estimates, because June estimates were calculated using the number of mature adults that survived overwintering, whereas teneral adults emerging from summer broods were used to calculate August estimates (Fig. 3). June sampling may have lower recapture probabilities because mature beetles

TABLE 1
MARK-RECAPTURE POPULATION ESTIMATES FOR AMERICAN BURYING BEETLES IN SIX NEBRASKA COUNTIES

County/Location	Year	Approx. area (km^2)	Population estimate (± S.D.) June	Population estimate (± S.D.) August	Estimated ABB/km^2	Comments
Loup	2003	18.84	n/a		1†	No population estimate possible
Rock	2003	18.84	157 ± 70		7	
Holt	2009	18.84	n/a		11†	No population estimate possible
Northeast Cherry (1)	2010	65.91	374 ± 65		6	
Southeast Cherry (2)	2010	52.47	498 ± 124		9	
Holt	2010	12.56	99 ± 62		8	
Blaine	2003	18.84		1338 ± 272	56	Unknown number of senescents
Brown	2003	18.84		277 ± 68	12	Unknown number of senescents
Holt	2010	12.56		451 ± 97	36	Only tenerals (removed 5 senescents)
Rock (Brown*)	2009	65.87		927 ± 113	14	Both senescents and tenerals
Rock (Brown*)	2009	65.87		487 ± 85	7	Only senescents
Rock (Brown*)	2009	65.87		391 ± 65	6	Only tenerals (removed 156 senescents)
Loup	2010	55.78		118 ± 25	2	Only tenerals (removed 3 senescents)

* Five traps followed a road into eastern Brown County.
†The total number of ABB marked was used in this estimate, not the population estimate.

are removed from the available population when they secure a source for reproduction. A visual comparison of recapture numbers in August (Fig. 4) and in June (Fig. 3) illustrates a potential trend in which recaptures are more likely in August. Please note these results are for separate locations in June and August (Figs. 3 and 4) and cannot be directly compared for population growth. Future research using multiple mark-recapture surveys in June and August in the same location is needed to test for trends in recapture rates. Additionally, consecutive surveys would allow for an estimate of population growth in a specific habitat from June to August, whereas consecutive surveys in August and the following June would allow for estimates in mortality rates.

Bedick et al. (1999) found that their extrapolated population of 1,174 American burying beetles in June increased in August to 3,046 ABBs (only teneral adults). They suggested the approximate 159% increase in population size was a result of either population growth or overwintering mortality, which would indicate an approximate 61% decrease in population size. A smaller overwintering mortality rate of 40% was found by Schnell et al. (2008) in 2005 at sites located in Fort Chaffee, Arkansas. In South Dakota, Backlund et al. (2008) found an approximate 104% increase from June to August population estimates, which may reflect either a smaller population growth rate or estimate a lower mortality rate (i.e., 51% decrease) farther north. Assuming an average 132% population increase calculated from Bedick et al. (1999) and Backlund et al. (2008), then Rock County in 2003 (Table 1) could have had as many as 249 American burying beetles in August, which is similar to the adjacent Brown County's estimate of 277 American burying beetles in 2003 (Table 1). Given the differences in experimental methods between the three aforementioned studies, we cannot make assumptions concerning differences in latitude or climate and mortality rates for American burying beetles.

Overall, the population sizes estimated using mark-and-recapture data should be cautiously interpreted because of assumed lack of emigration and immigration and because all individuals are assumed to be available

for recapture during the sampling period. Often, short sampling intervals (relative to the overall active season of the organism) are used to limit the variability of the first assumption. Five- to ten-day sampling periods are equal to or less than a third of the observed activity period for American burying beetles in either June or August. The availability of individuals is likely skewed for recapture in June, because ABBs are seeking out and securing carcasses for reproduction, which would continually reduce the number of available adults in an area. Similarly, August sampling could violate this assumption if sampling occurs too early, when many ABB tenerals have not yet eclosed, or if senescent adults are included in the calculations. To test the effects of these differences, we calculated the population size of American burying beetles in Rock County in 2010 using both senescent and teneral beetles, only senescent beetles, and only teneral beetles (Table 1). The use of both ages of beetles inflated the population size by 536 ABBs when compared to the estimate for only teneral ABBs. Also, the estimate using only senescent ABBs was greater than the estimate for only teneral ABBs, suggesting the sampling period was too early.

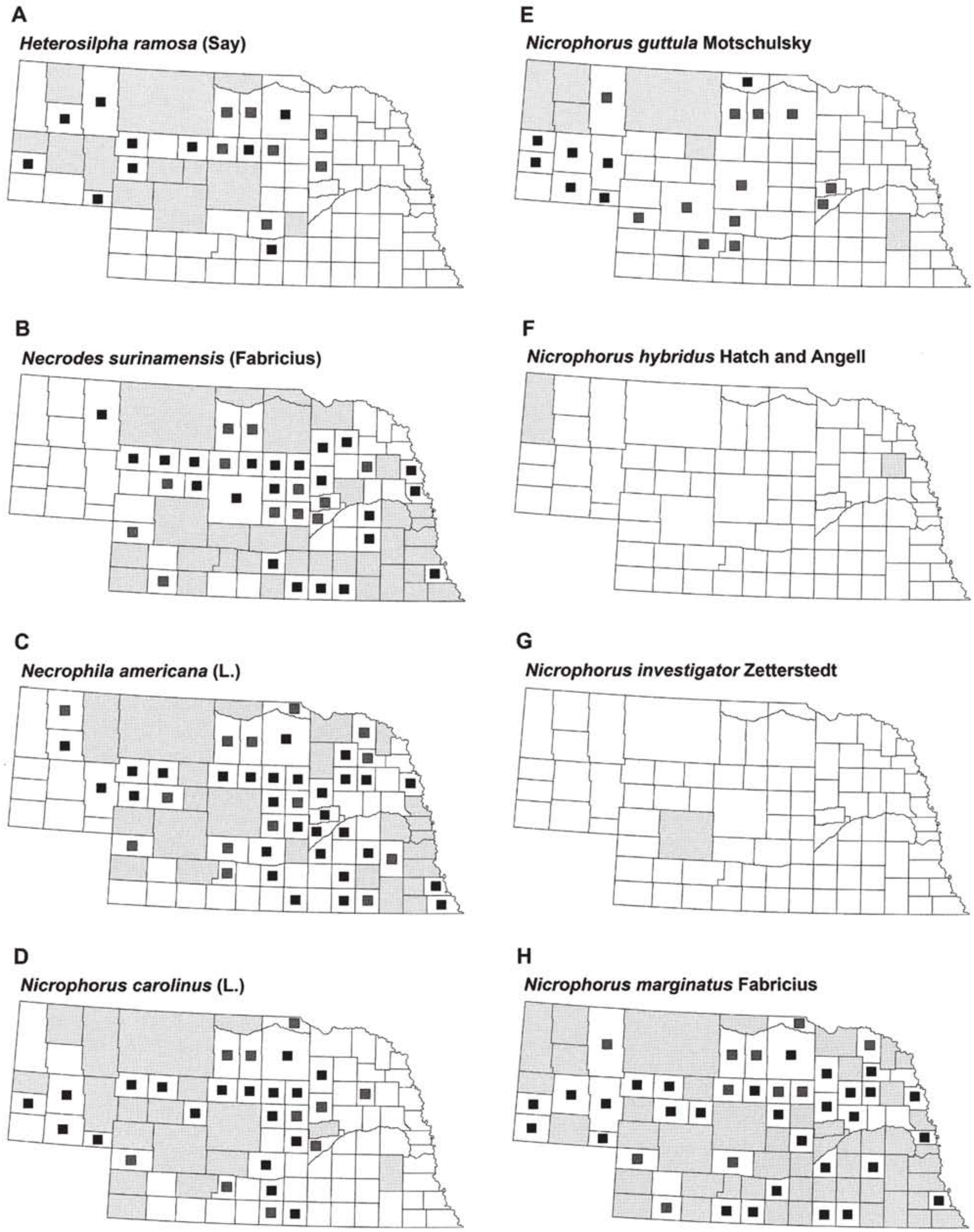
Additional Silphid Records

A total of 15 species of silphids were collected during surveys conducted in Nebraska from 2001 to 2010, resulting in 465 new county records (based on Ratcliffe 1996) (Fig. 5A–Q). Each species captured in our survey is listed and the number of new county records follows within the parentheses: *Heterosilpha ramosa* (Say) (17), *Necrodes surinamensis* (Fabricius) (34), *Necrophila americana* (L.) (43), *Nicrophorus americanus* (11), *N. carolinus* (L.) (28), *N. guttula* Motschulsky (19), *N. marginatus* Fabricius (40), *N. obscurus* Kirby (20), *N. orbicollis* Say (33), *N. pustulatus* Herschel (19), *N. tomentosus* Weber (50), *Oiceoptoma inaequale* (Fabricius) (36), *O. novaboracense* (Forster) (40), *Thanatophilus lapponicus* (Herbst) (35), and *T. truncatus* (Say) (40). Three species with few historical records, *Nicrophorus hybridus* Hatch and Angell, *N. investigator* Zetterstedt, and *N. mexicanus* Matthews, were not captured during our surveys.

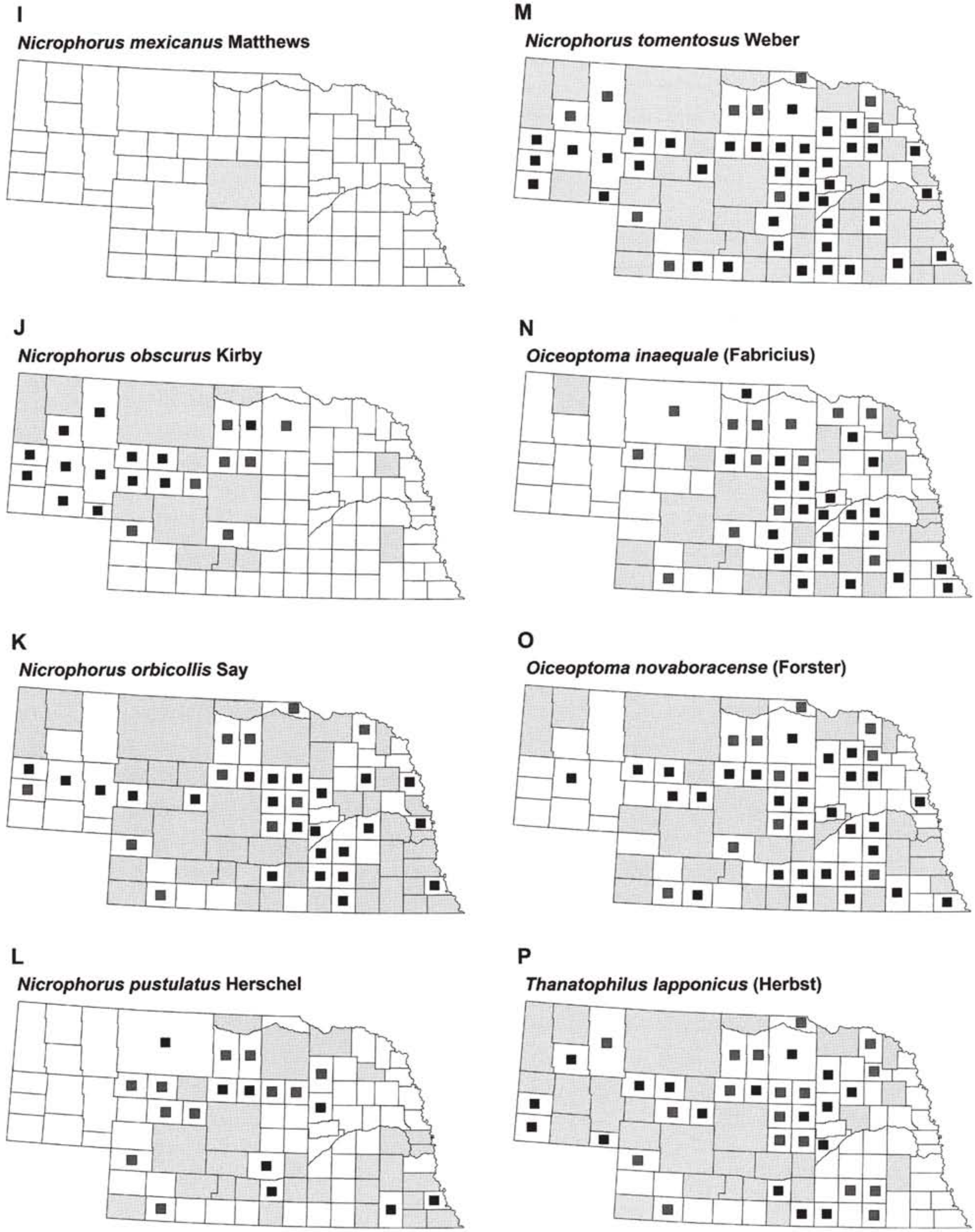
Prior to this study, there were 358 known county records for silphid beetles in the state of Nebraska (Ratcliffe 1996). This study more than doubled the number of silphid county records. In addition to new information at the county level, distributional ranges were greatly increased. Counties with few or no carrion beetle records, such as Colfax, Dakota, Dodge, Furnas, Hayes, Kimball, and Thurston, are likely to have similar species found in surrounding counties and should be surveyed (Fig. 6).

A South Dakota survey in three counties along the northern border of Nebraska captured 13 silphid species, all of which were also captured in our surveys, except for *N. hybridus* (Backlund and Marrone 1997). In surveys conducted from 1992 to 1994, Kansas researchers identified 11 of their 13 historically recorded species, all of which were found in the Nebraska surveys (Lingafelter 1995). Guarisco (1997) reconfirmed the presence of six silphid species and reported the discovery of extant populations of ABB in a 1996 survey of the Chautauqua Hills of southeastern Kansas. Further sampling in 1997 and 1998 on the Konza Prairie Biological Station (north-central Kansas) did not result in capture of American burying beetle but did find eight species previously documented by Lingafelter (1995). Trapping results from a northeastern Iowa study in 1996 showed the presence of 10 silphid species of which two, *N. hybridus* and *N. investigator*, were not identified in our surveys (Coyle and Larsen 1998). We found no current research on Wyoming silphids, but two resources provided some baseline information on silphid occurrence. Peck and Kaulbars (1987) reported the presence of 10 silphid species in Wyoming, including four species not found in our surveys, *Aclypea bituberosa* (LeConte), *N. hybridus*, *N. investigator*, and *Thanatophilus sagax* (Mannerheim). In addition, *Nicrophorus defodiens* Mannerheim were collected in Wyoming and used for laboratory research by Trumbo and Eggert (1994).

Despite the apparent population size and range in Nebraska, the American burying beetle is still rare compared to most other silphid species. For example, *N. marginatus* appeared in a majority of the traps reported in this paper and has been recorded in 89 of Nebraska's 93 counties. It is unknown why the American burying beetle has a patchy distribution in Nebraska. Additional studies of carrion resources, similar to research conducted in Arkansas comparing available biomass of birds and mammals to the presence of the American burying beetle (Holloway and Schnell 1997), should be conducted to better understand the ABB distribution in Nebraska. Some counties have apparently suitable ABB habitats but have not been surveyed extensively (both limited number of trap nights and coverage of the county) or have an unexplained absence of the American burying beetle. For example, Custer County is a large county that resides between our two known population areas and has large tracts of land without row crops and undisturbed rangeland with suitable water resources



Figures 5A–Q. County-level distributions of 17 Nebraska carrion beetle species. Shaded counties represent counties with records from Ratcliffe (1996). Gray squares within a county represent records from various research surveys without voucher specimens and black squares within a county represent records with voucher specimens housed at the University of Nebraska at Kearney.



Figures 5A–Q continued.

Q

***Thanatophilus truncatus* (Say)**

Figures 5A–Q continued.

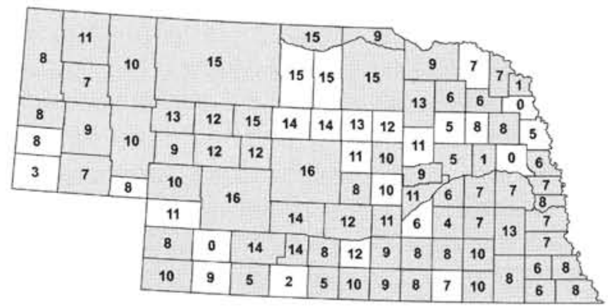


Figure 6. The number of silphid species recorded from each Nebraska county. The unshaded counties represent counties with zero species recorded in 1995 (Ratcliffe 1996).

(Hoback and Jurzenski, personal observation). Only small portions of the county have been sampled, which makes it difficult to assume or explain the presence or absence of ABB. In an Oklahoma study, Lomolino and Creighton (1996) found that habitat characteristics and competition influenced ABB occurrence and breeding success at some spatial scales but not others. The development of Nebraska ABB habitat suitability models, made possible by the dataset presented in this paper, is intended to discover candidate areas for conservation or management, along with enhancing our understanding of ABB habitat and breeding criteria in both the Sandhills and Loess Canyons. Crawford and Hoagland (2010) presented an evaluation of habitat suitability models for ABB in Oklahoma, which details the important complications encountered in this process.

Overall, we found that ABBs are locally abundant (>200 adult beetles per sampled area) in at least five counties in the Sandhills. By assessing both our data and other published reports, standardized population estimates of ABB in Nebraska should be performed using at least five survey nights and teneral beetle data collected in mid- to late August. These data would be complimented by the identification of an overwintering survival rate via June sampling, which could allow for adjustments of mark-recapture data collected in June. The movement of ABBs during trapping periods varied greatly, with a majority of beetles moving 1.6 km or less over a single night, but beetles were capable of traveling distances as far as 7.41 km on a calm night or 29.19 km on a wind-aided night. This information may impact the way conservation measures are implemented, especially the assessment of nearby suitable habitat and the use of trap-and-relocate or baiting-away methods. Our research provides a more complete view of the distribution of silphid species in Nebraska, all of which are important ecologically, and may help in conservation efforts of the American burying beetle.

ACKNOWLEDGMENTS

We thank the numerous individuals that contributed survey data and voucher specimens: Gary Marrone, Doug Backlund, Paul Timm, Stephanie Butler, Shelly McPherron, Jess Lammers, Jeremiah Carlson, S. Amami, T.J. Fyfe, Justin Haas, Brian Sass, Jeff Hamik, Mark Peyton, Chad Taylor, Lori Jumps, Tim Griffin, B. Wheeler, and Nick Dobesh. Brian Peterson, T.J. Walker, Mark Peyton, and Phil Dobesh have conducted carrion beetle surveys for several years and were gracious enough to share important data that significantly added to this update. The statewide ABB distribution map was made possible by John Riens and Andy Bishop (Rainwater Basin Joint Venture). Manuscript suggestions by Brett Ratcliffe (University of Nebraska State Museum), John Foster (University of Nebraska–Lincoln Entomology Department), Hayley Dikeman (U.S. Fish and Wildlife Service), and three anonymous reviewers were greatly appreciated. ABB trapping was conducted under U.S. Fish and Wildlife Service Permit #TE045150-0. We also owe thanks to various funding agencies, including the Nebraska Department of Roads, U.S. Fish and Wildlife Service, U.S. Forest Service, Nebraska Game and Parks Commission, and the University of Nebraska at Kearney. This report was funded in part through grants from the Federal Highway Administration (and Federal Transit Administration) of the U.S. Department of Transportation. The views and opinions of the authors expressed herein do not necessarily state or reflect those of the U.S. Department of Transportation.

REFERENCES

Anderson, R.L. 1982. On the decreasing abundance of *Nicrophorus americanus* Olivier (Coleoptera: Silphidae) in eastern North America. *Coleopterists Bulletin* 36:362–65.

Backlund, D.C., and G.M. Marrone. 1997. New records of the endangered American burying beetle, *Nicrophorus americanus* Olivier (Coleoptera: Silphidae), in South Dakota. *Coleopterists Bulletin* 51:53–58.

Backlund, D.C., G.M. Marrone, C.K. Williams, and K. Tilmon. 2008. Population estimate of the endangered American burying beetle, *Nicrophorus americanus* Olivier (Coleoptera: Silphidae), in South Dakota. *Coleopterists Bulletin* 62:9–15.

Bedick, J.C., B.C. Ratcliffe, and L.G. Higley. 2004. A new sampling protocol for the endangered American burying beetle, *Nicrophorus americanus* Olivier (Coleoptera: Silphidae). *Coleopterists Bulletin* 58:57–70.

Bedick, J.C., B.C. Ratcliffe, W.W. Hoback, and L.G. Higley. 1999. Distribution, ecology, and population dynamics of the American burying beetle [*Nicrophorus americanus* Olivier (Coleoptera: Silphidae)] in south-central Nebraska, USA. *Journal of Insect Conservation* 3:171–81.

Bishop, A.A., W.W. Hoback, M. Albrecht, and K.M. Skinner. 2002. GIS reveals niche partitioning by soil texture among carrion beetles. *Transactions in GIS* 6:457–70.

Coyle, D.R., and K.J. Larsen. 1998. Carrion beetles (Coleoptera: Silphidae) of northeastern Iowa: A comparison of baits for sampling. *Journal of the Iowa Academy of Science* 105:161–64.

Crawford, P.H.C., and B.W. Hoagland. 2010. Using species distribution models to guide conservation at the state level: The endangered American burying beetle (*Nicrophorus americanus*) in Oklahoma. *Journal of Insect Conservation* 14:511–21.

Creighton, J.C., and G.D. Schnell. 1998. Short-term movement patterns of the endangered American burying beetle, *Nicrophorus americanus*. *Biological Conservation* 86:281–87.

Davis, L.R., Jr. 1980. Notes on beetle distributions, with a discussion of *Nicrophorus americanus* Olivier and its abundance in collections (Coleoptera: Scarabaeidae, Lampyridae, and Silphidae). *Coleopterists Bulletin* 34:245–52.

Guarisco, H. 1997. Discovery of the federally endangered American burying beetle (*Nicrophorus americanus*) in the Chautauqua Hills of southeastern Kansas. *Transactions of the Kansas Academy of Science* 100:116–22.

Holloway, A.K., and G.D. Schnell. 1997. Relationship between numbers of the endangered American burying beetle *Nicrophorus americanus* Olivier (Coleoptera: Silphidae) and available food resources. *Biological Conservation* 81:145–52.

Kozol, A.J., M.P. Scott, and J.F.A. Traniello. 1988. The American burying beetle, *Nicrophorus americanus*: Studies on the natural history of a declining species. *Psyche* 95:167–76.

Lingafelter, S.W. 1995. Diversity, habitat preferences, and seasonality of Kansas carrion beetles (Coleoptera: Silphidae). *Journal of the Kansas Entomological Society* 68:214–23.

Lomolino, M.V., and J.C. Creighton. 1996. Habitat selection, breeding success, and conservation of the endangered American burying beetle (*Nicrophorus americanus*). *Biological Conservation* 77:235–41.

Lomolino, M.V., J.C. Creighton, G.D. Schnell, and D.L. Certain. 1995. Ecology and conservation of the American burying beetle (*Nicrophorus americanus*). *Conservation Biology* 9:605–14.

Miller, E.J., and L. McDonald. 1997. Rediscovery of *Nicrophorus americanus* Olivier (Coleoptera: Silphidae) in Kansas. *Coleopterists Bulletin* 51:22.

Peck, S.B., and M.M. Kaulbars. 1987. A synopsis of the distribution and bionomics of the carrion beetles (Coleoptera: Silphidae) of the conterminous United States. *Proceedings of the Entomological Society of Ontario* 118:47–81.

Peyton, M.M. 2003. Range and population size of the American burying beetle (Coleoptera: Silphidae) in the dissected hills of south-central Nebraska. *Great Plains Research* 13:127–38.

Pukowski, E. 1933. Okologische untersuchungen an *Necrophorus* F. [Ecological investigation of *Necrophorus* F.]. *Zeitschrift fur Morphologie und Oekologie der Tiere* 27:518–86.

Ratcliffe, B.C. 1972. The natural history of *Necrodes surinamensis* (Fabr.) (Coleoptera: Silphidae). *Transactions of the American Entomological Society* 98:359–410.

Ratcliffe, B.C. 1996. The carrion beetles (Coleoptera: Silphidae) of Nebraska. *Bulletin of the University of Nebraska State Museum* 13:1–100.

Ratcliffe, B.C., and M.L. Jameson. 1992. New Nebraska occurrences of the endangered American burying

beetle (Coleoptera: Silphidae). *Coleopterists Bulletin* 46:421–25.

Schnell, G.D., A.E. Hiott, J.C. Creighton, V.L. Smyth, and A. Komendat. 2008. Factors affecting overwinter survival of the American burying beetle, *Nicrophorus americanus* (Coleoptera: Silphidae). *Journal of Insect Conservation* 12:483–92.

Scott, M.P. 1998. The ecology and behavior of burying beetles. *Annual Review of Entomology* 43:595–618.

Sikes, D.S., and C.J. Raithel. 2002. A review of hypotheses of decline of the endangered American burying beetle (Silphidae: *Nicrophorus americanus* Olivier). *Journal of Insect Conservation* 6:103–13.

Sikes, D.S., R.B. Madge, and S.T. Trumbo. 2006. Revision of *Nicrophorus* in part: New species and inferred phylogeny of the nepalensis-group based on evidence from morphology and mitochondrial DNA (Coleoptera: Silphidae: Nicrophorinae). *Invertebrate Systematics* 20:305–65.

Trumbo, S.T., and A.-K. Eggert. 1994. Beyond monogamy: Territory quality influences sexual advertisement in male burying beetles. *Animal Behaviour* 48:1043–47.

U.S. Fish and Wildlife Service. 1991. American burying beetle (*Nicrophorus americanus*) recovery plan. Newton Corner, MA.

U.S. Fish and Wildlife Service. 2008a. American burying beetle (*Nicrophorus americanus*) 5-year review: Summary and evaluation. Newton Corner, MA.

U.S. Fish and Wildlife Service. 2008b. Endangered species protocol: American burying beetle Nebraska sampling protocol. http://www.fws.gov/mountain-prairie/endspp/protocols/protocols.html (accessed January 31, 2011).

Walker, T.L., Jr. 2005. Eastern redcedar effects on Silphidae including American burying beetles (*Nicrophorus americanus*). Master's thesis, University of Nebraska at Kearney, Kearney, NE.

Young, L.H., and J.H. Young. 1998. *Statistical Ecology.* Chapman and Hall, New York.

Great Plains Research 21 (Fall 2011):145–51

SURVEILLANCE OF SELECTED DISEASES IN FREE-RANGING ELK (*CERVUS ELAPHUS NELSONI*) IN NEBRASKA, 1995–2009

Michael A. Cover, Scott E. Hygnstrom, Scott R. Groepper

School of Natural Resources
University of Nebraska–Lincoln
Lincoln, NE 68583-0819
scott.groepper@yahoo.com

David W. Oates

Genetics and Forensics Analysis Laboratory
Wildlife Research Section
Nebraska Game and Parks Commission
Lincoln, NE 68503-0370

Kit M. Hams

Wildlife Division
Nebraska Game and Parks Commission
Lincoln, NE 68503-0370

and

Kurt C. VerCauteren

USDA-APHIS-WS-National Wildlife Research Center
Fort Collins, CO 80521-2154

ABSTRACT—Sera samples were collected from 21 free-ranging, captured female elk (*Cervus elaphus nelsoni*) in 1995–96, and tissue and sera samples were collected from 415 hunter-harvested elk from 1995 to 2006 and tested for selected diseases. Titers for *Anaplasma marginale* were detected in 81 of 436 (19%) elk. Occurrence of antibodies to anaplasmosis increased from 4 to 40 elk from 2002 to 2006. Titers for bovine viral diarrhea virus (BVDV) were detected in 18 of 346 (5%) samples. Titers for *Leptospira interrogans* serovars were detected in 21 of 289 (7%) of samples from 1995 to 2004. Titers for bluetongue virus (BTV) and epizootic hemorrhagic disease virus (EHDV) were detected in 65 of 370 (18%) sampled elk during 1995–2006. Biologists collected obex tissues from 566 elk from 1997 to 2009 and found evidence of chronic wasting disease (CWD) in one elk in 2009. No brucellosis was detected. Due to the prevalence of several diseases in elk in Nebraska, we recommend that surveillance efforts continue.

Key Words: anaplasmosis, bluetongue virus, bovine viral diarrhea virus, brucellosis, chronic wasting disease, elk, epizootic hemorrhagic disease virus, leptospirosis

INTRODUCTION

Transmission of diseases from livestock to wildlife, and vice versa, is an ongoing and increasing problem (Ward et al. 2008). Free-ranging elk (*Cervus elaphus nelsoni*) in Nebraska had never been tested or monitored for diseases. No records are available for elk to compare or evaluate the prevalence of *Anaplasma marginale*, brucellosis, bovine viral diarrhea virus (BVDV), bluetongue virus (BTV), epizootic hemorrhagic disease virus (EHDV), *Leptospira interrogans*, or chronic wasting disease (CWD). Prior

Manuscript received for review, September 2010; accepted for publication, January 2011.

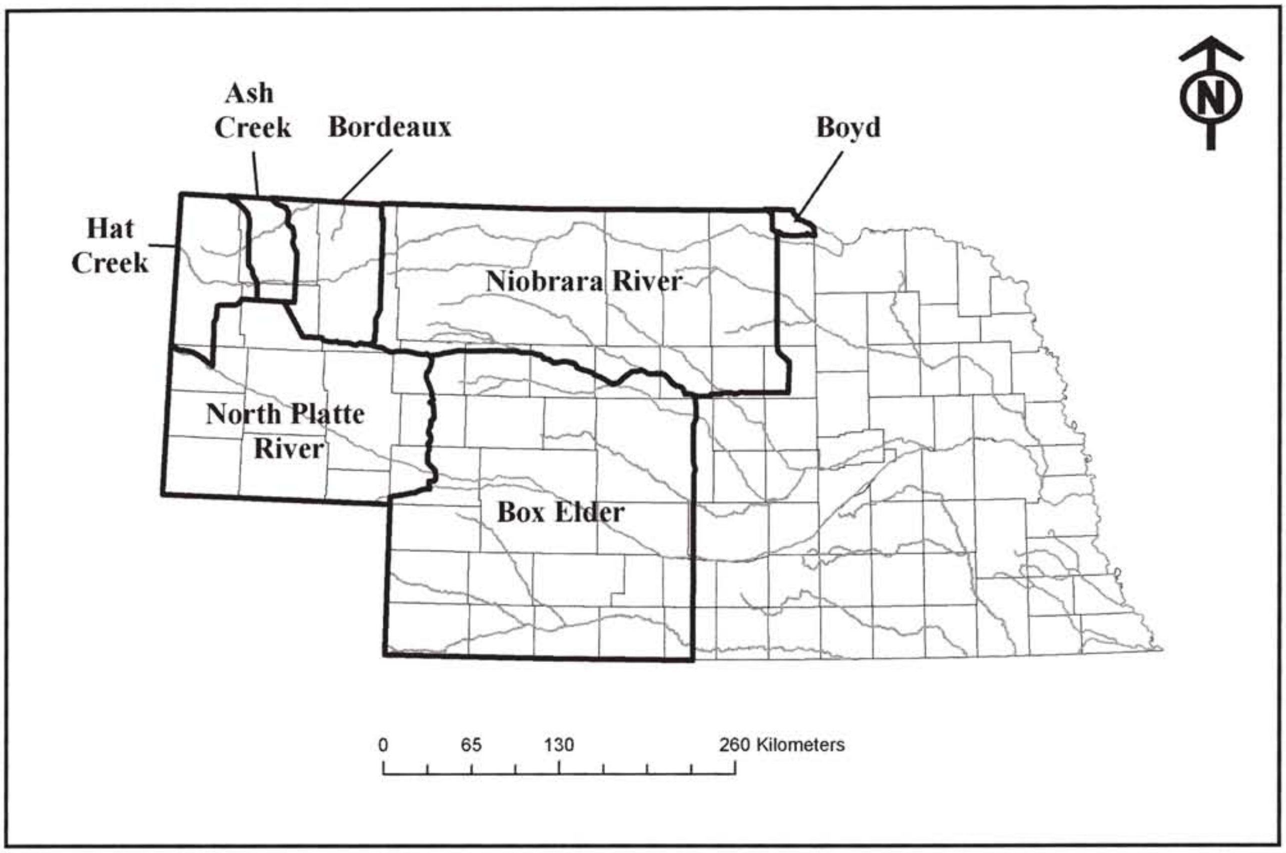


Figure 1. Elk management units (EMUs) in Nebraska, 1995–2010.

serologic surveys of wildlife in Nebraska have addressed anaplasmosis, brucellosis, BTV, EHDV, and bovine respiratory syncytial virus in free-ranging white-tailed deer (*Odocoileus virginianus*), mule deer (*O. hemionus*; Wilhelm and Trainer 1966), and pronghorn (*Antilocapra americana*; Johnson et al. 1986).

In the mid-1990s, the population of elk in Nebraska was estimated at 150–200 individuals (Fricke et al. 2008). The current population is approximately 1,400 and increasing at 15%–20% annually, with over half located in the three elk management units (EMUs) in the Pine Ridge region of northwestern Nebraska (NGPC 2007a; Fig. 1). Nebraska has the second-largest beef cattle herd in the United States, with 6.7 million head in 2007. Two of the top five cattle-producing counties in the state—Cherry and Sheridan, producing 166,000 and 56,000 head, respectively (Small et al., 2007)—are located within the Bordeaux and Niobrara River EMUs (Fig. 1). The risk of disease transmission between livestock and elk prompted us to carry out a long-term serologic study to determine prevalence of disease in elk. We tested for *Anaplasma marginale*, brucellosis, BVDV, BTV, EHDV, *Leptospira interrogans*, and CWD.

Sera samples were collected from 21 captured, free-ranging elk during 1995 and 1996, and tissue and sera samples were collected from 415 hunter-harvested elk at mandatory hunter check stations in six EMUs in Nebraska from 1995 to 2006. In 1995, the Nebraska Game and Parks Commission established Bordeaux and Hat Creek EMUs (Fig. 1). In 1996 Boyd EMU was established in response to depredation complaints associated with elk migrating back and forth from South Dakota (Cover 2000:151–82). The Box Elder, Ash Creek, and North Platte River EMUs were established in 2002, 2004, and 2005, respectively. The Niobrara River EMU was established in 2007, in recognition of the importance of elk management in the Sandhills region of Nebraska.

Biologists recorded information including identification number, sex, and date, time, and location of the kill. Three milliliters of serum from each elk was sent to the Veterinary Diagnostic Center, Nebraska State Brucellosis Laboratory, in Lincoln, NE, for analysis. Sera samples were tested for brucellosis antibodies using a particle concentration fluorescence immunoassay (PCFIA) test, Card test, Rivanol test, and plate agglutination

test. Five-milliliter samples of blood were centrifuged, and serum was forwarded to the South Dakota Veterinary Diagnostic Laboratory in Brookings (1995–1997), Wyoming State Veterinary Laboratory in Laramie (1998), National Veterinary Services Laboratories in Ames, IA (1999–2001), and the Veterinary Diagnostic Center in Lincoln, NE (2002–2006). Tests for antibodies to *Anaplasma marginale* were performed using a complement fixation or polymerase chain reaction enzyme-linked immunosorbent assay (PCR ELISA) test. In addition, tests for BVDV antibodies were performed using a serum neutralization test, BTV and EHDV antibodies using an Agar-Gel immunodiffusion and immunofluorescent antibody test, and *Leptospira interrogans* using a micro-agglutination test. Obexes from 566 hunter-harvested elk were collected at check stations from 1997 to 2009. Tissues were fixed in formalin, embedded in paraffin, and stained for a modified protease resistant protein (PrP^{CWD}) test. Tissue samples were tested for CWD using immunohistochemistry (IHC; Miller and Williams 2002) and ELISA tests (Hibler et al. 2003).

The University of Nebraska Institutional Animal Care and Use Committee (IACUC #94-09-075) approved all live animal procedures, and Nebraska Game and Parks Commission biologists conducted tissue collection on hunter-harvested animals.

RESULTS AND DISCUSSION

No antibodies to *Anaplasma marginale* were detected in elk from 1995 to 2001 (n = 182, $\bar{x}$ = 30). In 2002 antibodies were detected in four elk; however, we were unable to determine the sex of these elk and EMU where they were harvested, due to incomplete information (Table 1). Titers to anaplasmosis increased after 2002, with 38 male (20%, n = 187), 39 female (16%, n = 249) and four unknown elk with antibodies to *Anaplasma marginale* during the study. The number of elk exposed increased annually from 12% (n = 4) in 2002 to 61% (n = 40) in 2006. The number of areas affected increased from two EMUs in 2003 to five EMUs in 2006. Active infection can lead to abortions, low milk production, and death in cattle (Palmer 1989). Anaplasmosis has been identified as a major production-limiting disease in cattle in the United States in 2002–2006 (U.S. Department of Agriculture 2006), costing producers from $100 million to $300 million (Falkner 2001; Coetzee et al. 2005). The increase we detected may be due to expanding populations of elk in Nebraska. Distinct herds that expand in range may come into contact with other herds, increasing the probability of disease transmission. Additionally, we conducted sampling in areas where no sampling was previously conducted.

Five percent (18 of 346) of elk tested seropositive for BVDV during 1995 to 2001, 2003, 2004, and 2006 (Table 2), with titers ranging from 1:4 to 1:1,024. The prevalence of BVDV was relatively low and varied, from 0% in 1996, 1997, and 2001 to a maximum of 12% in 1995. Approximately 84% of cattle in western Nebraska have been exposed to BVDV (Jaggers 1984:36–56). Cattle producers in Nebraska supplement livestock with high-energy feed rations to increase weight gain and prepare for calving during the winter and early spring. Supplemental feeding is done in protected areas to avoid adverse weather. Elk may become conditioned to using cattle feed lines in winter, bringing them in contact with infected cattle or contaminated feed. Transmission of BVDV between cattle and elk has not been documented in Nebraska. Cattle persistently infected with BVDV are more likely to suffer abortions, stillbirth, or birth of weak calves (Carman et al. 2005).

Seven percent (21 of 289) of elk tested seropositive for *Leptospira interrogans* serovars (*L. i. bratislava, L. i. hardjo, L. i. pomona, L. i. grippotyphosa,* and *L. i. icterohemmorrhagiae*) during 1995 to 2002 and 2004 (Table 2), with titers ranging from 1:100 to 1:400. Prevalence of leptospirosis varied from 0% in 1997, 2001, and 2002 to 42% in 1996. Fifteen male elk (13%, n = 115) and six females (3%, n = 174) had titers. Leptospirosis is caused by a bacterial agent and cattle can act as a principal reservoir (Davidson and Nettles 1997:49–59). Elk and cattle sharing common pasture, rangelands, or watering areas may share the disease (Adrian and Keiss 1977).

Eleven percent (39 of 370) of elk had titers for BTV during 1995 to 2005 and 12% (26 of 214) had titers for EHDV during 1995 to 2001 and 2006. Prevalence of BTV varied from 0% in 1995–97 to 30% in 2005. Prevalence of EHDV varied from 0% in 1996–97 to 15% in 2006. Thirty-five male elk (19%, n = 187) and 30 female elk (12%, n = 249) were seropositive to BTV or EHDV (Table 2). Outbreaks of BTV and EHDV in cervids and cattle in Nebraska are limited to warmer months because transmission occurs through biting midges (*Culicodes* spp.) and ceases with the first killing frost (Kistner et al. 1982; Gibbs et al. 1983). Periodic outbreaks of BTV and EHDV have been reported in white-tailed deer in the Bordeaux and Niobrara River EMUs. Both diseases are considered enzootic in northern regions of the Sandhills and Platte River valley of Nebraska (Wilhelm and Trainer 1966). Prevalence of antibodies is higher (66%)

TABLE 1
SEROLOGIC TESTS INDICATING NUMBER OF POSITIVE RESULTS (*N*) FOR ANAPLASMOSIS AND THEIR LOCATION IN SAMPLED ELK IN NEBRASKA, 2002–2006

			Anaplasmosis	
Year	N tested	Sex	N	Location (EMU)
2002	15	M	4	*
	18	F		*
2003	12	M	6	Bordeaux, Hat Creek
	12	F	4	Bordeaux, Hat Creek
2004	26	M	3	Bordeaux, Hat Creek
	26	F	3	Ash Creek
2005	30	M	11	Ash Creek, Bordeaux, Hat Creek
	27	F	10	Ash Creek, Hat Creek, North Platte
2006	30	M	18	Ash Creek, Bordeaux, Box Elder, Hat Creek, North Platte
	36	F	22	Bordeaux, Hat Creek, North Platte

Note: Asterisk (*) indicates incomplete data on sex and location.

in deer in western and central Nebraska, compared to deer in eastern Nebraska (35%, Frost 2009). In the past, significant BTV prevalence (28%) has been detected in cattle in western Nebraska (Jaggers 1984). Experimental infections of cattle with EHDV derived from a deer led only to subclinical infections (Gaydos and Nettles 1998).

Chronic wasting disease was detected in 1 of 566 (<0.2%) samples collected from hunter-harvested elk from 1997 to 2009. The CWD-infected female elk was harvested in 2009 in the Hat Creek EMU (Fig. 1). In 1997, a captive elk infected with CWD was detected in the Hat Creek EMU. Chronic wasting disease was first observed in wild mule deer in Nebraska in the North Platte River EMU in 2000. One hundred ninety-eight positives were documented in mule deer and white-tailed deer in Nebraska from 2000 to 2009 (NGPC 2007b; D. Oates, pers. comm. 2010). Effective strategies for controlling CWD have yet to be discovered.

All 403 samples tested for brucellosis from 1995 to 2006 were negative. Elk are susceptible to brucellosis, as are bison (*Bison bison*; Jessup and Boyce 1996), mule deer, white-tailed deer (Trainer and Hanson 1960), moose (*Alces alces*; Forbes et al. 1996), and pronghorn (Thorne et al. 1979), all of which, except moose, have established populations in western Nebraska. Transmission of brucellosis from elk to cattle under free-range conditions was documented in cattle in Idaho and Wyoming in 2005 (Donch et al. 2006). Nebraska has been considered brucellosis free for ≥12 years (Donch and Gertonson 2008).

CONCLUSIONS

We recommend that the Nebraska Game and Parks Commission conduct annual serologic surveys of harvested elk in Nebraska. The prevalence and distribution of *Anaplasma marginale* increased considerably from 2002 to 2006, and it would be appropriate to continue monitoring. Bovine viral diarrhea and leptospirosis have all been detected in Nebraska, so it is important to monitor the status of these transmissible diseases, considering that elk are highly mobile (Fricke et al. 2008). In addition, elk may have been infected with chronic wasting disease due to their sympatric relationship with infected populations of mule deer and white-tailed deer in western Nebraska. We encourage continued surveillance of CWD in elk. We do not recommend further surveillance for EHDV or BTV in Nebraska. Both diseases are considered enzootic and cause little or no risk to cattle. While brucellosis has yet to be observed in elk in Nebraska, it is important to continue monitoring because of the social behavior

TABLE 2
SEROLOGIC TESTS INDICATING NUMBER OF POSITIVE TESTS FOR FOUR DISEASES AND THEIR LOCATION IN ELK SAMPLED IN NEBRASKA, 1995–2006

			BVDV		**Leptospirosis**		**Bluetongue virus**		**EHDV**	
Year	***N***	**Sex**	***N***	**Location (EMU)**	***N***	**Location (EMU)**	***N***	**Location (EMU)**	***N***	**Location (EMU)**
1995	5	M	1	Bordeaux	1	Bordeaux	—		1	Bordeaux
	28	F	3	Ash Creek, Bordeaux	1	Hat Creek	—		1	Hat Creek
1996	9	M	—		6	Bordeaux, Boyd, Hat Creek	—		—	
	10	F	—		2	Bordeaux, Boyd	—		—	
1997	15	M	—		—		—		—	
	14	F	—		—		—		—	
1998	21	M	—		2	Bordeaux	—		1	Bordeaux
	24	F	2	Bordeaux	—		1	Bordeaux	1	Bordeaux
1999	10	M	—		—		1	Bordeaux	4	Bordeaux, Boyd, Hat Creek
	17	F	1	Boyd	3	Bordeaux	—		1	Bordeaux
2000	9	M	1	Hat Creek	1	Bordeaux	1	Hat Creek	1	Bordeaux
	20	F	—		—		2	Bordeaux, Hat Creek	4	Bordeaux, Hat Creek
2001	5	M	—		—		3	Bordeaux, Hat Creek	—	
	17	F	—		—		1	Hat Creek	2	Bordeaux
2002	15	M	NT		—		5*		NT	
	18	F	NT		—		*		NT	
2003	12	M	—		NT		3	Bordeaux, Hat Creek	NT	
	12	F	1	Bordeaux	NT		—		NT	
2004	26	M	2	Bordeaux	5	Ash Creek, Bordeaux, Hat Creek	3	Ash Creek, Bordeaux	NT	
	26	F	2	Bordeaux, Hat Creek	—		2	Bordeaux, Hat Creek	NT	
2005	30	M	NT		NT		8	Ash Creek, Bordeaux, Hat Creek, North Platte	NT	
	27	F	NT		NT		9	Bordeaux, Hat Creek, North Platte	NT	
2006	30	M	2	North Platte	NT		NT		4	Ash Creek, Bordeaux, Box Elder, North Platte
	36	F	3	North Platte	NT		NT		6	Bordeaux, Box Elder, North Platte

Notes: Dash (—) indicates disease not found; NT indicates disease not tested; asterisk (*) indicates incomplete data on sex and location.

and mobility of elk and the economic significance of brucellosis-free status for livestock in Nebraska. We did not test for bovine tuberculosis in our study; however, it was detected in cattle in the Niobrara EMU and in captive elk east of the EMUs in Nebraska in 2009 (D. Oates, pers. comm. 2010), so surveillance is merited in elk.

ACKNOWLEDGMENTS

We thank Dr. John Gamby and Dr. Jack Klase for their veterinary services. We thank Daniel Crank, Bruce Stillings, and NGPC personnel for assisting with collection of data. We thank Dr. Doug Rogers, Dr. Butch Sahara, and the late Dr. Elizabeth Williams for consultation and we thank hunters for providing blood samples. Funding was provided by the Nebraska Game and Parks Commission, the Nebraska National Forest, the Rocky Elk Mountain Foundation, and the University of Nebraska–Lincoln.

REFERENCES

Adrian, W.J., and R.E. Keiss. 1977. Survey of Colorado's wild ruminants for serologic titers to brucellosis and leptospirosis. *Journal of Wildlife Diseases* 13:429–32.

Carman, S., N. Carr, J. DeLay, M. Baxi, D. Derget, and M. Hazlett. 2005. Bovine viral diarrhea virus in alpaca: Abortion and persistent infection. *Journal of Veterinary Diagnostic Investigation* 17:589–93.

Coetzee, J.F., M.D. Apleya, K.M. Kocanb, F.R. Rurangirwac, and J. Van Donkersgoedd. 2005. Comparison of three oxytetracycline regimens for the treatment of persistent *Anaplasma marginale* infections in beef cattle. *Veterinary Parasitology* 127:61–73.

Cover, M.A. 2000. Ecology of elk in the Pine Ridge region of northwest Nebraska: Seasonal distribution, characteristics of wintering sites, and herd health. Master's thesis, University of Nebraska–Lincoln.

Davidson, W.R., and V.F. Nettles. 1997. Field manual of wildlife diseases in the southeastern United States. Southeast Cooperative Wildlife Disease Study, College of Veterinary Medicine, University of Georgia, Athens.

Donch, D.A., and A.A. Gertonson. 2008. *Status Report–Fiscal Year 2008, Cooperative State-Federal Brucellosis Eradication Program.* http://www.aphis.usda.gov/animal_health/animal_diseases/brucellosis/downloads/yearly_rpt.pdf (accessed June 18, 2009).

Donch, D.A., A.A. Gertonson, J.C. Rhyan, and M.J. Gilsdorf. 2006. *Status Report–Fiscal Year 2006. Cooperative State-Federal Brucellosis Eradication Program.* http://www.aphis.usda.gov/animal_health/animal_diseases/brucellosis/downloads/yearly_rpt.pdf (accessed January 23, 2008).

Falkner, R. 2001. Is anaplasmosis spreading in the United States? *Bovine Veterinarian*, May–June, 24–30.

Forbes, L.B., S.V. Tessaro, and W. Lees. 1996. Experimental studies on *Brucella abortus* in moose (*Alces alces*). *Journal of Wildlife Diseases* 32:94–104.

Fricke, K.A., M.A. Cover, S.E. Hygnstrom, S.R. Groepper, H.H. Genoways, K.M. Hams, and K.C. VerCauteren. 2008. Historic and recent distributions of elk in Nebraska. *Great Plains Research* 18:189–204.

Frost, C.J. 2009. Survival and movement of mule deer and white-tailed deer in Nebraska with implications for the spread of chronic wasting disease and hemorrhagic disease. PhD diss., University of Nebraska–Lincoln.

Gaydos, J., and V. Nettles. 1998. EHDV and cattle. *SCWDS Briefs* 14 (3).

Gibbs, E.P., E.C. Greiner, W.P. Taylor, T.L. Barber, J.A. House, and J.E. Pearson. 1983. Isolation of bluetongue virus serotype 2 from cattle in Florida: Serotype of bluetongue hitherto unrecognized in the Western Hemisphere. *American Journal of Veterinary Research* 44:2226–28.

Hibler, C.P., K.L. Wilson, T.R. Spraker, M.W. Miller, R.R. Zink, L.L. Debuse, E. Anderson, D. Schweitzer, J.A. Kennedy, L.A. Baeten, J.F. Smeltzer, M.D. Salman, and B.E. Powers. 2003. Field validation and assessment of an enzyme-linked immunosorbent assay for detecting chronic wasting disease in mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), and Rocky Mountain elk (*Cervus elaphus nelsoni*). *Journal of Veterinary Diagnostic Investigation* 15:311–19.

Jaggers, R. 1984. Bovine bluetongue in western Nebraska cow herds: A serological study of bluetongue and bovine viral diarrhea virus and relationship to neonatal calf defects. Master's thesis, University of Nebraska–Lincoln.

Jessup, D.A., and W.M. Boyce. 1996. Diseases of wild ungulates and livestock. In *Rangeland Wildlife*, ed. P.R. Krausman, 397–411. Society for Range Management, Denver.

Johnson, J.L., T.L. Barber, M.L. Frey, and G. Nason. 1986. Serosurvey for selected pathogens in hunter-

harvested pronghorns in western Nebraska. *Journal of Wildlife Diseases* 22:87–90.

Kistner, T.P., K.R. Greer, D.E. Worley, and O.A. Brunetti. 1982. Diseases and parasites. In North American Elk: Ecology and Management, ed. J.W. Thomas and D.E. Toweill, 181–217. Stackpole Books, Harrisburg, PA.

Miller, M.W., and E.S. Williams. 2002. Detection of PrP^{CWD} in mule deer by immunohistochemistry of lymphoid tissues. Veterinary Record 151:610–12.

NGPC (Nebraska Game and Parks Commission). 2007a. Big game hunting guide. http://www.ngpc.state.ne.us/hunting/guides/biggame/BGelk.asp (accessed February 17, 2008).

NGPC (Nebraska Game and Parks Commission). 2007b. Deer, elk tested for CWD. http://www.ngpc.state.ne.us/wildlife/guides/cwd/cwdnews.asp (accessed January 6, 2008).

Palmer, G. 1989. Anaplasma vaccines. In Veterinary Protozoan and Haemoparasite Vaccines, ed. I.G. Wright, 1–29. CRC Press, Boca Raton, FL.

Small, R.M., M.R. Darrell, and D.J. Peters. 2007. Nebraska's cattle feeding industry: Size, structure, and related industries. Cooperative Extension, University of Nebraska–Lincoln.

Thorne, E.T., J.K. Morton, and W.C. Ray. 1979. Brucellosis, its effect and impact on elk in western Wyoming. In North American Elk: Ecology, Behavior, and Management, ed. M.S. Boyce and L.O. Hayden-Wing, 212–20. University of Wyoming, Laramie.

Trainer, D.O., and R.P. Hanson. 1960. Leptospirosis and brucellosis serological reactors in Wisconsin deer, 1957–58. Journal of Wildlife Management 24:45–51.

U.S. Department of Agriculture. 2006. Requested information on anaplasmosis and bluetongue status in the United States. In USDA 2002 *Report on Anaplasmosis Science and Policy Based on Meeting of United States Experts* by B. Bokama, T. Bunn, H. Coetzee, D. Dargatz, J. Katz, D. Knowles, K. Kocan, J. de la Fuente, D. Maloy, T. McElwain, D. Nelson, B. Wagner, G. Wagner, and T. Walton, 17–31. Fort Collins, CO.

Ward, A.I., K.C. VerCauteren, W.D. Walter, E. Gilot-Fromont, S. Rossi, G. Edwards-Jones, M. Lambert, M.R. Hutchings, and R.J. Delahay. 2008. Options for the control of disease 3: Targeting the environment. In *Management of Disease in Wild Mammals*, ed. R.J. Delahay, G.C. Smith, and M.R. Hutchings, 147–68. Springer, Tokyo.

Wilhelm, A.R., and D.O. Trainer. 1966. A serological study of epizootic hemorrhagic disease of deer. *Journal of Wildlife Management* 30:777–80.

Great Plains Research 21 (Fall 2011):153–73

HISTORICAL BIOGEOGRAPHY OF NEBRASKA PRONGHORNS (*ANTILOCAPRA AMERICANA*)

Justin D. Hoffman

Department of Biological and Health Sciences
McNeese State University
Lake Charles, LA 70609
jhoffman@mcneese.edu

Hugh H. Genoways

University of Nebraska State Museum
University of Nebraska–Lincoln
Lincoln, NE 68588

and

Rachel R. Jones

School of Natural Resources
University of Nebraska–Lincoln
Lincoln, NE 68583

ABSTRACT—Archeological and paleontological records indicate that the pronghorn (*Antilocapra americana*) have a history of at least 20,000 years of occurrence within the current boundaries of Nebraska. Pronghorns occurred throughout the state for much of its history. With the evidence at hand we concluded that the eastern boundary of the geographic distribution of the pronghorn south of the Niobrara River in Nebraska at the beginning of the 19th century was along the western perimeter of the eastern deciduous forest and tallgrass prairie. This excluded most of the easternmost tier of counties in the state. This geographic arrangement persisted throughout most of the Holocene. The boundary, however, was never a straight line, but a dynamic system of fluctuating distribution. By the early 20th century, the pronghorn was nearly extirpated from Nebraska, with only scattered herds in the western panhandle. With a ban on hunting beginning in 1907 and management by the Nebraska Game and Parks Commission, the population in the panhandle had increased to the point that a hunting season was reinstituted in 1953. To establish herds of pronghorns in previously occupied areas beyond the panhandle, 1,106 individuals were translocated between 1958 and 1962 primarily to the Sandhills region of Nebraska. Currently, the pronghorn possess stable populations throughout nearly half of Nebraska, including the panhandle and most of the Sandhills.

Key Words: *Antilocapra americana*, distribution, historical biogeography, Nebraska, pronghorn

INTRODUCTION

The pronghorn (*Antilocapra americana*) historically was a widespread resident of the state of Nebraska. Together with bison, elk, white-tailed deer, and mule deer, pronghorns constituted the "big game" of the plains and forest edges of the western United States, northern Mexico, and the prairie provinces of central Canada. The population of pronghorns has undergone many changes over the more than 200-year history of Nebraska, but the species remains part of the fauna of some areas of the state under regulation and management of the Nebraska Game and Parks Commission (NGPC). The Lewis and Clark expedition produced one of the earliest written records of pronghorns based on observations made on September 3, 1804, near the mouth of the Niobrara River

Manuscript received for review, January 2011; accepted for publication, February 2011.

in northeastern Nebraska. William Clark noted in his journal: "Several wild Goats Seen in the Plains they are wild & fleet" (Moulton 1987:44).

As was the case with Captain Clark, some early writers considered the pronghorn to be a goat or related to goats. Many authors, including many modern authors, refer to the species under the common name of antelope. However, as noted by one early writer (Paul Wilhelm 1973:332): "I consider the designation *Antilocapra americana* as more fitting since the head and the hoofs would classify them among the goats, their mode of living, however, among the antelopes." Indeed, the genus name *Antilocapra* reflects this dual identity, *Antilo-* based on the Greek for a horned mammal and the basis of the generic name *Antilope* for the Indian blackbuck, and *-capra* from the Latin meaning goat. Thus the name would mean the "antelope goat," but the pronghorn is neither antelope nor goat. Both antelope and goats are members of the mammalian family Bovidae, which originated in the Old World, being members of the subfamilies Antilopinae (antelopes) and Caprinae (goats and sheep), respectively. The pronghorn, however, is the sole living representative of the family Antilocapridae. This family is strictly New World in its origin and distribution, and although there is only one living genus and species, there are at least 20 fossil genera with a history extending back to about 20 million years ago in the Early Miocene (McKenna and Bell 1997:422–23).

The pronghorn has been the subject of extensive research dealing both with its basic biology as well as its management as a game species (O'Gara 1978; O'Gara and Yoakum 2004). However, in Nebraska along the eastern boundary of the geographic range of the species, very few research results have been published in the scientific literature. It is our objective in this article to continue to fill this gap in our knowledge of this important species (Hoffman et al. 2010). We attempt to develop a picture of the trends in geographic distribution of pronghorns in Nebraska.

First, based on archeological and paleontological literature, we assess the Holocene distribution of the species. Second, we estimate the historical distribution of pronghorns in Nebraska based on the written record of direct observations, covering the period from Lewis and Clark's first observation in 1804 through the beginning of transplanting of herds in 1958. Finally, we determine the current distribution of pronghorns in Nebraska based on recent population surveys and reintroductions by the Nebraska Game and Parks Commission.

METHODS

We identified records of pronghorns during the Holocene by surveying the archeological and paleontological literature. We defined the Holocene as that time period from the end of Pleistocene glaciation (≈12,000 BC) until 1850. This literature, particularly reports on archeological sites, is extremely scattered and presents significant challenges in completing a thorough survey. These reports range from books published by major university and commercial presses, to reports kept in the files of individual investigators or historical organizations. Only one or two copies of some reports have ever existed. We hope that our efforts have found and evaluated as much as 90% of this relevant literature. The identification of pronghorn remains is based on the original reports. We have included only those records in which the investigators definitively identified the remains as those of the pronghorn. There are some challenges in interpreting some archeology records. For instance, these records are associated primarily with human hunting activity. This is problematic because the location of the remains probably represented the area where hunters brought the animal to be eaten and not where it was killed. Skeletal remains that were made into utilitarian and ceremonial objects could be subject to even longer distance transportation by humans.

The historical distribution was determined based on written observations gathered from the published literature, information noted in the accounts of early expeditions that took place within the state, and museum records. These records cover a period from 1804 to 1958. Although there is overlap in time periods covered by the Holocene (≈12,000 BC to 1850) and historical (1804–1958) records, the nature of these records differentiates the two. Holocene records are based on the physical objects represented by the bones of the pronghorn. The historical records are based solely on written reports of human observations. Finally, we searched the MaNIS (Mammal Networked Information System) website for any museum specimens of pronghorn that were collected in Nebraska.

The current distribution was estimated through data collected from the Nebraska Game and Parks Commission, including harvest records, population monitoring, relocation of populations, and observations made by wildlife biologists. Information on current Nebraska pronghorn populations primarily was taken from the Pittman-Robertson W-15-R Pronghorn Job Completion Report series compiled by the NGPC. This information

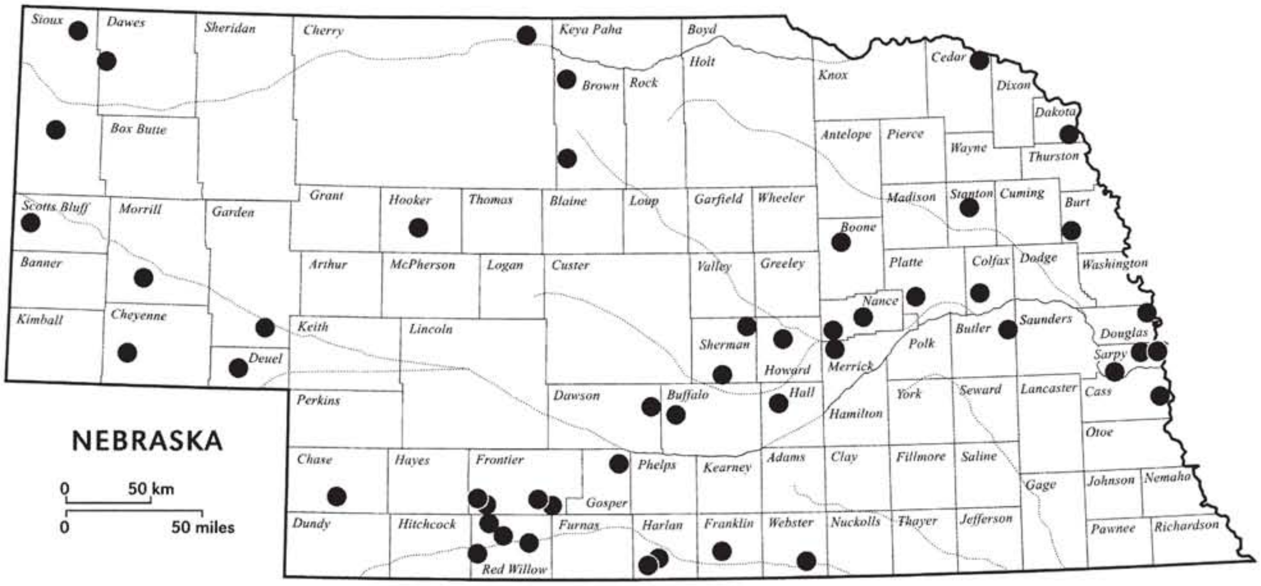


Figure 1. Location of Holocene records of pronghorn (*Antilocapra americana*) in Nebraska.

summarized all the work conducted in a calendar year by the NGPC as it pertained to the management of pronghorns in Nebraska. This included inventory and monitoring of populations, harvest records, and various special projects undertaken.

RESULTS

Holocene Records

Archeological and paleontological records provide some insight into the early distribution of pronghorns in Nebraska and indicate that this species has a long history of occurrence within the boundaries of the current state (Fig. 1, Table 1). Our search of the literature has identified 72 archeological and paleontological sites in 35 counties where remains of pronghorns have been found in Nebraska. There is an almost continuous record in space and time through the Holocene. There are records from eastern Nebraska in Douglas and Cass Counties, from western Nebraska in Scotts Bluff and Sioux Counties, from northern Nebraska in Cedar and Cherry Counties, and from southern Nebraska in Red Willow and Webster Counties. The concentration of archeological records in southwestern Nebraska is the result of intensive archeological surveys associated with dam building in Frontier, Harlan, and Red Willow Counties. On the other hand, southeastern Nebraska and the Sandhills of central Nebraska lack sites where pronghorn remains have been found, at least in part because of the restricted number of archeological surveys conducted in these areas.

The oldest records for *Antilocapra americana* in Nebraska come from two fossil sites in Red Willow County (Rw-101, Rw-102) believed to date from the late Wisconsin ice age, about 20,000 years ago. This was probably a time near the end of the last continental glaciation when there was a fauna of 24 species, of which half are now extinct and another six no longer occur in the state (Corner 1977; Chorn et al. 1988). The oldest archeological site (11,000–7500 BC) from which pronghorn remains have been recovered in Nebraska is the Allen site (25FT50) in Frontier County, discovered as part of the work on the Medicine Creek Reservoir (Bamforth 2002). At the nearby site of Lime Creek (25FT41), remains of pronghorns from 7500 BC were recorded. In western Nebraska, a pronghorn found just above the Hudson-Meng bone bed dates from nearly 8000 BC. These three sites are believed to have been occupied by Paleoindians.

At a slightly younger site in eastern Nebraska, pronghorn material was recovered from the Logan Creek site (25BT3) in Burt County, which is believed to have been occupied by Early Plains Archaic people by 5000 BC (Snyder and Bozell 1983; Semken and Falk 1987). Other Plains Archaic sites (6000 BC–AD 500) where pronghorn material has been recovered include 25DW59 in Dawes County, the Spring Creek site (25FT31) in Frontier County, the Signal Butte site in Scotts Bluff County, and two sites (25SX157, 25SX163) in the Agate Fossil Beds

TABLE 1
HOLOCENE RECORDS OF THE PRONGHORN (*ANTILOCAPRA AMERICANA*)
FROM 72 ARCHEOLOGICAL AND PALEONTOLOGICAL SITES IN 35 COUNTIES IN NEBRASKA

County	Site	Specific location	Age	Reference
Boone	Beaver Creek Site, 25BO23	4.5 miles south of Petersburg	AD 1100–1400	Koch and Nelson 2002:87
Brown	McIntosh Site, 25BW15	Enders Lake, ≈12 miles south, 12.5 miles west of Ainsworth	AD 1200–1450	Koch 2004:117
Brown	25BW252	16 miles north, 5.5 miles west of Johnstown	Unknown	Pepperl and Falk 1983:B81
Buffalo	*25BF161*	*SE 1/4, NE 1/4, Sec. 18, T10N, R17W*	Unknown	Ludwickson 1978b:35
Buffalo	25BF187	3.75 miles northwest of Amherst	AD 1000–1350	Ludwickson 1978b:35
Burt	Logan Creek Site B, 25BT3	Logan Creek, southwest of Oakland	BC 4340 ± 120	Snyder and Bozell 1983:20 Graham et al. 1987:283 Widga 2006:67
Burt	*Logan Creek Site C, 25BT3*	*Logan Creek, southwest of Oakland*	BC 5020 ± 90	Snyder and Bozell 1983:20 Graham et al. 1987:283 Widga 2006:67
Burt	*Logan Creek Site D, 25BT3*	*Logan Creek, southwest of Oakland*	BC 5070 ± 110	Widga 2006:68
Butler	Barcal Site, 25BU4	Near Abie	AD 1700–1750	O'Shea and Ludwickson 1992:338
Cass	Walker Gilmore, 25CC28	6 miles southeast of Murray	AD 800–1285	Strong 1935:194
Cedar	Ferber Site, 25CD10	Near Bow Valley Mill	AD 800–1300	Ludwickson et al. 1981:22–23
Chase	Lovitt Site, 25CH1	12 miles west of Wauneta	Circa AD 1700	Hill and Metcalf 1942:204; Gunnerson 1960:212–216
Cherry	25CE309	3 miles south, 0.4 miles west of Sparks	AD 0–1000	Pepperl and Falk 1983:B85
Cheyenne	Thurston Site, 25CN11	Lodgepole Creek, 6 miles east of Potter	AD 0–1000	Jensen 1973:167
Colfax	Schuyler Site, 25CX1	along Shell Creek, ≈3 miles northwest of Schuyler	AD 1500–1650	Bozell et al. 1982:28 Graham et al. 1987:286
Dakota	Hancock Site, 25DK14	1 mile southeast of Homer	AD 1450–1500	Frantz 1963:97–98
Dawes	25DW59	0.70 mile west of Crawford	BC 1000–AD 900	Bozell and Ludwickson 1988:86
Dawson	25DS118	SE 1/4, SW 1/4, SE 1/4, Sec. 16, T10N, R19W	AD 1000–1350	Ludwickson 1978b:36
Douglas	Ponca Creek District	2.25 miles north of former town of Florence	Unknown	Gilder 1907:706, 711
Duel	Neumann Site, 25DU3	Lodgepole Creek, 3.5 miles southeast of Chappell	AD 0–1000	Carlson 1973:104
Franklin	Lost Creek Site	Lost Creek, 2.25 miles south, 1.5 miles east of Bloomington	AD 1000–1350	Strong 1935:100
Frontier	*Owens Site, 25FT3*	*On Medicine Creek*	AD 1000	Mick 1983:172 Graham et al. 1987:285
Frontier	*25FT13*	*Vicinity of Medicine Creek Dam*	AD 1010	Mick 1983:175 Graham et al. 1987:285 Kivett and Metcalf 1997:213
Frontier	*25FT14*	*Vicinity of Medicine Creek Dam*	AD 1250–1400	Mick 1983:182 Kivett and Metcalf 1997:213
Frontier	*25FT16*	*Vicinity of Medicine Creek Dam*	AD 1020–1235	Mick 1983:185 Graham et al. 1987:285 Kivett and Metcalf 1997:213

TABLE 1 continued

County	Site	Specific location	Age	Reference
Frontier	25FT17	Vicinity of Medicine Creek Dam	AD 1080–1240	Mick 1983:191 Graham et al. 1987:286 Kivett and Metcalf 1997:213
Frontier	*25FT18*	*Near point where Lime Creek originally entered Medicine Creek*	AD 595 ± 225	Kivett and Metcalf 1997:212
Frontier	*25FT20*	*Near point where Lime Creek originally entered Medicine Creek*	AD 1000–1350	Kivett and Metcalf 1997:213
Frontier	*25FT22*	*≈ 4 km upstream on Medicine Creek from Medicine Creek Dam*	AD 1000–1350	Nepstad-Thornberry et al. 2002:199
Frontier	*25FT30*	*Near point where Lime Creek originally entered Medicine Creek*	AD 1100–1300	Mick 1983:202 Graham et al. 1987:286 Kivett and Metcalf 1997:213
Frontier	Spring Creek Site, 25FT31	Red Willow Creek, adjacent to Red Willow Dam	BC 3850–3500	Granger 1980:166 Widga 2004:29
Frontier	*Mowry Bluff Site, 25FT35*	*6 miles northwest of Cambridge (in Furnas County)*	AD 1020–1180	Falk 1969a:42, 1969b:48 Mick 1983:205 Graham et al. 1987:286:213 Nepstad-Thornberry et al. 2002:199
Frontier	*25FT36*	*≈4 km upstream on Medicine Creek from Medicine Creek Dam*	AD 1175 ± 25	Mick 1983:206 Kivett and Metcalf 1997:213
Frontier	*25FT39*	*≈5 km upstream on Medicine Creek from Medicine Creek Dam*	AD 1200–1280	Mick 1983:210 Graham et al. 1987:286 Kivett and Metcalf 1997:213
Frontier	*Lime Creek Site, 25FT41*	*North side of Lime Creek valley, 1 mile from original junction of Lime and Medicine creeks*	BC 7500–6000	Davis 1962:23 Graham et al. 1987:283 Wedel 1986:69
Frontier	Allen Site, 25FT50	≈3 miles upstream from Medicine Creek Dam	BC 11,000–7500	Holder and Wike 1949:261 Bamforth 2002:65 Hudson 2007:195
Frontier	25FT54	Red Willow Creek, 5 miles upstream from Red Willow Dam	AD 1310	Granger 1980:166 Mick 1983:169
Frontier	*25FT70*	*Vicinity of Medicine Creek Dam*	AD 690–1450	Mick 1983:210 Graham et al. 1987:286 Kivett and Metcalf 1997:213 Nepstad-Thornberry et al. 2002:199
Garden	Ash Hollow Cave Site, 25GD2	3 miles southeast of Lewellen	AD 0–1700	Champe 1946:43
Gosper	Wallace Site, 25GO2	Plum Creek, 5.5 miles north, 9.5 miles east of Elwood	AD 425–650	Winfrey 1991:83
Hall	Hulme Site, 25HL28	16 miles west of Grand Island	AD1170–1220	Bozell 1991:234
Harlan	25HN36	2 miles south of Alma	AD 1050–1350	Adair and Brown 1987:154, 585
Harlan	25HN40	0.8 mile south, 2 miles east of Alma	AD 400–900	Adair and Brown 1987:194, 590
Hooker	Humphrey Site, 25HO21	Middle Loup River, about 5 miles east of Mullen	Circa AD 1700	Gunnerson 1960:204
Hooker	*Kelso Site, 25HO23*	*Middle Loup River, about 5 miles east of Mullen*	AD 0–1000	Kivett 1952:39–40
Howard	Schmidt Site, 25HW301	Along North Loup River, near Elba	AD 1100–1550	Mick 1983:157 Graham et al. 1987:284
Merrick	Tahaksu Site, 25MK15	4.8 miles north, 1.2 miles west of Palmer	AD 1100–1400	Watson 1996:135
Morrill	Greenwood Site	Old Greenwood Stage Station, Keenan Ranch, ≈9 miles south, 8 miles east of Redington	Unknown	Renaud 1933:14

TABLE 1 continued

County	Site	Specific location	Age	Reference
Nance	Brown Site, 25NC8	Vicinity of Fullerton	AD 1250–1450	Ludwickson 1978a:98 Mick 1983:160 Graham et al. 1987:285
Nance	*Cunningham Site, 25NC10*	*Vicinity of Fullerton*	AD 1250–1450	Ludwickson 1978a:98 Mick 1983:163 Graham et al. 1987:285
Nance	*25NC13*	*Vicinity of Fullerton*	AD 1250–1450	Ludwickson 1978a:98 Mick 1983:166
Nance	Palmer Locality (in part), 25NC29	5.5 miles south, 19 miles west of Fullerton	AD 1100–1400	Meadow and Peterson 2001:157
Platte	Hill-Rupp Site, 25PT13	1.5 miles north of Monroe	AD 1650–1750	Metcalf 1941:34
Red Willow	25RW22	3 miles north, 6.25 west of Indianola	AD 1000–1350	Granger 1980:166 Mick 1983:169
Red Willow	Doyle Site, 25RW28	9.5 miles north, 0.75 mile west of McCook	BC 60–AD 680	Granger 1980:167
Red Willow	Gillen Pits, Rw-101	4.5 miles west of McCook	Late Pleistocene–early Holocene	Corner 1977:79, 85–86
Red Willow	Davidson Pits, Rw-102	1 mile west of Bartley	Late Pleistocene–early Holocene	Corner 1977:79, 85–86
Sarpy	Childs Point District	≈ 1.5 miles northwest of Bellevue	Unknown	Gilder 1909:72–73
Sarpy	Lucien Fontenelle's Post	Bellevue	AD 1822–1842	Bozell et al. 1990:30
Sarpy	Patterson Site, 25SY31	≈ 7 miles south of Gretna	AD 100–1300	Bozell and Ludwickson 1999:84
Scotts Bluff	Signal Butte Site	Signal Butte	BC 3000–AD 500	Strong 1935:236
Sherman	Bill Packer Site, 25SM9	Along Davis Creek in extreme northeastern corner of county	AD 980–1050	Graham et al. 1987:285 Bozell and Rogers 1989:28
Sherman	Sweetwater Site	0.5 mile northwest of Sweetwater (in Buffalo County)	Unknown	Champe 1936:268
Sioux	Hudson-Meng Site, 25SX115	23 miles northwest of Crawford (in Dawes County)	BC 7820	Agenbroad 1978:36
Sioux	25SX157	Agate Fossil Beds National Monument, 19.25 miles south, 5.75 miles east of Harrison	BC 6000–1000	Bozell 1993:61 Bozell 1994:48, 62
Sioux	*25SX163*	*Agate Fossil Beds National Monument, Agate Fossil Beds National Monument, 19.25 miles south, 7.25 miles east of Harrison*	BC 1000–AD 500	Bozell 1993:64
Sioux	*25SX476*	*Agate Fossil Beds National Monument, 1.7 miles east of Agate*	AD 900	Bozell 1993:67
Sioux	25SX486	*Agate Fossil Beds National Monument, Agate Fossil Beds National Monument, 19.25 miles south, 5.25 miles east of Harrison*	Unknown	Bozell 1994:50, 63
Sioux	*25SX487*	*0.1 mile north, 0.15 mile east of Visitor Center*	Unknown	Bozell 1993:67
Stanton	25ST1	1 mile east of Stanton	AD 1200–1500 and AD 1800–1833 (mixed site)	Gunnerson n.d.
Webster	Hill Site	2 miles south, 7 miles east of Red Cloud	AD 1700–1850	Wedel 1936:62
Webster	*Shipman Site, 25WT7*	*South side of Republican River, between Red Cloud and Guide Rock*	Post–AD 1350	Mick 1983:154 Graham et al. 1987:286

Note: County names and localities in roman lettering are plotted on Figure 1; those county names and localities in italics are not plotted on Figure 1 to prevent overcrowding of symbols

National Monument in Sioux County. All other pronghorn remains in Nebraska come from sites that are less than 2,000 years old.

Because eastern Nebraska is at or near the eastern boundary of the geographic range of the species, records along the eastern edge of the state and their basis are of particular interest. Material from the Logan Creek site (25BT3) in Burt County (Snyder and Bozell 1983) and the Walker Gilmore site (25CC28) in Cass County (Strong 1935), although fragmentary, showed no modifications or working by humans. The historic period remains from the Euro-American trading post operated by Lucien Fontenelle in northeastern Sarpy County were probably the result of subsistence hunting and could have originated anywhere within travel distance of the post (Bozell et al. 1990:30). The remains from the Hancock site (25DK14) in Dakota County consisted of two right mandibles that had been modified and polished (Frantz 1963). Gilder (1909:72) found five pronghorn mandibles near Bellevue in Sarpy County that had been modified to attach a handle and "having a higher polish than any other of the bone implements." These latter implements, like those from Dakota County, have been hypothesized to be used as a sickle or corn sheller. At the site north of Florence in Douglas County, Gilder (1907) recovered a pronghorn horn core and a small portion of attached cranium that had a hole drilled through it and a scapula that had been modified into a small hoe. The former object probably was used for ornamentation or for a sacred purpose and the latter clearly had a utilitarian purpose. In southwestern Sarpy County, at least one of several pronghorn bones found at the Patterson site (25SY31) had been modified (Bozell and Ludwickson 1999). Another site with numerous utilitarian objects produced from pronghorn bones was the Sweetwater site in Sherman County, where Champe and Bell (1936) recorded: "Ten complete bone awls made from the front metapodial or cannon bone of the antelope (*Antilocapra americana*) were found, and four fragments of awls."

At a majority of sites, pronghorns account for only a small portion of the faunal remains, with the minimum numbers of individuals being five or less at each site (Granger 1980; Semken and Falk 1987). At the vast majority of sites the remains of bison (*Bison bison*) far outnumber those of other game mammals, followed by deer (*Odocoileus* sp.) and elk (*Cervus elaphus*), with pronghorn usually the fourth most abundant. There may be several reasons for this ranking of pronghorns among the hunted game animals, including availability (size of local populations), palatability, and huntability (these weary and speedy animals would have been particularly difficult to hunt, especially before the introduction of the horse). However, there are at least two exceptions to this rule, including the oldest zone (7500–6000 BC) of the Lime Creek site (25FT41) in the southwestern part of the state, where beaver and pronghorn bones dominated, whereas in younger layers *Bison* bones were most abundant (Davis 1962). At the Hulme site (25HL28) pronghorn remains predominate, with a minimum of 306 individuals in addition to 248 individuals that were either pronghorn or deer. The site, which is located on an upland area in the Platte River drainage in western Hall County, dates from about 1250 AD. Pronghorn and deer (*Odocoileus* sp.) accounted for 66.2% of the identified mammalian remains, whereas the other large ungulates from the site, bison (*Bison bison*) and elk (*Cervus elaphus*), accounted for only 2.4% (Bozell 1991).

Historical Record

It appears that the first written record of a pronghorn (Fig. 2, Table 2) within the current boundaries of the state of Nebraska was by members of the Lewis and Clark expedition on September 3, 1804. The expedition at this point was passing up the Missouri River between Knox County, Nebraska, and Bon Homme County, South Dakota (Moulton 1987:44). That night the party camped on the Nebraska side of the river "at the edge of a Plain" that was probably near the western boundary of the present Santee Sioux Indian Reservation, east of the relocated town of Niobrara in Knox County (Moulton 1987:44–46). On September 14, 1804, when the party was well into present-day South Dakota, Captain Clark killed a pronghorn in Lyman County (Moulton 1987:71–72). Both Lewis and Clark described this individual in detail in their journals, which later probably formed part of Ord's scientific description of the species (Ord 1815).

Other early explorers (Brackenridge 1814; Bradbury 1819; Maximilian 1843; Luttig 1920) that primarily moved along the Missouri River did not encounter the species until the river turned northward into present-day South Dakota. It was not until 1843 that another explorer, James J. Audubon, noted the pronghorn along the Missouri River in extreme northeastern Nebraska (Audubon and Coues 1897:504). Later, it was Hayden (1862, 1875:95) who, based on his travels in 1856 and 1857, stated that the pronghorn occurred no farther south in this part of Nebraska than the "mouth of the Niobrara River."

Members of the Stephen H. Long expedition spent the winter of 1819–20 along the Missouri River at Engineer

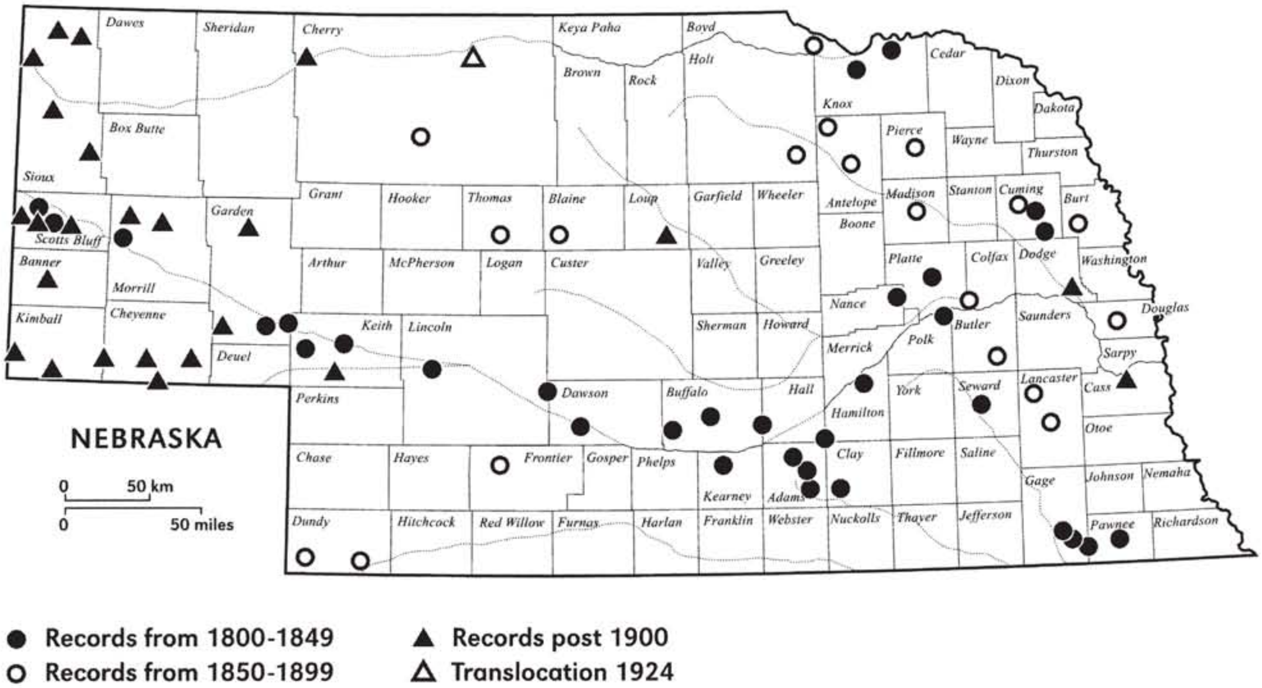


Figure 2. Location of historical records (1804 to 1958) of pronghorn (*Antilocapra americana*) in Nebraska.

Cantonment in southern Washington County, just north of Omaha in central eastern Nebraska. They did not encounter pronghorns until February 1820 when members of the expedition were exploring farther to the west along the Elkhorn River, probably in Cuming County (James 1823:191). Again in April, they observed pronghorns as they were visiting the Pawnee village in Nance County even farther to the west. Duke Paul (Paul Wilhelm 1973:332) observed pronghorns along the Elkhorn River where Plum Creek enters in central Cuming County in 1823. We believe that the record given by Jones (1964:324) for Engineer Cantonment in Washington County is incorrect because it was based on an erroneous reading of James (1823:370) (see Genoways and Ratcliffe 2008). The easternmost historical record that we have been able to locate in central eastern Nebraska is from the vicinity of the town of Elkhorn in western Douglas County. This record is based on the observation of Lawrence Bruner, an early noted naturalist and professor at the University of Nebraska, that a few were reported on the high ground east of the Elkhorn River in Douglas County, or possibly in Sarpy County (Jones 1964:324).

In southeastern Nebraska, the easternmost record for the pronghorn appears to be the observation of Carleton (1943) made on August 19–20, 1844. As his party was traveling along a branch of the Big Nemaha River in Pawnee County, he sighted "six antelopes," and the following day, as they progressed farther to the west and into Gage County, he noted that they saw "a great many antelope" during their day's journey.

Examination of the remainder of the records in Table 2 supports the idea that pronghorns occurred historically in all other areas of the state. However, by 1849, Captain Howard Stansbury already was noting that hunting was poor along the Little Blue River valley because of "the game having been driven from the vicinity of the traveled route by the unintermitted stream of emigration which had already passed over the road" (Stansbury 1852). Subsistence hunting along the various emigrant trails, such as the Oregon, Mormon, and Deadwood Trails, had a negative impact on populations of pronghorns and other game species. Beyond need-based hunting, however, was the impact of the "slaughter every day, from the mere wantonness and love of killing, the greenhorns glorying in the sport, like our stripling of the city, in their annual murdering of robin and sparrows," noted naturalist John Townsend as he journeyed along the Platte River in 1834 (Townsend 1839). Both C. Irvine and John A. MacMurphy remarked on the deadly impact of the weather during the winter of 1856–57, which began "with deep snow about December 1 of nearly four feet, ending with a blizzard" (Irvine 1902:158). As the result of starvation and killing by Native and pioneer hunters during this winter, "[t]he bones of elk, antelope, deer and buffalo were numerous

TABLE 2
SEVENTY-EIGHT HISTORICAL AND MUSEUM RECORDS OF PRONGHORN (*ANTILOCAPRA AMERICANA*) IN NEBRASKA

Reference	Date of record	Location in Nebraska	Comments
Moulton 1987:44	September 3, 1804	Probably near the western boundary of the present Santee Sioux Indian Reservation, east of relocated town of Niobrara, Knox County.	"Several wild Goats Seen in the Plains they are wild & fleet"
James 1823:191	February 1820	Elkhorn River, possibly Cuming County	"Saw a few bisons and antelopes and Elks"
James 1823:348	April 23, 1820	"Beaver creek," possibly Nance County	"In this vicinity several antelopes (*Cervicapra americana*, Ord) were seen by the party"
James 1823:433	June 9, 1820	Platte County	"Seen no game except a few antelope"
James 1823:454	June 15, 1820	Hall–Buffalo Counties	"Some antelopes were seen during the day"
James 1823:456	June 16, 1820	Buffalo County	"Two of the hunters . . . bringing in a buck antelope"
James 1823:456	June 17, 1820	Near Odessa, Buffalo County	Herd seen at a distance from which Lt. Swift shot a buck
James 1823:462	June 20, 1820	Dawson–Lincoln Counties	Mr. Peale killed an antelope and others killed two antelope "all at a distance from camp."
Paul Wilhelm 1973:332	August 11, 1823	Along Elkhorn River in central Cuming County	"Toward evening we encountered our first antelopes. The French Creoles call it *cabril*, also *cabris*."
Townsend 1839:45	May 15, 1834	Along Blue River, probably Gage County	"We saw to-day several large white wolves, and two herds of antelope."
Townsend 1839:47	May 18, 1834	Along south side of Platte River near Grand Island, probably Adams County	"Wolves and antelope were in great abundance here."
Townsend 1839:49	May 20, 1834	Along south side of Platte River, probably Dawson County	"The antelopes are very numerous here. There is not half an hour during the day in which they are not seen."
Townsend 1839:67	May 27, 1834	Along North Platte River, probably Keith County	"A few elk and antelopes"
Townsend 1839:68	May 28, 1834	Keith–Garden Counties	One pronghorn killed
Townsend 1839:69	May 30, 1834	Along south side of North Platte River near Mitchell, Scotts Bluff County	"One of our men caught a young antelope."
Frémont 1845:13	June 20, 1842	Near Big Blue River in southern Gage County	"To-day antelope were seen running over the hills."
Frémont 1845:45	June 24, 1842	On hills above Little Blue River, Clay County	"Now and then an antelope bounded across our path."
Frémont 1845:16	June 26, 1842	Between Little Blue River and Platte River, Adams County	"Antelope were seen frequently during the morning."
Audubon and Coues 1897:504	May 21, 1843	Poncas Island, Knox County	"Three Antelopes were seen this evening."
Carleton 1943:35	August 19, 1844	Pawnee County	Six antelopes sighted
Carleton 1943:39-40	August 20, 1844	Pawnee–Gage Counties	Saw "a great many antelope" during day's ride.
Carleton 1943:49	August 24, 1844	Seward County	"Nine antelope were also seen to-day."
Carleton 1943:59	August 28, 1844	In northeastern Polk County, in valley of Platte River	"Saw a great many antelopes."
Carleton 1943:194	May 27, 1845	Hamilton County	"Antelopes were seen from time to time."
Carleton 1943:199	May 29, 1845	Hamilton–Adams Counties	Several . . . of these animals we have seen this afternoon."
Carleton 1943:205	June 1, 1845	Kearney County	"Two fine antelopes . . . were aroused by the noise of our column."
Carleton 1943:216	June 4, 1845	Along South Platte River just west of confluence with North Platte River, Lincoln County	One killed during bison hunt

TABLE 2 continued

Reference	Date of record	Location in Nebraska	Comments
Carleton 1943:223	June 7, 1845	On divide between North and South Platte Rivers, Keith County	"During the afternoon we saw a great many buffaloes, antelope, and white wolves."
Carleton 1943:226	June 8, 1845	Ash Hollow, Garden County	"Emigrants sent the Colonel a fine large antelope this morning."
Carleton 1943:241	June 11, 1845	Near base of Scotts Bluff, Scotts Bluff County	"A young antelope sprang out of the grass"
Stansbury 1852:28	June 17, 1849	Valley of Little Blue River, probably Adams County	Among animals brought in was "one miserably poor little antelope."
Stansbury 1852:50	July 8, 1849	North Platte valley near Chimney Rock, Morrill County	"They had killed three elk and an antelope"
Bryan 1857:473	September 25, 1856	Along the Republican River, near Benkelman, Dundy County	"To-day we have again reached the region of game, buffalo and antelope having been killed."
National Museum of Natural History	1857	"Platte River" probably near the mouth of the Loup River, Platte–Colfax Counties	Catalog numbers 3447, 3454, 3460, 3461
Hayden 1862:150	1850s	Knox–Boyd Counties	No pronghorns seen "below the mouth of the Niobrara river"
Jones 1964:324	1856–1864	Vicinity of Elkhorn River, Douglas County	From Swenk manuscript
Dunlap 1898:54	June 15, 1866	Northwestern Lancaster County	"We saw the first antelope."
Dunlap 1898:55	June 16, 1866	Near Dwight, Butler County	"The ranchman's name is David Reed. He had just killed an antelope."
Jones 1964:324	1867–1868	"Logan Creek flats" west of Oakland, Burt County	From Swenk manuscript
Jones 1964:324	1867–1869	Plum Creek, east of Wisner, Cuming County	From Swenk manuscript
Hardy 1902:210	Early 1870s	Lancaster County	"The buffaloes had all been driven west of the Blue river. . . . Wolves, deer, and antelope were often seen."
Cary 1905:14-15	1877	Near Neligh, Antelope County	"A doe . . . shot on the river bottom just south of the town"
Cary 1905:15	1878	Verdigris Creek, northern Antelope County	"Another was killed"
Jones 1964:324	1870s	Madison County	From Swenk manuscript
Cary 1905:14	Fall 1880	Between North Fork of Elkhorn River and Dry Creek, about 18 miles north of Norfolk, in Pierce County	"A band of five antelope ranging the country . . . and killed one"
Cary 1905:14	Fall 1881	Cache Creek, south of Ewing, Holt County	"Killed five"
Jones 1964:324	1888	Dismal River, south of Thedford, Thomas County	From Swenk manuscript
Jones 1964:324	Late 1880s/early 1890s	West of Curtis, Frontier County	From Swenk manuscript
Cary 1905:15	1893	Between Brewster and Dunning, Blaine County	"Killed one"
Jones 1964:324	1896	North of Haigler, Dundy County	From Swenk manuscript
Cary 1905:14	1890s	South of Snake River, Cherry County	"Until a few years ago a small herd roamed south of the Snake River"
Cary 1905:15	1900	Western edge of Cherry County	"Saw a band of a dozen antelope"
Cary 1902:68, 1905:13	Summer 1901	Hat Creek Basin, northern Sioux County	"Confined to a small area of the Hat Creek Basin"
Swenk 1908:75	Summer 1906	Nebraska-Wyoming state line west of Harrison, Sioux County	"A small herd was present"
Swenk 1908:75	Fall 1906	Ogalalla, Keith County	"One was shot"
Wolcott and Shoemaker 1919:7	1918	Near Sidney, Cheyenne County	"A young one was observed"

TABLE 2 continued

Reference	Date of record	Location in Nebraska	Comments
Wolcott and Shoemaker 1919:7	1919	Nearly due west of Alliance, in Sioux County	Stationary band present
Wolcott and Shoemaker 1919:7	1919	Near Crescent Lake, Garden County	Stationary band present
Nelson 1925:37	1920–1921	Along North Platte River north of Bridgeport, Morrill County	"A band of about 40 antelope"
Grinnell 1929:135	December 1921	Near Louisville, Cass County	"An Omaha newspaper item, December 28, 1921, tells of an antelope being seen."
Nelson 1925:37	1922	Banner County	There was a band of antelope present
Nelson 1925:37	1922	Scotts Bluff County	There was a band of antelope present; secured conviction for killing an antelope
Nelson 1925:37	*1922*	*33 Ranch, Sioux County*	*"A band of about 12"*
Nelson 1925:38	1922	Near Agate, Sioux County	"A band of about 25"
Nelson 1925:38	1922	About 10 miles west of Bushnell, Kimball County	"A band of about 5"
Nelson 1925:38	1922	Near state line south of Kimball, Kimball County	"Band of 5"
Nelson 1925:38	1922	Between Dix and Potter, Cheyenne-Kimball Counties	"A band of 14"
Nelson 1925:38	1922	About 18 miles south of Sidney, Cheyenne County	"A band of about 40"
Nelson 1925:38	Spring 1922	Near Sunol, in eastern Cheyenne County	"A band of 43 was reported . . . as grazing in fields"
Nelson 1925:38	1922	About 12 miles south of Lisco, Garden County	"A band of 25"
Nelson 1925:38	1924	About 15 miles north of Sargent, in Loup County	"A band of 8"
Nelson 1925:38	September 1924	Fort Niobrara, National Wildlife Refuge, Cherry County	"Ten young antelope, 6 females and 4 males, were placed on the Niobrara Game Reservation. . . . These antelope were part of the fawns captured in northwestern Nevada."
Grinnell 1929:138	1927–1928	Not very far from Scottsbluff, Scotts Bluff County	"Two small bands estimated as about forty in all."
Grinnell 1929:135	1920s	A very few miles west of Fremont, Dodge County	"Saw a wild antelope"
National Museum of Natural History	1932	Signal Butte, Scotts Bluff County	Catalog number 257916
Leister 1932:187	*1932*	*Fort Niobrara, National Wildlife Refuge, Cherry County*	*"13 are on the Niobrara Reservation"*
H. Genoways, personal observations	Mid-1940s	Good Streak Township, northwestern Morrill County	Single pronghorn and small group up to five regularly observed
University of Nebraska State Museum	1957	7 miles northwest of Orella, Sioux County	Catalog number 12189, 12190

Notes: Records are arranged in chronological order based on the date of the observation. One locality set in italics could not be located and the other duplicates an earlier locality. See Figure 2 for map of locations of records.

on the prairie. It seems to me as if every forty acres must have had at least one skeleton or a portion of the remains of these animals" (MacMurphy 1894:17).

Samuel Aughey (1880) wrote about pronghorns in the late 1870s: "It was formerly common to meet these on the prairie in herds of 20 to 500. Only a few years ago it was yet common to meet herds of hundreds of these beautiful and graceful animals in Central and Western Nebraska. They are now mostly confined to the northern and western portions of the State."

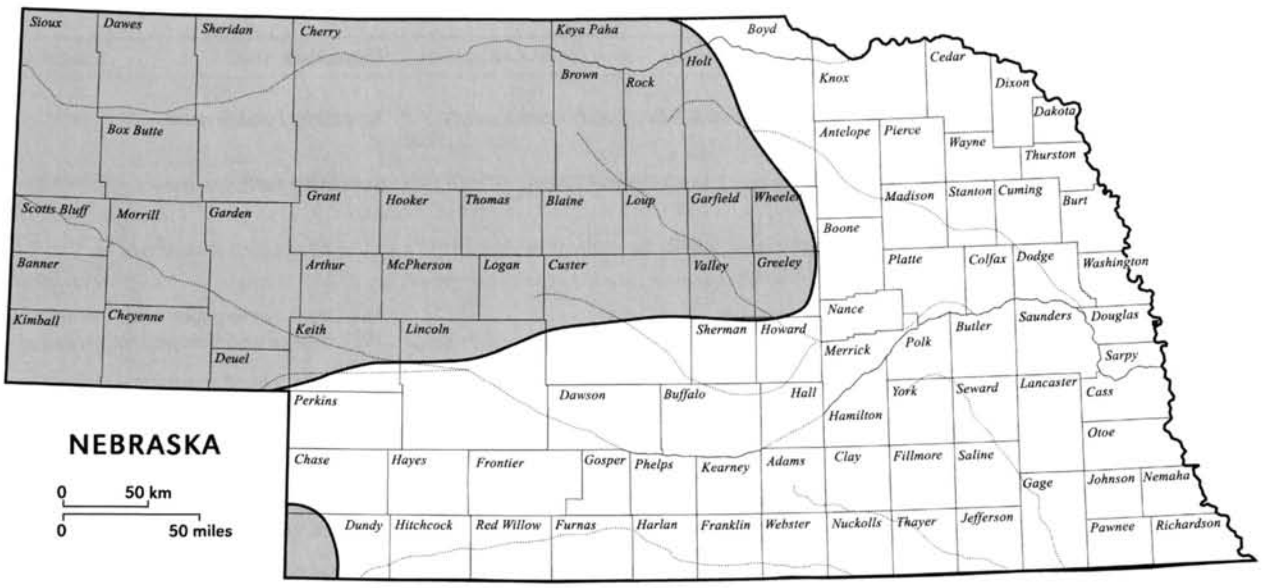


Figure 3. Current distribution (shaded area) of pronghorn (*Antilocapra americana*) in Nebraska.

Through the 1880s and 1890s there are scattered reports of pronghorns, primarily from the northern areas of the state and the Sandhills. Near the end of the 19th century, Grinnell (1897) was able to document only scattered populations in extreme northwestern and southwestern corners of the panhandle of Nebraska, although C. Hart Merriam just a few years later mapped the geographic range of pronghorns covering as much as the western third of the state (Roosevelt et al. 1902). Cary (1902, 1905) believed that the species was essentially extirpated from the state by the time he undertook his studies in northern Sioux County in the summer of 1901, although he saw sign of some individuals in Hat Creek Basin. Hornaday (1904) showed possible herds in extreme northwestern Nebraska, probably based on Cary's (1902) observations. Although pronghorns were almost extirpated from the state, scattered records of individuals and small herds were documented over the next two decades (Table 2), all confined to the panhandle of Nebraska. However, Hornaday (1914) in his survey of pronghorn populations throughout its geographic range mapped no herds in Nebraska. Nebraska gave pronghorns full protection in 1907, which helped to keep the species from becoming extinct in the state (Jones 1964).

E. W. Nelson (1925) presented the results of a comprehensive survey of pronghorns conducted between 1922 and 1924 by the U.S. Biological Survey. This survey identified nine herds of pronghorns in Nebraska occurring in five counties. These herds were estimated to contain a total of 187 individuals. Four of these counties—Cheyenne, Garden, Kimball, and Sioux—were in the panhandle, with the first three located adjacent to or near the Colorado state line and the last two adjacent to Wyoming. The other herd of eight individuals was located in southeastern Loup County, probably near the town of Taylor in the eastern Sandhills. The survey also received reports of pronghorns in Banner, Morrill, and Scotts Bluff Counties, all in the panhandle, but no herds were documented. Nelson (1925) also documented the translocation of 10 young pronghorns from northwestern Nevada to the Fort Niobrara National Wildlife Refuge in Cherry County in 1924 by members of the Biological Survey.

Grinnell (1929) reported single pronghorns from Cass and Dodge Counties in eastern Nebraska during the 1920s, but Jones (1964) questioned the record from Dodge County. There is little documentation on the development of pronghorn populations during the 1930s and 1940s, but by 1953, there were sufficient numbers for the beginning of a hunting season. As noted by Jones (1964), these pronghorn populations developed and increased in the panhandle counties of Nebraska.

Current Distribution

The current distribution of pronghorns in Nebraska closely resembles that presented in Figure 3. The primary range of pronghorns is concentrated in the panhandle and Sandhills of Nebraska, with small populations occurring in the southwest portion of the state. Occasionally, sightings of pronghorns beyond the geographic range limits

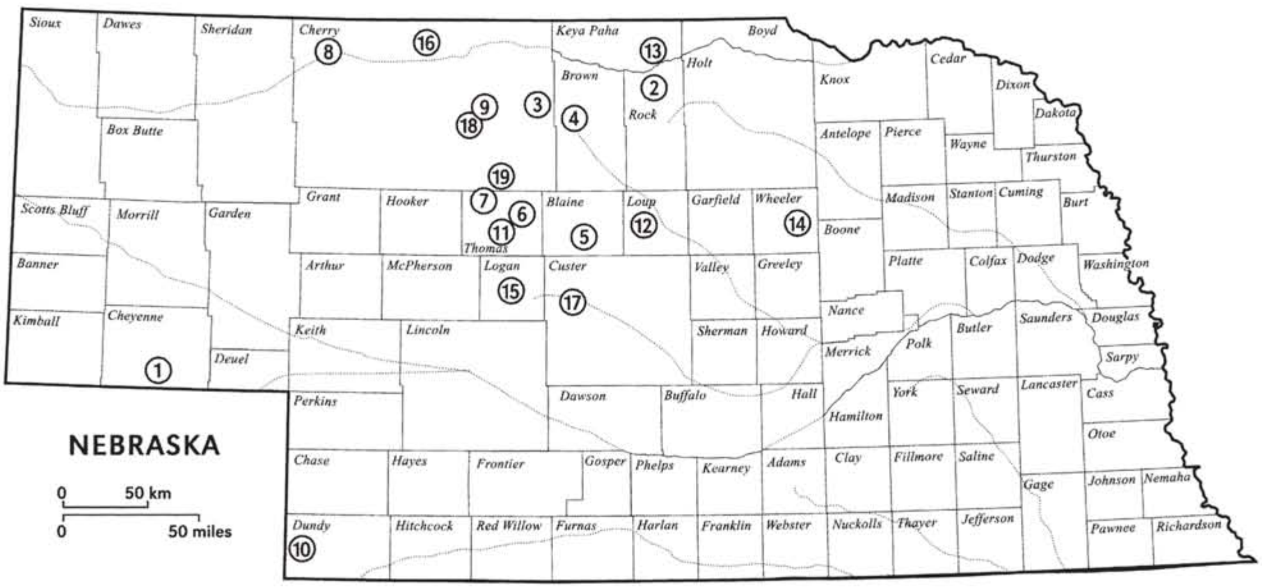


Figure 4. Release sites of pronghorn (*Antilocapra americana*) in Nebraska. Numbers within the circles correspond to release sites listed in Table 3.

depicted in Figure 3 have been observed, especially in northeastern and south-central Nebraska. However, these individuals are not thought to be part of established, reproductive herds.

The current distribution of pronghorn in Nebraska was undoubtedly aided by certain management practices, specifically reintroduction programs. Trapping of pronghorn first took place in January 1958 and continued until February 1962. In the initial trapping session, 63 individuals were taken from the Pueblo Ordnance Depot, Pueblo County, CO. A total of 36 pronghorn were released in Rock County, NE, and 27 pronghorns were released in the Sioux Ordnance Depot, Cheyenne County, NE (Fig. 4, Table 3). After the initial trapping session, all other pronghorns were trapped in western Nebraska and released throughout the Sandhills (Fig. 4, Table 3). Release sites were chosen based upon a cooperative agreement between landowners and the NGPC and the overall suitability of the habitat. A total of 1.6 million acres of Sandhills habitat were signed up under the agreements.

DISCUSSION

The archeological and paleontological records provide some insight into the early distribution of pronghorns in Nebraska and indicate that this species has a history of at least 20,000 years of occurrence within the boundaries of the current state. Although the archeological and paleontological records do not provide equal coverage to all parts of the state, these data (Fig. 1, Table 1) are sufficient to show that pronghorns were statewide in distribution throughout much of the species' history in the state. Holocene records appear to confirm that pronghorns occurred in the easternmost counties of Nebraska for at least the last 6,000 years. There are records from six counties along the Missouri River south of the mouth of the Niobrara River. The complication of interpreting these records is that only the two from Burt and Cass Counties apparently were based on bone that was not modified into utilitarian or ceremonial/decorative objects.

Early authors (Cary 1905; Swenk 1908, 1915; Wolcott and Shoemaker 1919) writing about mammals of Nebraska during historic times (after 1800) considered the pronghorn to have been statewide in its original distribution. However, Jones (1964:321) believed that the geographic range of the pronghorn did not reach the Missouri River in Nebraska except in the extreme northeastern part of the state, its eastern distribution being "sharply limited by the forested areas bordering the Missouri River." These counties contained the largest tracts of eastern deciduous forest in Nebraska before Euro-American settlement (Kaul and Rolfsmeier 1993). Lewis and Clark did not encounter pronghorns until they reached the area near the mouth of the Niobrara River (Moulton 1987) in Knox County. Early expeditions in southeastern Nebraska crossing Johnson, Otoe, Nemaha, and Richardson Counties did not document pronghorns until they reached farther west in more prairie-dominated regions of western Cass, Pawnee, and Gage Counties (Carleton 1943).

TABLE 3
SUMMARY OF RELEASE SITE, RELEASE DATE, AND NUMBER OF PRONGHORN RELEASED IN NEBRASKA

Site no.	County	Locality	Date	Number of pronghorn		
				Males	Females	Total
1	Cheyenne	Sioux Orndance Depot	January 25, 1958	10	17	27
2	Rock	23 miles south of Newport	January 11, 1959	13	23	36
3	Cherry	16 miles south of Wood Lake	January 16, 1959, and February 2, 1960	31	40	71
4	Brown	10 miles south of Johnstown	January 23, 1959, and February 3, 1959	7	21	28
5	Blaine	15 miles east of Dunning	December 3, 1959	28	33	61
6	Thomas	10 miles northwest of Halsey	December 7, 1959	11	37	48
7	Thomas	11 miles northwest of Thedford	December 9, 1959	22	22	44
8	Cherry	5 miles southwest of Merriman	January 7, 1960	24	26	50
9	Cherry	3 miles east of Kennedy	February 8, 1960	14	32	46
10	Dundy	16 miles north of Haigler	January 13, 1960	33	28	61
11	Thomas	Halsey National Forest	January 27, 1960	24	48	72
12	Loup	16 miles north of Almeria	January 28, 1960	23	38	61
13	Keya Paha	24 miles east of Springview	February 3, 1960	21	20	41
14	Wheeler	12 miles southeast of Cumminsville	January 20, 1960, and February 3, 1961	15	65	80
15	Logan	16 miles north of Stapleton	December 2, 1960	44	68	112
16	Cherry	South of Cody	December 10, 1960, and January 6, 1961	42	75	117
17	Custer	15 miles northeast of Arnold	January 12, 1961	17	40	57
18	Cherry	Valentine National Refuge	February 15, 1961	30	22	52
19	Cherry	7 miles north of Thedford	February 22, 1962	13	29	42

Note: Numbers correspond to locations shown in Figure 4.

We believe these historical records confirm Jones's (1964) observation that pronghorns did not reach the Missouri River in Nebraska except in Boyd and Knox Counties in the northeast. If the easternmost historical records are connected by an imaginary line, it would appear that pronghorns did not occupy the easternmost counties along the Missouri River. Jones (1964) hypothesized that pronghorns were not in this area because of

the forests bordering the Missouri River. We disagree, at least in part, with this idea because the forest in the area of eastern Nebraska along the Missouri River was historically very limited and fragmented (Genoways and Ratcliffe 2008). We believe that in addition to the trees, and more importantly, tallgrass prairie restricted the occurrence of pronghorns in eastern Nebraska. Grinnell (1897:5) observed that "the antelope never seemed to like the tall grass." Given that the survival strategy of pronghorns is based on sight and flight, both of which would be impeded by the tallgrass prairie, this seems a logical conclusion.

The pronghorns' avoidance of eastern forests and tallgrass prairie is further confirmed by the paucity of records of pronghorns in Iowa and Missouri. Grinnell (1897) could not document any occurrences of pronghorns in Iowa, but Jones (1960) presented historical records based on sightings of pronghorns made in 1850 near the Little Sioux River in Harrison and Monona Counties. Bowles (1970, 1975) reviewed all information available on pronghorns in Iowa and found general historical accounts in several counties in western Iowa, but the only definite sighting was that reported by Jones (1960). The Holocene record in Iowa is restricted to two sites, including the Hanging Valley site in northwestern Harrison County (Tiffany et al. 1988: 229, 238–39) and the Arthur site (13DK27) in Dickenson County (Semken 1982). The Hanging Valley site (AD 190–700) is near the mouth of the Little Sioux River into the Missouri River across from Tekamah in Burt County, NE, and the Arthur site (AD 650–950) is on East Okoboji Lake near the drainage of the Little Sioux River far to the north, close to the Minnesota state line south of Jackson in Jackson County. The pronghorn material from Hanging Valley consists of two partial crania, with one appearing "to have been coated with red pigment after the horn was removed from the horncore" (Tiffany et al. 1988:229). At the Arthur site the evidence for pronghorn is more equivocal, as Semken (1982:130) only tentatively assigned a metapodial fragment as "an artiodactyl the size of a pronghorn."

The situation in Missouri seems to be similar to that in Iowa. McKinley (1960:504) studied the historical references to the pronghorn in the state and concluded: "These county history references are uncertain as to the time and place, and are not sufficiently elaborated in personal narratives to be accepted with assurance." There are two archeological records of the pronghorn, but only one of these, Brynjulfson Cave No. 2, is east of the Missouri River at a place six miles south–southeast of Columbia in Boone County (Parmalee and Oesch 1972). This record is based on two isolated teeth that date to approximately 510 BC. The other site, which is south and west of the Missouri River, is the Rodgers Shelter in Benton County along the western edge of the Ozark Highlands. The three pronghorn molars recovered from the site cover the time from 6200 BC to 500 BC (Parmalee et al. 1976).

Our conclusion based on the evidence at hand is that the eastern boundary of the geographic distribution of the pronghorn south of the Niobrara River in Nebraska at the beginning of the 19th century was along the western perimeter of the eastern deciduous forest and tallgrass prairie. This would have excluded most of the easternmost tier of counties in the state. This geographic arrangement persisted throughout most of the Holocene; its boundary was never a straight line but a dynamic system of fluctuating distribution. At times, because of shifting climatic or environmental changes, such as prairie fires or decreased rainfall, short- and midgrass prairies penetrated to the east of the Missouri River, and the pronghorn followed these habitats, but the record indicates that these forays did not persist through time. Therefore, as Euro-Americans entered Nebraska, pronghorns were relatively abundant and were widespread in distribution, occurring anywhere that shortgrass and midgrass prairies were present.

Although Zebulon Pike when he briefly visited south-central Nebraska in 1806 (Coues 1895) did not note the presences of pronghorns, many early historical records are concentrated along the Big Blue, Little Blue, and central Platte Rivers in this area. These areas were along the route of the emigrant trails heading to the western United States. There also are a number of records of pronghorn from along the North Platte River, as these trails followed that valley of the river to the current border between Nebraska and Wyoming. The concentration of historical records (Fig. 2, Table 2) seems to be in the midgrass and mixed-grass prairies along the Elkhorn River and the Platte River from the mouth of the Loup River to about the location of the modern town of Cozad in Dawson County. Whether or not this is an artifact of the historical record or was the area of highest pronghorn populations cannot be determined with the information at hand. Although some recent authors (Walker 2000; Shaw and Lee 1997) claim that pronghorns are primarily adapted to the shortgrass prairie, the affinity of pronghorns for the midgrass prairie should be considered as one examines the historical records from other areas of the Great Plains.

By 1850, pronghorn numbers were declining noticeably in Nebraska. This trend also was apparent elsewhere in the geographic range of the pronghorns, as Sexson and

Choate (1981) documented that pronghorn populations were declining in eastern and central Kansas during this same period. Almost certainly sport and subsistence hunting continued to place pressure on the pronghorn populations, but also the settlement of the land was restricting and fragmenting the habitat available to the species. Farms of 160 acres were being established and the prairie was plowed for the growing of row crops. Cattle and sheep ranchers negatively affected pronghorn populations by erecting fences and shooting pronghorns because they potentially competed with domestic animals for food. The populations of pronghorns continued to retreat to the west so that the only reproducing herds were confined to the panhandle region. These events led many to believe that the pronghorn had been extirpated from the state (Cary 1902, 1905; Hornaday 1914) by the beginning of the 20th century, but apparently the species was never extirpated from Nebraska (Roosevelt et al. 1902). The reproduction of these local populations probably aided the increase in numbers in the first half of the 20th century, but undoubtedly the increase was enhanced by emigration of herds from the adjoining states of Colorado and Wyoming where populations were estimated to be 2,000 and 25,000, respectively, in 1932 (Leister 1932). The shortgrass Sandhills prairies in the panhandle are considered favorable habitat, but pronghorns were absent from the areas due to intensive cultivation (i.e., in the North Platte River valley). Pronghorns clearly favored areas of open grassland pastures and large, unfenced fields planted to winter wheat.

There is a marked difference in the current distribution of pronghorn in Nebraska compared to distribution based on archeological and historical records. While the latter suggests that pronghorns possessed a near statewide distribution, the current distribution shows that pronghorns are restricted to areas of the panhandle and Sandhills of Nebraska. Since the early 1900s, pronghorns have been recolonizing parts of their historic range, which can be attributed in large part to management strategies implemented by the Nebraska Game and Parks Commission.

Harvest of Nebraska pronghorn was banned in 1907. Pronghorns responded favorably to the lack of hunter harvest, and in 1953 a hunting season was reimplemented in western Nebraska, primarily in Sioux and Dawes Counties. Prior to 1958, pronghorns were restricted to portions of the western and southern panhandle. The process of pronghorns' natural dispersal and colonization of unoccupied areas of suitable habitat was extremely slow, probably for several reasons, including distance to be traveled, habitat fragmentation, and fencing. To facilitate the return of pronghorns to unoccupied portions of their historic range in Nebraska, the NGPC implemented a pronghorn relocation program (Mathisen 1958). One of the areas selected for colonization was the Nebraska Sandhills, which was part of the historic range of the pronghorn (Figs. 1 and 2). The Sandhills is an ecoregion of approximately 20,000 square miles comprised of sharply rolling hills, sandy soils, and short- and mixed-grass prairies with an abundance of native forbs. Because of the soil characteristics, early attempts to cultivate this area by settlers generally were unsuccessful, resulting in primarily undisturbed habitat that was highly suitable for pronghorns. Therefore, between 1958 and 1962 the relocation program conducted by the Nebraska Game and Parks Commission moved 1,106 pronghorns into suitable habitat areas of the Sandhills. Most areas of the Sandhills currently possess reproducing populations of pronghorn, and pronghorn hunting seasons have also been established in these areas.

In conclusion, the distribution of pronghorn in Nebraska has experienced significant changes in the past 20,000 years. The paleontological record suggests that pronghorns were found statewide in Nebraska. At the beginning of the 19th century, the distributional limit of pronghorn in Nebraska had retreated to the western edge of the deciduous forest and tallgrass prairie habits. By the mid-19th century populations of pronghorn were declining throughout the state, most likely the result of increased harvest and habitat fragmentation by European settlers. At the beginning of the 20th century, pronghorns were restricted to small areas of native prairie in extreme northwestern Nebraska. The restriction of pronghorn hunting in 1907 allowed populations to slowly increase, and the implementation of a relocation program in 1958 greatly increased the distribution of pronghorn in Nebraska. Presently, pronghorn possess stable populations throughout nearly half the state and are considered an important game animal. As long as the pronghorn continue to be managed, their status as an important member of Nebraska's fauna should be secure.

ACKNOWLEDGMENTS

We wish to thank Gayle Carlson for permitting access and Kelli Bacon for facilitating the use of the outstanding collection of archeological site reports held by the Nebraska State Historical Society. We are grateful to Alan Osburn for making archeological reports from the University of Nebraska State Museum available for our

study. Special recognition is given to the interlibrary loan librarians at Love Library of the University of Nebraska–Lincoln for searching out many obscure reports for us. George Corner was helpful in finding the necessary publications covering Holocene paleontology in Nebraska. Chad Taylor, Ben Rutten, Todd Nordeen, Richard Nelson, and Jeff Hoffman, wildlife biologists for the Nebraska Game and Parks Commission, provided helpful comments on the current distribution of pronghorn in Nebraska. Angie Fox, technical artist for the University of Nebraska State Museum, prepared the final figures. Finally, we thank two anonymous reviewers for providing helpful comments on an earlier version of the manuscript.

REFERENCES

Adair, M.J., and K.L. Brown, eds. 1987. *Prehistoric and Historic Cultural Resources of Selected Sites at Harlan County Lake, Harlan County, Nebraska: Test Excavations and Determination of Significance for 28 Sites.* Kaw Valley Engineering and Development, Inc., Junction City, KS, and Parkville, MO.

Agenbroad, L.D. 1978. *The Hudson-Meng Site: An Alberta Bison Kill in the Nebraska High Plains.* University Press of America, Washington, DC.

Audubon, M.R., and E. Coues. 1897. *Audubon and His Journals*, vols. 1 and 2. Charles Scribner's Sons, New York. Reprint, Dover Publications, Mineola, NY, 1986.

Aughey, S. 1880. *Sketches of the Physical Geography and Geology of Nebraska.* Daily Republican Book and Job Office, Omaha, NE.

Bamforth, D.B. 2002. The paleoindian occupation of Medicine Creek drainage, southwestern Nebraska. In *Medicine Creek: Seventy Years of Archaeological Investigations*, ed. D.C. Roper, 54–83. University of Alabama Press, Tuscaloosa.

Bowles, J.B. 1970. Historical record of some Iowan mammals. *Transactions of the Kansas Academy of Science* 73:419–30.

Bowles, J.B. 1975. Distribution and biogeography of mammals of Iowa. *Special Publications of the Museum, Texas Tech University* 9:1–184.

Bozell, J.R. 1991. Fauna from the Hulme site and comments on Central Plains tradition subsistence variability. *Plains Anthropologist* 36:229–53.

Bozell, J.R. 1993. Vertebrate remains from 1991 archeological investigations at Agate Fossil Beds National Monument, Sioux County, Nebraska. In *Archeological Survey and Testing at Agate Fossil Beds National Monument, Sioux County, Nebraska*, ed. C.P. Clark, 59–82. National Park Service, Midwest Archeological Center, Technical Report 22:1–82.

Bozell, J.R. 1994. Vertebrate remains from select 1991 and 1992 archeological investigations at Agate Fossil Beds National Monument, Sioux County, Nebraska. In *Archeological Investigations on Marsland Road, Agate Fossil Beds National Monument, Sioux County, Nebraska,* ed. C.P. Clark, 45–63. National Park Service, Midwest Archeological Center, Technical Report 31:1–63.

Bozell, J.R., S. Donnelly, M. Rogers, and S. Zink. 1990. Animal utilization at two nineteenth century trading posts in east central Nebraska. Report on file at the Nebraska State Historical Society, Lincoln.

Bozell, J.R., and J. Ludwickson. 1988. *Highway Archeological Investigations at the Slaughterhouse Creek Site and Other Cultural Resources in the Pine Ridge Area.* Nebraska State Historical Society, Report for the Nebraska Department of Roads, Lincoln.

Bozell, J.R., and J. Ludwickson. 1999. Archeology of the Patterson Site: Native American life in the Lower Platte Valley, AD 1000–1300. Nebraska State Historical Society, Report for the Nebraska Department of Roads and Federal Highway Administration, Lincoln.

Bozell, J.R., and M.K. Rogers. 1989. A Great Oasis fauna from central Nebraska. *Central Plains Archaeology* 1:3–36.

Bozell, J.R., L.M. Snyder, and C.R. Falk. 1982. Descriptive analysis of unmodified vertebrate remains recovered from the Schuyler site (25CX1), Colfax County, Nebraska. Division of Archeological Research, Department of Anthropology, University of Nebraska–Lincoln, Technical Report 82-06.

Brackenridge, H.M. 1814. *Views of Louisiana; Together with a Journal of a Voyage Up the Missouri River, in 1811.* Cramer, Spear and Eichbaum, Pittsburgh. Reprint, "A Journal of a Voyage Up the Missouri River, in 1811," 199–268, Readex Microprint Corporation, 1966.

Bradbury, J. 1819. *Travels in the Interior of America, in the Years 1809, 1810, and 1811; Including a Description of Upper Louisiana, Together with the States of Ohio, Kentucky, Indiana, and Tennessee, with Illinois and Western Territories, Containing Remarks and Observations Useful to Persons Emigrating to Those Countries.* 2nd ed. Sherwood, Neely, and Jones, London. Reprint, University of Nebraska Press, Lincoln, 1986.

Bryan, F.T. 1857. Appendix H to No. 11. Report of the Chief Topographical Engineer. In *Report of the Secretary of War (J. B. Floyd, Secretary of War), Message from the President of the United States, to the Two Houses of Congress at the Commencement of the First Session of the Thirty-fifth Congress*, 2:455–520. Cornelius Wendell Printer, Washington, DC.

Carleton, J.H. 1943. *The Prairie Logbooks: Dragoon Campaigns to the Pawnee Villages in 1844, and the Rocky Mountains in 1845* [edited by L. Pelzer]. The Caxton Club, Chicago. Reprint, Bison Books, University of Nebraska Press, Lincoln, 1983.

Carlson, G.F. 1973. Archeological salvage and survey in Nebraska, Part I: Highway archeological and historical salvage investigations in Nebraska, 1965 to 1968. *Nebraska State Historical Society, Publications in Anthropology* 5:1–155.

Cary, M. 1902. Some general remarks upon the distribution of life in northwest Nebraska. *Proceedings of the Nebraska Ornithological Union* 3:63–75.

Cary, M. [1905]. The mammals of Nebraska. Handwritten manuscript held by U.S. Fish and Wildlife Service, Washington DC.

Champe, J.L. 1946. Ash Hollow cave: A study of stratigraphic sequence in the central Great Plains. *University of Nebraska Studies* 1 (n.s.): 1–30.

Champe, J.L., and E.H. Bell. 1936. The Sweetwater Culture complex. In *Chapters in Nebraska Archaeology*, ed. E.H. Bell, 249–99. University of Nebraska, Lincoln.

Chorn, J.D., B.A. Frase, and C.D. Frailey. 1988. Late Pleistocene pronghorn, *Antilocapra americana*, from Natural Trap cave, Wyoming. *Transactions of the Nebraska Academy of Sciences* 16:127–39.

Corner, R.G. 1977. A Late Pleistocene-Holocene vertebrate fauna from Red Willow County, Nebraska. *Transactions of the Nebraska Academy of Sciences* 4:77–93.

Coues, E., ed. 1895. *The Expeditions of Zebulon Montgomery Pike, to Headwaters of the Mississippi River, through Louisiana Territory, and in New Spain, during the Years 1805–6–7.* F.P. Harper, New York.

Davis, E.M. 1962. Archeology of the Lime Creek site in southwestern Nebraska. *Special Publication of the University of Nebraska State Museum* 3:1–106.

Dunlap, J.P. 1898. Travels in Nebraska in 1866. *Proceedings and Collections of the Nebraska State Historical Society* 2 (2nd ser.):53–57.

Falk, C.R. 1969a. Faunal remains; faunal evidence. In *Two House Sites in the Central Plains: An Experiment in Archaeology*, ed. W.R. Wood, 44–51, 80–81, 102. Plains Anthropologist Memoir 6:1–132.

Falk, C.R. 1969b. Mowry Bluff artifacts: Faunal remains. In *Two House Sites in the Central Plains: An Experiment in Archaeology*, ed. W.R. Wood, 44–51. Plains Anthropologist Memoir 6:1–132.

Frantz, W. 1963. Four Aksarben sites in Dakota County, Nebraska. Unpublished master's thesis, University of Nebraska–Lincoln.

Frémont, J.C. 1845. *Report of the Exploring Expedition to the Rocky Mountains in the Year 1842, and to Oregon and North California in the Years 1843–44.* Blair and Rives, Printers, Washington, DC.

Genoways, H.H., and B.C. Ratcliffe. 2008. Engineer Cantonment, Missouri Territory, 1819–1820: America's first biodiversity inventory. *Great Plains Research* 18:3–31.

Gilder, R.F. 1907. Archeology of the Ponca Creek District, eastern Nebraska. *American Anthropologist* 9:702–19.

Gilder, R.F. 1909. Excavation of earth-lodge ruins in eastern Nebraska. *American Anthropologist* 11:56–84.

Graham, R.W., H.A. Semken, Jr., and M.A. Graham. 1987. Late Quaternary mammalian biogeography of the Great Plains and Prairies. *Scientific Papers, Illinois State Museum* 22:1–491.

Granger, R.T., Jr. 1980. Salvage archeology in the Red Willow Reservoir, Nebraska. *Nebraska State Historical Society, Publications in Anthropology* 9:1–236.

Grinnell, G.B. 1897. Range of the pronghorn antelope in 1896. *Forest and Stream* 48:5–6.

Grinnell, G.B. 1929. Pronghorn antelope. *Journal of Mammalogy* 10:135–41.

Gunnerson, D.A. n.d. [1956]. The Stanton site, 25ST1. Unpublished master's thesis, University of Nebraska–Lincoln, pages unnumbered, Nebraska State Historical Society, Lincoln.

Gunnerson, J.H. 1960. An introduction to Plains Apache archeology—The Dismal River Aspect. *Smithsonian Institution, Bureau of American Ethnology Bulletin* 173:131–260.

Hardy, H.W. 1902. Reminiscences. *Proceedings and Collections of the Nebraska State Historical Society* 5 (2nd ser.): 207–11.

Hayden, F.V. 1862. On the geology and natural history of the Upper Missouri. *Transactions of the American Philosophical Society* 12:1–218.

Hayden, F.V. 1875. Catalogue of the collections in geology and natural history, obtained by the expedition under the command of Lieut. G. K. Warren,

Topographical Engineers. In *Preliminary Report of Explorations in Nebraska and Dakota, in the Years 1855–'56–'57*, ed. G. K. Warren, 61–125. Government Printing Office, Engineer Department, U.S. Army, Washington, DC. Originally printed in the appendixes to the report of the secretary of war, in the President's Message and Documents, December 1858.

Hill, A.T., and G. Metcalf. 1942. A site of the Dismal River Aspect in Chase County, Nebraska. *Nebraska History* 22:158–226.

Hoffman, J.D., H.H. Genoways, and R.R. Jones. 2010. Factors influencing long-term population dynamics of pronghorns (*Antilocapra americana*): Evidence of an Allee effect. *Journal of Mammalogy* 91:1124–34.

Holder, P., and J. Wike. 1949. The Frontier Culture Complex, a preliminary report on a prehistoric hunters' camp in southwestern Nebraska. *American Antiquity* 14:260–66.

Hornaday, W.T. 1904. *The American Natural History*. Charles Scribner's Sons, New York.

Hornaday, W.T. 1914. *The American Natural History*. Charles Scribner's Sons, New York.

Hudson, J. 2007. Faunal evidence for subsistence and settlement patterns at the Allen Site. In *The Allen Site: A Paleoindian Camp in Southwestern Nebraska*, ed. D.B. Bamforth, 194–226. University of New Mexico Press, Albuquerque.

Irvine, C. 1902. Recollections of Omaha, 1855–61. *Proceedings and Collections of the Nebraska Historical Society* 5 (2nd ser.): 150–60.

James, E. 1823. *Account of an Expedition from Pittsburgh to the Rocky Mountains, Performed in the Years 1819 and '20, by Order of the Hon. J. C. Calhoun, Sec'y of War: Under the Command of Major Stephen H. Long, from the Notes of Major Long, Mr. T. Say, and Other Gentlemen of the Exploring Party*, vol. 1. H.C. Carey and I. Lea, Philadelphia. Reprint, Readex Microprint Corporation, 1966.

Jensen, R.J. 1973. Archeological salvage and survey in Nebraska, Part II: A preliminary report of the Point of Rocks Archeological Survey. *Nebraska State Historical Society, Publications in Anthropology* 5:159–240.

Jones, J.K., Jr. 1960. The pronghorn, *Antilocapra americana*, in western Iowa. *American Midland Naturalist* 63:249.

Jones, J.K., Jr. 1964. Distribution and taxonomy of mammals of Nebraska. *University of Kansas Publications, Museum Natural History* 16:1–356.

Kaul, R.B., and S.B. Rolfsmeier. 1993. *Native Vegetation of Nebraska*. Conservation and Survey Division, University of Nebraska–Lincoln.

Kivett, M.F. 1952. Woodland sites in Nebraska. *Nebraska State Historical Society, Publications in Anthropology* 1:1–102.

Kivett, M.F., and G.S. Metcalf. 1997. The prehistoric people of the Medicine Creek Reservoir, Frontier County, Nebraska: An experiment in mechanized archeology (1946–1948). *Plains Anthropologist* 42:1–218.

Koch, A. 2004. McIntosh: A late prehistoric occupation in the Nebraska Sand Hills. *Central Plains Archeology* 10:1–167.

Koch, A., and T. Nelson. 2002. Material recovered. In *Archeology of he Beaver Creek Site, Boone County, Nebraska*, ed. A. Koch, 19–108. Nebraska State Historical Society, Report to the Nebraska Department of Roads.

Leister, C.W. 1932. The pronghorn of North America. *Bulletin of the New York Zoological Society* 35:182–207.

Ludwickson, J. 1978a. Central Plains Tradition settlements in the Loup River Basin: The Loup River Phase. In *The Central Plains Tradition: Internal Development and External Relationships*, ed. D.J. Blakeslee, 94–108. Report no. 11, Office of the State Archaeologist, University of Iowa, Iowa City.

Ludwickson, J. 1978b. *Artifact Descriptions Midstate Survey*. Midstate Archaeological Survey, National Park Service.

Ludwickson, J., D. Blakeslee, and J. O'Shea. 1981. *Missouri National Recreational River: Native American Cultural Resources*. Report for Heritage Conservation and Recreation Service, Interagency Archeological Services, Denver.

Luttig, J.C. 1920. *Journal of a Fur-Trading Expedition on the Upper Missouri, 1812–1813*, ed. S.M. Drumm. Missouri Historical Society, St. Louis. Reprint, Argosy-Antiquarian Ltd., New York, 1964.

MacMurphy, J.A. 1894. Part of the making of a great state. *Proceedings and Collections of the Nebraska Historical Society* 1 (2nd ser.):3–24.

Mathisen, J. 1958. A reconnaissance of potential release sites for antelope. In *Job Completion Report, Pittman-Robertson Project W-15-R*, 476–85. Nebraska Game, Forestation, and Parks Commission.

Maximilian, Prince of Wied [H.E. Lloyd, translator]. 1843. *Travels in the Interior of North America, in the Years 1832, 1833, and 1834* [Part I]. Ackermann

and Co., London. Reprint, AMS Press, Inc., New York, 1966, of 1905 reprint edited by R.G. Thwaites in *Early Western Travels, 1748–1846* (Maximilian), 22:1–393. Arthur H. Clark Co., Cleveland.

McKenna, M.C., and S.K. Bell. 1997. *Classification of Mammals Above the Species Level.* Columbia University Press, New York.

McKinley, D. 1960. The question of the pronghorn in pioneer Missouri. *Journal of Mammalogy* 41:503–5.

Meadow, B., and J.K. Peterson. 2001. Unmodified and modified faunal remains. In *Central Plains Tradition at the Palmer Locality: Features and Artifacts from 25NC29*, ed. J.K. Peterson, S.R. Holen, and D.R. Watson, 154–77. Nebraska Archaeological Survey, University of Nebraska State Museum 2001-01.

Metcalf, G. 1941. The Hill-Rupp (or Monroe) site. Report on file at Nebraska State Historical Society, Lincoln.

Mick, L.S. 1983. An ecological evaluation of faunal diversity in the Central Plains tradition. Unpublished MA thesis, University of Nebraska–Lincoln.

Moulton, G.E., ed. 1987. *The Journal of Lewis and Clark Expedition, August 25, 1804–April 6, 1805*, vol. 3. University of Nebraska Press, Lincoln.

Nelson, E.W. 1925. Status of the pronghorned antelope, 1922–1924. *Bulletin of the United States Department of Agriculture* 1346:1–64.

Nepstad-Thornberry, C., L.S. Cummings, and K. Puseman. 2002. A model for the Upper Republican subsistence and nutrition in the Medicine Creek locality: A new look at extant data. In *Medicine Creek: Seventy Years of Archaeological Investigations*, ed. D.C. Roper, 197–211. University of Alabama Press, Tuscaloosa.

O'Gara, B.W. 1978. *Antilocapra americana. Mammalian Species* 90:1–7.

O'Gara, B.W., and J.D. Yoakum. 2004. *Pronghorn Ecology and Management.* University Press of Colorado, Boulder.

Ord, G. 1815. Zoology of North America. In *A Universal Geography, or a View of the Present State of the Known World*, compiled by W. Guthrie, 2:290–361. 2nd ed. Johnson and Warner, Philadelphia. Reprint, 1894. Samuel N. Rhoads, Haddonfield, NJ.

O'Shea, J.M., and J. Ludwickson. 1992. *Archaeology and Ethnohistory of the Omaha Indians: The Big Village Site.* University of Nebraska Press, Lincoln.

Parmalee, P.W., B.B. McMillan, and F.B. King. 1976. Changing subsistence patterns at Rodgers Shelter. In *Prehistoric Man and His Environments: A Case Study from the Ozark Highlands*, ed. W.R. Wood and R.B. McMillan, 141–61. Academic Press, New York.

Parmalee, P.W., and R.D. Oesch. 1972. Pleistocene and Recent faunas from the Brynjulfson Caves, Missouri. *Reports of Investigations, Illinois State Museum* 25:1–52.

Paul Wilhelm, Duke of Württemberg. 1973. *Travels in North America, 1822–1824.* Translated by W.R. Nitske and edited by S. Lottinville. American Exploration and Travel Series, 63. University of Oklahoma Press, Norman.

Pepperl, R.E., and C.R. Falk. 1983. *Native American Archeological Resources of the Central Niobrara River Valley: The Norden Study, North-Central Nebraska.* Division of Archeological Research, Department of Anthropology, University of Nebraska–Lincoln, Technical Report 82-10.

Renaud, E.B. 1933. *Archaeological Survey of Western Nebraska.* Department of Anthropology, University of Denver.

Roosevelt, T., T.S. van Dyke, D.G. Elliot, and A.J. Stone. 1902. *The Deer Family.* Macmillan Company, New York.

Semken, H.A., Jr. 1982. Mammalian remains. In *A Preliminary Report on the Arthur Site, East Okoboji Lake, Iowa*, ed. J.A. Tiffany, 119–32. Office of the State Archaeologist of Iowa, Research Papers Series 7 (1):1–305.

Semken, H.A., Jr., and C.R. Falk. 1987. Late Pleistocene/Holocene mammalian faunas and environmental changes on the northern plains of the United States. In *Late Quaternary Mammalian Biogeography and Environments of the Great Plains and Prairies*, ed. R.W. Graham, H.A. Semken, Jr., and M.A. Graham, 176–313. Illinois State Museum, Scientific Papers 22:1–491.

Sexson, M.L., and J.R. Choate. 1981. Historical biogeography of the pronghorn in Kansas. *Transactions of the Kansas Academy of Science* 84:128–33.

Shaw, J.H., and M. Lee. 1997. Relative abundance of bison, elk, and pronghorn on the Southern Plains. *Plains Anthropologist* 42:163–72.

Snyder, L.M., and J.R. Bozell. 1983. *Identification and Analysis of Vertebrate Faunal Remains Recovered from the Logan Creek Site (25bt3), Burt County, Nebraska.* Division of Archeological Research, Department of Anthropology, University of Nebraska–Lincoln, Technical Report 83-03.

Stansbury, H. 1852. *Exploration and Survey of the Valley of the Great Salt Lake of Utah, Including a*

Reconnaissance of a New Route through the Rocky Mountains. Lippincott, Grambo and Company, Philadelphia.

Strong, W.D. 1935. An introduction to Nebraska archeology. *Smithsonian Miscellaneous Collections* 93 (10):1–323.

Swenk, M.H. 1908. A preliminary of the mammals of Nebraska, with synopses. *Proceedings of the Nebraska Academy of Sciences* 8:61–144.

Swenk, M.H. 1915. The birds and mammals of Nebraska, I. *The Nebraska Blue Book for 1915*, pp. 835–55. State Journal Company, Lincoln, NE.

Tiffany, J.A., S.J. Schermer, J.L. Theler, D.W. Owsley, D.C. Anderson, E.A. Bettis III, and D.M. Thompson. 1988. The Hanging Valley site (13HR28): A stratified Woodland burial locale in western Iowa. *Plains Anthropologist* 33:219–59.

Townsend, J.K. 1839. *Narrative of a Journey Across the Rocky Mountains, to the Columbia River, and a Visit to the Sandwich Islands, and Chili, &c.: With a Scientific Appendix*. H. Perkins, Philadelphia. Reprint (pp. 1–186 and 217–264 of the original), Bison Books, University of Nebraska Press, Lincoln, 1978.

Walker, D.N. 2000. Pleistocene and Holocene records of *Antilocapra americana*: A review of the FAUNMAP data. *Plains Anthropologist* 45:13–28.

Watson, D.R. 1996. Chapter 5: Summary of faunal analysis and artifacts. In *The Tahaksu Site (25MK15), Merrick County, Nebraska*, ed. J.K. Peterson and S.R. Holen, 128–36. Nebraska Archaeological Survey, University of Nebraska State Museum, Technical Report 96-03.

Wedel, W.R. 1936. An introduction to Pawnee archeology. *Smithsonian Institution, Bulletin of the Bureau of American Ethnology* 112:1–122.

Wedel, W.R. 1986. *Central Plains Prehistory: Holocene Environments and Culture Change in the Republican River Basin*. University of Nebraska Press, Lincoln.

Widga, C.C. 2004. Early Archaic subsistence in the Central Plains: The Spring Creek (25FT31) fauna. *Plains Anthropologist* 49:25–58.

Widga, C.C. 2006. Bison, bogs, and big bluestem: The subsistence ecology of Middle Holocene hunter-gatherers in the eastern Great Plains. Unpublished PhD diss., University of Kansas, Lawrence.

Winfrey, J.V. 1991. Spatial distribution of cultural material and post-depositional disturbances at the Wallace site (25GO2): A Plains Woodland occupation site in south-central Nebraska. Unpublished MA thesis, University of Nebraska–Lincoln.

Wolcott, R.H., and F.H. Shoemaker. 1919. Nebraska's game resources and their conservation. *Bulletin of the Nebraska Conservation and Soil Survey* 12:1–32.

Great Plains Research 21 (Fall 2011):175–80

NATIVE AND EUROPEAN HAPLOTYPES OF *PHRAGMITES AUSTRALIS* (COMMON REED) IN THE CENTRAL PLATTE RIVER, NEBRASKA

Diane L. Larson

U.S. Geological Survey
Northern Prairie Wildlife Research Center
1561 Lindig Street
St. Paul, MN 55108
dlarson@usgs.gov

Susan M. Galatowitsch and **Jennifer L. Larson**

Department of Horticultural Science
University of Minnesota
St. Paul, MN 55108

ABSTRACT—*Phragmites australis* (common reed) is known to have occurred along the Platte River historically, but recent rapid increases in both distribution and density have begun to impact habitat for migrating sandhill cranes and nesting piping plovers and least terns. Invasiveness in *Phragmites* has been associated with the incursion of a European genotype (haplotype M) in other areas; determining the genotype of *Phragmites* along the central Platte River has implications for proper management of the river system. In 2008 we sampled *Phragmites* patches along the central Platte River from Lexington to Chapman, NE, stratified by bridge segments, to determine the current distribution of haplotype E (native) and haplotype M genotypes. In addition, we did a retrospective analysis of historical *Phragmites* collections from the central Platte watershed (1902–2006) at the Bessey Herbarium. Fresh tissue from the 2008 survey and dried tissue from the herbarium specimens were classified as haplotype M or E using the restriction fragment length polymorphism procedure. The European haplotype was predominant in the 2008 samples: only 14 *Phragmites* shoots were identified as native haplotype E; 224 were non-native haplotype M. The retrospective analysis revealed primarily native haplotype individuals. Only collections made in Lancaster County, near Lincoln, NE, were haplotype M, and the earliest of these was collected in 1973.

Key Words: braided river, common reed, Great Plains, invasive plants, *Phragmites australis*, Platte River, RFLP

INTRODUCTION

The central Platte River (Nebraska, USA) is a large, braided river with origins in the Rocky Mountains. The river provides important roosting habitat for hundreds of thousands of staging sandhill cranes (*Grus canadensis*) and nesting habitat for federally endangered least terns (*Sterna antillarum*) and threatened piping plovers (*Charadrius melodus*) (Sidle et al. 1992; Kirsch and Sidle 1999; Kinzel et al. 2006). Dams upstream of the central Platte River—here defined as the reach between Lexington, NE, and Chapman, NE—regulate flows far below historic records, especially during spring runoff periods (Eschner et al. 1981). Reduced flows have allowed encroachment by woody species, which have subsequently narrowed channels (Johnson 1994). Likewise, the absence of flooding is thought to have removed a major source of sandbar creation, reducing breeding habitat for terns and plovers (Sidle et al. 1992).

Recently (within the last 12–15 years), land managers have noted the rapid expansion of *Phragmites australis* (hereafter, *Phragmites*) throughout the active channel (i.e., the portion of the river influenced by flowing water) of the central Platte River. The expansion has resulted in vegetation of the bare sandbars required by nesting terns and plovers, and substantial armoring of the river banks, which contributes to channelization (Tal et al. 2004). Records at the University of Nebraska Bessey Herbarium

Manuscript received for review, October 2010; accepted for publication, February 2011.

indicate that *Phragmites* has been collected at sites within the central Platte River watershed since 1887. The reasons for the current rapid expansion are unknown. Elsewhere, low water levels, increased salinity, eutrophication, and the arrival of an exotic genotype have been considered possible triggers for rapid expansion of *Phragmites* (Galatowitsch et al., 1999; Hudon et al. 2005; Vasquez et al. 2005; Lelong et al. 2007).

Saltonstall (2003a) found both a native haplotype of *Phragmites* (haplotype E; now recognized as a subspecies, *P. australis* subsp. *americanus* Saltonstall, P.M. Peterson and Soreng) and the European haplotype (haplotype M; known as *P. australis* [Cav.] Trin. ex Streud.) in six samples collected in 1998 at various locations within the Platte River basin of Nebraska. Because haplotype M has been found to be invasive in freshwater wetlands (T'Ulbure et al. 2007), determining which haplotype is present in the central Platte River is key to developing appropriate management plans. If haplotype M is the dominant form in the central Platte River, managers may take more aggressive action against it than if the native haplotype is dominant. In addition, knowledge of the time course of the arrival of haplotype M may suggest reasons for its spread. Objectives of our study were (1) to assess the current distribution of the native and European haplotypes of *Phragmites* in active channels of the central Platte River and (2) to determine haplotypes of herbarium specimens representing historic collections from the Platte River basin.

METHODS

We collected samples of *Phragmites australis* leaf tissue during the summer of 2008. Our study area extended west from Chapman to Lexington, NE (151 km) and was divided into segments based on bridge crossings near towns (Fig. 1). We sampled at 5–13 random locations within each segment (Table 1); differences in number of locations sampled reflect ownership and access limitations. We collected leaf tissue from three individual shoots at each location (hereafter referred to as a patch, which we define as a discrete group of *Phragmites* shoots, clearly separated from any other patch by open water, bare ground, or other vegetation); only one set of three samples was taken from any given patch. One shoot was sampled from the edge of the patch nearest the center of the channel, the second from the middle of the patch. The third leaf was collected from any shoot that in the opinion of the collector appeared different from the rest of the patch. Although certain morphological characteristics such as ligule length (Saltonstall et al. 2004) and internode coloration (Catling et al. 2007) would have been visible during our early summer collections, we did not base our selection on them. In this way we hoped not to miss one haplotype that might have been present within a larger clone of a differing haplotype. All patches were within the active channel. Sample locations were recorded on a handheld global positioning system unit. Samples were kept chilled in the field and were shipped on ice to the lab at the University of Minnesota where they were frozen until analysis. In all, 238 shoots were sampled.

Tissue from dried herbarium specimens was used for the retrospective analysis. Tissue samples were removed from the collection at the Bessey Herbarium at the University of Nebraska and shipped to the University of Minnesota for analysis. Collection dates ranged from 1902 to 2006; locations were all within the watershed of the central Platte River (Fig. 1).

The protocol for restriction fragment length polymorphism (RFLP) was based on the method developed by Saltonstall (2003b), which distinguishes native from non-native genotypes of *Phragmites australis*. A 0.16 cm disk was punched from frozen or dried leaf tissue and placed in a 96-well plate; the paper punch was sterilized in 70% ethanol in between samples and allowed to dry prior to punching the next sample to avoid contamination between samples. We used the REDExtract-N-Amp Plant PCR kit (Sigma-Aldrich) to extract DNA from frozen leaf tissue and amplify our regions of interest. One hundred milliliters of extraction solution was added to each leaf tissue disk and heated to 95°C for 10 minutes. One hundred milliliters of dilution solution was then added to each well. Two noncoding chloroplast regions were amplified using the polymerase chain reaction (PCR). One region is a portion of the intergenic spacer between the *trn*T (UGU) and *trn*L (UAA) using the amplification primer pairs *trn*L (UAA) 5′ "b" (5′ TCTACCGATTTCGCCATATC)—*trn*LbR (5′ GGAGAAGATAGAATCATAGC) (Taberlet et al. 1991; Saltonstall 2002). The other region is a portion of the intergenic spacer between *rbc*L and *psal* using primer pairs *rbc*L (5′ TGTACAAGCTCGTAACGAAGG)—*rbc*L3R (5′ GATTTGTCAAGTCTCATGATCGT) (Saltonstall 2001; Saltonstall 2003b). PCR reactions consisted of 2 µl leaf disk extract, which included DNA, 10 µl REDExtract-N-Amp PCR ready mix, 2 µl each of the forward and reverse primers, 2 µl deionized and autoclaved water, and 1 µl each of the extraction and dilution solutions in a total volume of 20 µl. The thermal cycling profile was 2 minutes at 94°C, followed by 35

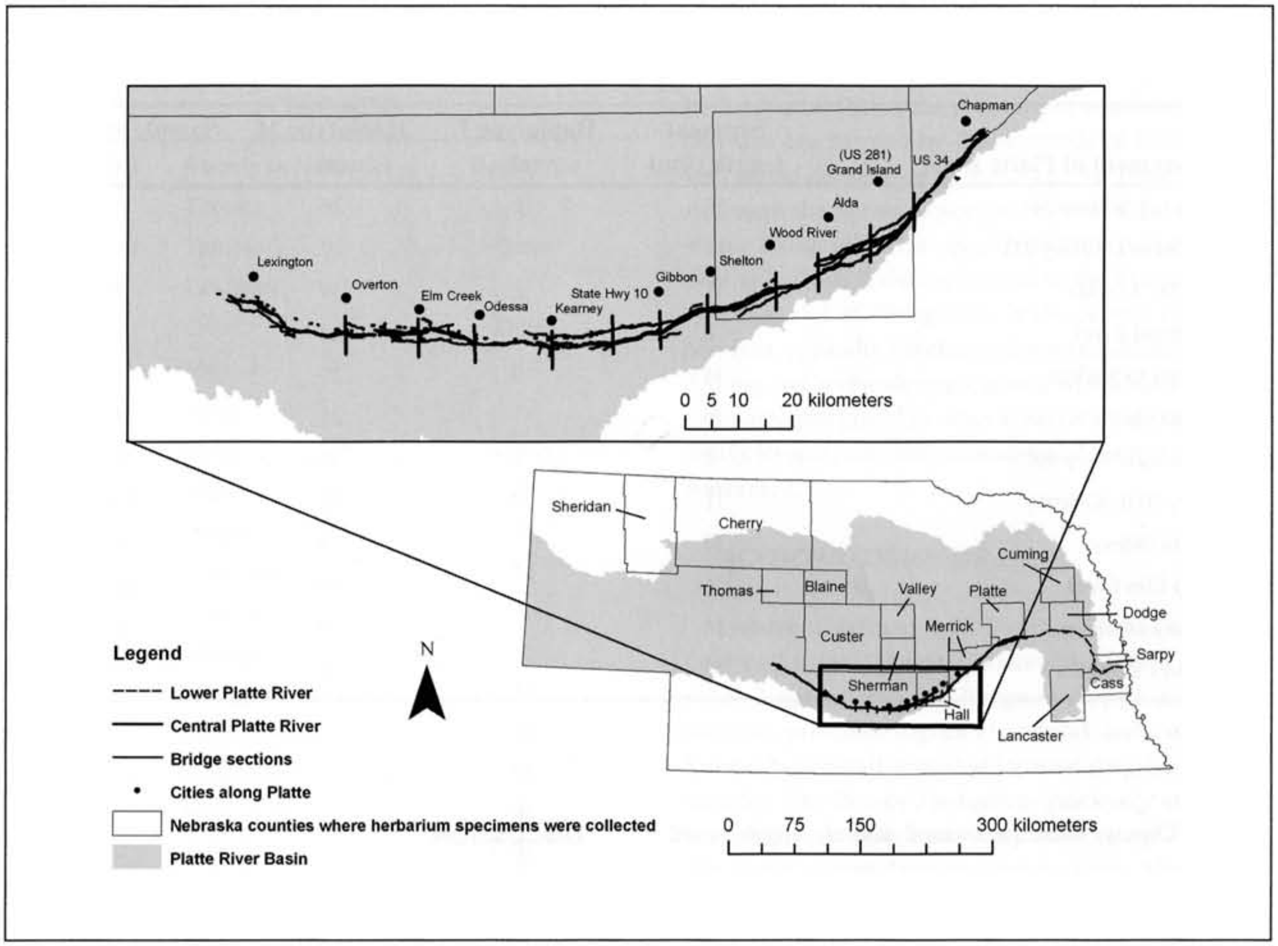


Figure 1. Map of study area in Nebraska, showing bridge sections for sampling *Phragmites* on the Platte River. Bridges are indicated by vertical lines crossing the river. The shaded area indicates the Platte River drainage basin. Identified counties are those from which herbarium specimens we analyzed were collected.

cycles of 94°C for 45 seconds, 52°C at 45 seconds, and 72°C for 1 minute 30 seconds, followed by an extension of 72°C for 1 minute 30 seconds. After the 35 cycles were completed, a final extension step at 72°C was run for 2 minutes. Ten milliliters of PCR product was digested using the restriction enzyme R*sa*I for the *trn*Lb region and the HhaI for the *rbc*L region following the manufacturer's directions. Restriction fragments were electrophoresed in ethidium bromide stained 3% TAE agarose gels and visualized with UV light.

The HhaI restriction enzyme generates a 104 bp fragment that is unique to haplotype M (and other European haplotypes). The R*sa*I restriction enzyme generates a 282 bp fragment in native haplotypes but not in European haplotypes. Verified specimens of haplotype M and a native haplotype were analyzed as controls for the assay.

The extraction technique described above failed to extract DNA from some of the dried tissue from herbarium specimens. For these, we extracted DNA from 50 mg of ground air-dried leaf tissue using the DNeasy Plant Mini Kit (Qiagen). DNA extracts were then diluted to a concentration of 5 ng DNA per 1 µl solution. AmpliTaq Gold DNA Polymerase (Applied Biosystems) was used to amplify the same regions of interest. PCR reactions consisted of 8 µl DNA extract, 4 µl buffer, 4 µl each of the forward and reverse primers, 4 µl dNTPs, 0.4 µl Taq polymerase, 17.6 µl deionized and autoclaved water, and 4 µl magnesium chloride in a total volume of 40 µl. The thermal cycling profile was 2 minutes at 94°C, followed by 35 cycles of 92°C for 30 seconds, 57°C for 15 seconds, and 72°C for 30 seconds. After the 35 cycles were completed, a final extension step at 72°C was run for 5

Platte River basin: A historical perspective. *Open File Report*. U.S. Geological Survey, Reston, VA.

Galatowitsch, S.M., N.O. Anderson, and P.D. Ascher. 1999. Invasiveness in wetland plants in temperate North America. *Wetlands* 19:733–55.

Hudon, C., P. Gagnon, and M. Jean. 2005. Hydrological factors controlling the spread of common reed (*Phragmites australis*) in the St. Lawrence River (Quebec, Canada). *Ecoscience* 12:347–57.

Johnson, W.C. 1994. Woodland expansion in the Platte River, Nebraska: Patterns and causes. *Ecological Monographs* 64:45–84.

Kinzel, P.J., J.M. Nelson, R.S. Parker, and L.R. Davis. 2006. Spring census of mid-continent sandhill cranes using aerial infrared videography. *Journal of Wildlife Management* 70:70–77.

Kirsch, E.M., and J.G. Sidle. 1999. Status of the interior population of least tern. *Journal of Wildlife Management* 63:470–83.

Lelong, B., C. Lavoie, Y. Jodoin, and F. Belzile. 2007. Expansion pathways of the exotic common reed (*Phragmites australis*): A historical and genetic analysis. *Diversity and Distributions* 13:430–37.

Ludwig, D.F., T.J. Iannuzzi, and A.N. Esposito. 2003. Phragmites and environmental management: a question of values. *Estuaries* 26:624–30.

Meadows, R.E., and K. Saltonstall. 2007. Distribution of native and introduced *Phragmites australis* in freshwater and oligohaline tidal marshes of the Delmarva Peninsula and southern New Jersey. *Journal of the Torrey Botanical Society* 134:99–107.

Saltonstall, K. 2001. A set of primers for amplification of noncoding regions of chloroplast DNA in the grasses. *Molecular Ecology Notes* 1 (1–2):76–78.

Saltonstall, K. 2002. Cryptic invasion by a non-native genotype of the common reed, *Phragmites australis*, into North America. *Proceedings of the National Academy of Sciences of the United States of America* 99:2445–49.

Saltonstall, K. 2003a. Genetic variation among North American Populations of *Phragmites australis*: Implications for management. *Estuaries* 26:444–51.

Saltonstall, K. 2003b. A rapid method for identifying the origin of North American Phragmites populations using RFLP analysis. *Wetlands* 23:1043–47.

Saltonstall, K., P.M. Peterson, and R.J. Soreng. 2004. Recognition of *Phragmites australis* subsp. *americanus* (Poaceae: Arundinoideae) in North America: Evidence from morphological and genetic analyses. *Sida* 21:683–92.

Sidle, J.G., D.E. Carlson, E.M. Kirsch, and J.J. Dinan. 1992. Flooding—mortality and habitat renewal for least terns and piping plovers. *Colonial Waterbirds* 15:132–36.

Soons, M.B., C. van der Vlugt, B. van Lith, G.W. Heil, and M. Klaassen. 2008. Small seed size increases the potential for dispersal of wetland plants by ducks. *Journal of Ecology* 96:619–27.

Taberlet, P., L. Gielly, G. Pautou, and J. Bouvet. 1991. Universal primers for amplification of three noncoding regions of chloroplast DNA. *Plant Molecular Biology* 17:1105–9.

Tal, M., K. Gran, A.B. Murray, C. Paola, and D.M. Hicks. 2004. Riparian vegetation as a primary control on channel characteristics in multi-thread rivers. In *Riparian Vegetation and Fluvial Geomorphology*, ed. S. Bennett and A. Simon, 8:43–58. American Geophysical Union, Washington, DC.

T'Ulbure, M.G., C.A. Johnston, and D.L. Auger. 2007. Rapid invasion of a Great Lakes coastal wetland by non-native *Phragmites australis* and *Typha*. *Journal of Great Lakes Research* 33:269–79.

van den Broek, T., R. van Diggelen, and R. Bobbink. 2005. Variation in seed buoyancy of species in wetland ecosystems with different flooding dynamics. *Journal of Vegetation Science* 16:579–86.

Vasquez, E.A., E.P. Glenn, J.J. Brown, G.R. Guntenspergen, and S.G. Nelson. 2005. Salt tolerance underlies the cryptic invasion of North American salt marshes by an introduced haplotype of the common reed *Phragmites australis* (Poaceae). *Marine Ecology-Progress Series* 298:1–8.

Great Plains Research 21 (Fall 2011):181–89

EFFECTS OF HERBICIDES AND GRAZING ON FLORISTIC QUALITY OF NATIVE TALLGRASS PASTURES IN EASTERN SOUTH DAKOTA AND SOUTHWESTERN MINNESOTA

Alexander J. Smart

Department of Animal and Range Sciences
Box 2170
South Dakota State University
Brookings, SD 57007
alexander.smart@sdstate.edu

Matthew J. Nelson

Department of Animal and Range Sciences
Box 2170
South Dakota State University
Brookings, SD 57007

Peter J. Bauman

The Nature Conservancy
Clear Lake, SD 57226

and

Gary E. Larson

Department of Biology and Microbiology
Box 2207B
South Dakota State University
Brookings, SD 57007

ABSTRACT—Historic herbicide use and grazing have influenced natural diversity and quality of native pasturelands in the Great Plains. Floristic quality assessments are useful to assist agencies in prioritizing conservation practices to enhance native grasslands. The objective of this study was to determine the effects of past land-use practices on the floristic quality of remnant native pastures in eastern South Dakota and southwestern Minnesota. Floristic quality assessments were conducted on 30 native pastures and categorized by past management practices (herbicide application and grazing intensity). Mean coefficient of conservatism ($\overline{C}$) and floristic quality index (FQI) were calculated for each site. Results showed that increased herbicide use and grazing intensity resulted in a lower species richness, forb $\overline{C}$, and FQI. However, grass and grasslike plants were minimally affected. Pastures that were infrequently sprayed with herbicides and lightly grazed consistently had the highest species richness, $\overline{C}$, and FQI. Pastures with no grazing produced similar values to those with moderate grazing. Pastures managed as preserves or wildlife habitat areas had higher FQI than those managed for livestock grazing. The implications of this study should further help ecologists and managers understand the positive and negative effects of grazing practices and herbicide application on tallgrass prairie remnants.

Key Words: tallgrass prairie, floristic quality, species richness, grasses, forbs, grazing, herbicides

Manuscript received for review, July 2010; accepted for publication, November 2010.

INTRODUCTION

The natural landscape of the eastern Great Plains has been immensely altered since European-American settlement. Large areas of land have been put into agricultural production, and as a result, less than 1% of the native tallgrass prairie remains (Samson and Knopf 1996). Remnant tallgrass prairies display varying degrees of quality due to habitat disturbance and invasion by exotic species (Northern Great Plains Floristic Quality Assessment Panel 2001). Long-term use of herbicides that control broadleaf species has resulted in decreased forb diversity in eastern Nebraska rangelands (Masters et al. 1992; Masters et al. 1994) and in eastern Texas (Hickman and Derner 2007). Exotic cool-season grasses such as smooth bromegrass (*Bromus inermis* Leyss.) and Kentucky bluegrass (*Poa pratensis* L.) have increased greatly in the Great Plains (Weaver and Fitzpatrick 1934; Casler and Carlson 1995). Anthropogenic additions of nitrogen deposition have contributed to the competitiveness of exotic cool-season grasses (Wedin and Tilman 1996; Vinton and Goergen 2006). It is likely that remnant grasslands of the eastern Great Plains have experienced greater grazing intensities since the removal of the bison (*Bison bison*), fencing of pastures, and introduction of domestic livestock (Weaver and Fitzpatrick 1934). Grazing intensity has been shown to decrease the vigor of pasture forage species and increase weedy species (Harker et al. 2000). Therefore, tallgrass prairie remnants are a high priority for conservation by natural resource agencies. The objectives of this study were to determine the effects of past management practices, involving varying levels of herbicide application and grazing intensity, and whether the primary land use (either nature preserve/wildlife production or livestock grazing) has had an impact on floristic quality of native prairies pastures in the Prairie Coteau Ecoregion of eastern South Dakota and southwestern Minnesota. The literature suggests that herbicide use and grazing intensity decrease the floristic quality of native pastures and that prairies managed as nature preserves/wildlife areas should have higher floristic quality than pastures managed for livestock grazing.

MATERIALS AND METHODS

Thirty native tallgrass prairie pastures in the Prairie Coteau Ecoregion of eastern South Dakota and southwestern Minnesota were sampled for floristic quality, defined by Swink and Wilhelm (1979, 1994) as the assessment of native plants' degree of dependence on intact native plant communities, in the field seasons of 2006 and 2009 (Fig. 1). Pasture size averaged 88 ha and ranged from 12 to 810 ha. Field methodology followed standard protocol for floristic quality index (FQI) assessment (Northern Great Plains Floristic Quality Assessment Panel 2001). Pastures were surveyed in July and August to identify all vascular plant species within a parcel of the pasture until no new species were detected after 10 minutes of additional searching. Once the 10-minute period expired, the surveyor moved to a new location within the pasture. This procedure was repeated until no new species were found within the entire pasture. The average time spent surveying pastures was 5 minutes per hectare. Each plant is assigned a conservatism value as determined by the Northern Great Plains Assessment Panel (2001). Values of conservatism, or coefficient of conservatism, are integral values ranging from 0 to 10, with 0 assigned to species typifying disturbed habitats and 10 assigned to the most conservative species, that is, those occurring strictly in undisturbed habitats. The coefficient of conservatism value thus represents the plant species' ability to indicate or predict the quality of a natural area (Higgins et al. 2001). Exotic species are not assigned a value. Mean coefficient of conservatism ($\overline{C}$) and FQI values were calculated for each pasture based on floristic composition. The mean coefficient of conservatism for a particular land parcel is thus the average of coefficient of conservatism values for all of the native species occurring on the parcel. Floristic quality index is calculated by the following equation:

$$FQI = \overline{C}\sqrt{N},$$

where $\overline{C}$ is the mean coefficient of conservatism for a site and N is the total number of native plant species found. This procedure is not density dependent, and thus $\overline{C}$ and FQI values for a land parcel are stable over time, at least provided that the management does not change, and given the fact that most prairie plants are perennials and are observed during both wet and dry years.

Herbicide use was categorized as frequent if it was broadcast over an entire pasture annually or up to every 3 to 4 years and infrequent if the pasture was only spot sprayed when and where necessary. Grazing intensity was categorized as no grazing, light, moderate, and heavy relative to the recommended stocking rate for South Dakota rangeland and pasture (SDSU 2007) and was based on fall stubble height (Mousel and Smart 2007). Light grazing was usually practiced seasonally (spring or summer) for <4 months to achieve utilization of approximately 25% or

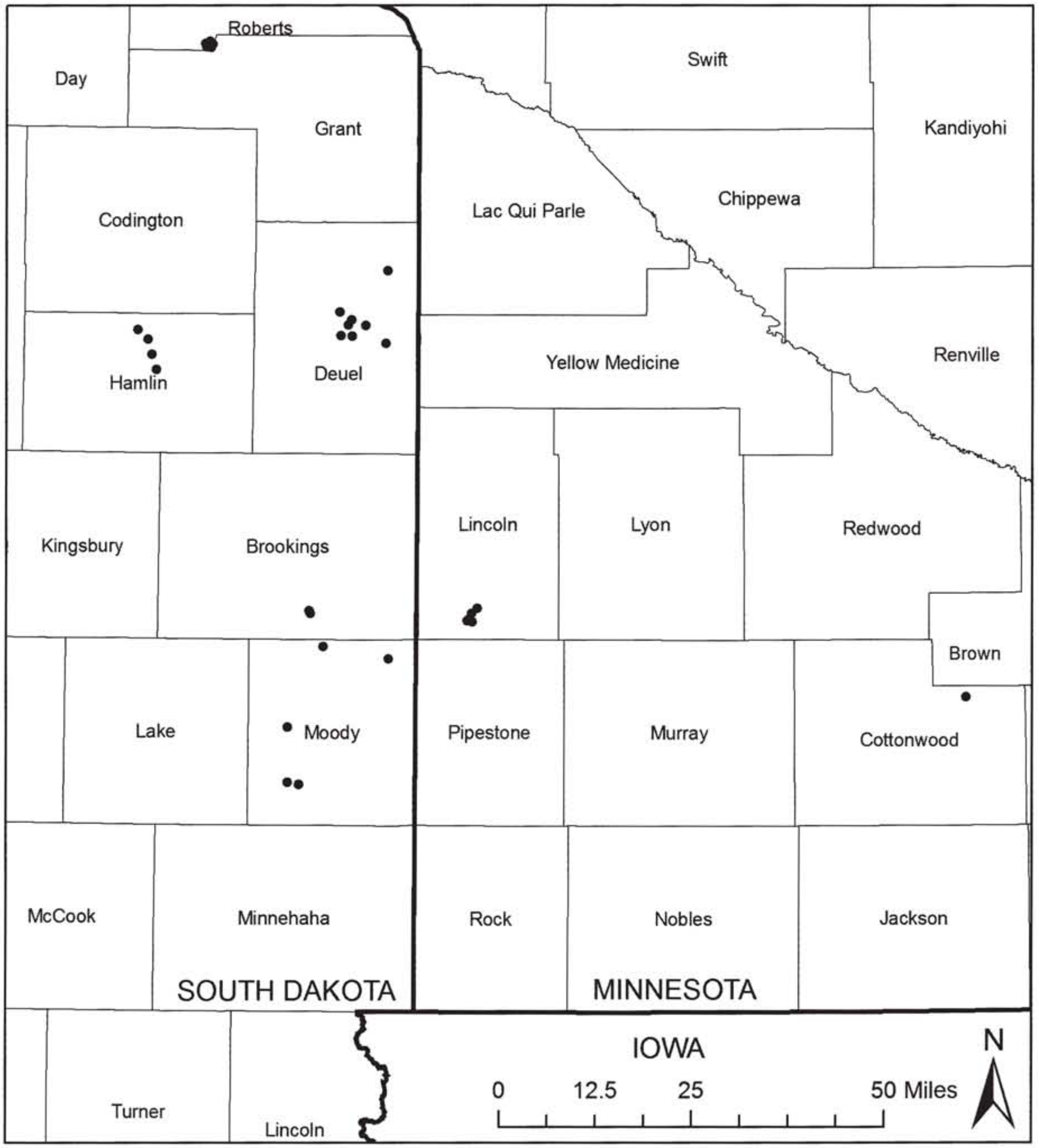


Figure 1. Locations of remnant tallgrass prairie sites (solid circles) in the Prairie Coteau Ecoregion of eastern South Dakota and southwestern Minnesota.

less of the annual herbage production. Moderate and heavy grazing was usually practiced season-long to achieve an approximate utilization of 50% and >65%, respectively. Ranchers and managers verified that land parcels had never been plowed and provided past management information that allowed us to categorize the combined use of herbicides and grazing intensity into six categories: frequent herbicide–heavy grazing (n = 8), frequent herbicide–moderate grazing (n = 6), infrequent herbicide–heavy grazing (n = 3), infrequent herbicide–moderate grazing (n = 3), infrequent herbicide–light grazing (n = 6), and infrequent herbicide–no grazing (n = 4). Primary land use was categorized as either nature preserve/wildlife habitat (n = 12) or livestock grazing land (n = 18). A one-way analysis of variance was used to compare herbicide–grazing combinations and primary land-use effects using PROC GLM (SAS Institute 2009). Normality of the residuals was verified using the NORMAL and PLOT options in

PROC UNIVARIATE (SAS Institute 2009). The Shapiro-Wilk's test yielded values close to 1 and the normality plots validated the assumptions of normality for all variables. Levene's test and Welch's ANOVA were computed to evaluate equal variances among herbicide–grazing treatments and primary-use treatment groups using the HOVTEST and WELCH options in the MEANS statement of PROC GLM (SAS Institute 2009). When the *P*-value was <0.05, Welch's ANOVA was used instead. Means were separated using the PDIFF option in PROC GLM (SAS Institute 2009) when the *P*-value for the main effect was $P < 0.05$. Preplanned contrast statements were used to separate the effects of herbicide and grazing intensity among the frequent and infrequent herbicide-treated pastures and the heavily and moderately grazed pastures. (We excluded the infrequent herbicide–lightly grazed and infrequent–no grazing pastures).

RESULTS

Herbicide–Grazing Intensity

The number of grass and grasslike species, grass and grasslike $\overline{C}$, and grass and grasslike FQI were not statistically different among herbicide–grazing intensities, although heavily grazed pastures averaged 6.5 fewer species than did moderately grazed pastures (Table 1). The number of forb species, forb $\overline{C}$, and forb FQI were significantly different among herbicide–grazing intensities (Table 2). The number of forb species was highest for pastures that were infrequently sprayed and grazed lightly or moderately. Pastures that were frequently sprayed with herbicide and heavily grazed had the fewest forb species. Forb $\overline{C}$ was not different among pastures where herbicides were infrequently used. Pastures that were frequently sprayed with herbicide and heavily grazed had a lower forb $\overline{C}$ than those that were moderately grazed. Forb FQI was 1.5 times greater on pastures that were infrequently sprayed with herbicide compared to those that were frequently sprayed with herbicide. Prairies where herbicide was infrequently used but grazed lightly had 1.25 times greater forb FQI than those that were not grazed. Moderately grazed pastures had 1.26 times greater forb FQI than those that were heavily grazed.

The overall number of species, overall $\overline{C}$, and overall FQI were significantly different among herbicide–grazing intensities and had rankings similar to the forbs for the different herbicide–grazing intensity combinations (Table 3). The number of exotic grasses and forbs was not statistically different among herbicide–grazing intensities except that frequent use of herbicides averaged 6.8 fewer exotic forbs than pastures that were infrequently sprayed with herbicide (Table 4).

Primary Land Use

Preserves/wildlife habitat areas were similar to areas managed for livestock grazing in the number of grass and grasslike species, grass and grasslike $\overline{C}$, and grass and grasslike FQI (Table 5). Pastures managed primarily for livestock grazing averaged 57.7 fewer forb species, had a 14% lower forb $\overline{C}$, and a 41% lower forb FQI (Table 5). Overall number of species, overall $\overline{C}$, and overall FQI were 1.8, 1.1, and 1.5 times greater, respectively, for pastures managed as preserves/wildlife habitat compared to those managed for livestock grazing (Table 5). Pastures managed for livestock grazing averaged 2.1 more exotic grasses and 10.7 fewer forbs than areas managed as preserves/wildlife habitat areas (Table 5).

DISCUSSION

Herbicide–Grazing Intensity

There are several reasons why herbicide use did not affect grass diversity as much as it affected forb diversity (Tables 1 and 2). The most frequently used herbicides on pasturelands in the Prairie Coteau Ecoregion of eastern South Dakota and southwestern Minnesota are those that control broadleaf plants (Darrel Deneke, South Dakota State University, integrated pest management coordinator, pers. comm., 2010). State noxious weed laws require the control of invasive species such as leafy spurge (*Euphorbia esula* L.) and Canada thistle (*Cirsium arvense* [L.] Scop.), and these species have high infestation rates in counties of this region (South Dakota Department of Agriculture 2009). In addition, the forb $\overline{C}$ was higher on lands that were infrequently sprayed with herbicides, suggesting that rare and more sensitive forbs are not able to survive frequent herbicide treatment.

It is well documented that increased grazing intensity decreases floral diversity on native rangelands (Lauenroth et al. 1999), and our study found likewise. However, grass and grasslike FQI was not significantly different among grazing intensities (Table 1). The reason for this was that the grass and grasslike $\overline{C}$ was not different between grazing intensities even though heavy grazing averaged 6.5 fewer grass and grasslike species compared to moderately grazed pastures. Numerous stocking rate studies show that taller and midsize grasses are replaced

TABLE 1

NUMBER OF GRASS AND GRASSLIKE SPECIES (*N*), GRASS AND GRASSLIKE MEAN COEFFICIENT OF CONSERVATISM ($\overline{C}$), AND GRASS AND GRASSLIKE FLORISTIC QUALITY INDEX (FQI) FROM 30 NATIVE PASTURES

	Grass and grasslike species		
Herbicide–grazing intensity	**N** $\bar{x}$ **(SE)**[1]	$\overline{C}$ $\bar{x}$ **(SE)**	**FQI** $\bar{x}$ **(SE)**
Frequent–heavy	18.1 (2.24)	4.70 (0.16)	19.5 (1.27)
Frequent–moderate	23.7 (2.59)	4.84 (0.18)	23.6 (1.47)
Infrequent–heavy	16.0 (3.66)	5.28 (0.26)	21.1 (2.08)
Infrequent–moderate	23.3 (3.66)	4.69 (0.26)	22.5 (2.08)
Infrequent–light	27.2 (2.59)	4.95 (0.18)	25.5 (1.47)
Infrequent–none	20.0 (3.17)	4.74 (0.22)	21.1 (1.80)
P-value	0.1011	0.1293	0.2650
Contrasts[2]			
Frequent vs. infrequent	0.6957	0.3305	0.8624
Heavy vs. moderate	0.0490	0.3369	0.1347
Interaction	0.7754	0.1063	0.4590

Note: Pastures were surveyed from 2006 to 2009 in eastern South Dakota and southwestern Minnesota.
[1]SE indicates standard error of the mean.
[2]Contrasts do not include infrequent—light and infrequent—none pastures.

TABLE 2

NUMBER OF FORB SPECIES (*N*), FORB MEAN COEFFICIENT OF CONSERVATISM ($\overline{C}$), AND FORB FLORISTIC QUALITY INDEX (FQI) FROM 30 NATIVE PASTURES

	Forb species		
Herbicide–grazing intensity	**N** $\bar{x}$ **(SE)**[1]	$\overline{C}$ $\bar{x}$ **(SE)**	**FQI** $\bar{x}$ **(SE)**
Frequent–heavy	40.1 (8.26) d[2]	4.01 (0.14) c	25.4 (2.77) d
Frequent–moderate	66.3 (9.54) c	4.46 (0.16) b	36.3 (3.20) c
Infrequent–heavy	75.3 (13.49) bc	5.03 (0.22) a	43.6 (4.52) b
Infrequent–moderate	105.7 (13.49) ab	4.96 (0.22) ab	50.7 (4.52) ab
Infrequent–light	132.8 (9.54) a	5.23 (0.16) a	59.9 (3.20) a
Infrequent–none	87.5 (11.68) bc	5.16 (0.19) a	47.9 (3.92) b
P-value	0.0001	0.0001	0.0001
Contrasts[3]			
Frequent vs. infrequent	0.0033	0.0005	0.0003
Heavy vs. moderate	0.0209	0.3331	0.0275
Interaction	0.8584	0.1769	0.6294

Note: Pastures were surveyed from 2006 to 2009 in eastern South Dakota and southwestern Minnesota.
[1]SE indicates standard error of the mean.
[2]Means followed by different letters are significantly different ($P < 0.05$).
[3]Contrasts do not include infrequent—light and infrequent—none pastures.

TABLE 3
NUMBER OF OVERALL SPECIES (*N*), OVERALL MEAN COEFFICIENT OF CONSERVATISM ($\overline{C}$), AND OVERALL FLORISTIC QUALITY INDEX (FQI) FROM 30 NATIVE PASTURES

	Overall species		
Herbicide–grazing intensity	**N** $\bar{x}$ **(SE)**[1]	$\overline{C}$ $\bar{x}$ **(SE)**	**FQI** $\bar{x}$ **(SE)**
Frequent–heavy	58.3 (9.35) d[2]	4.23 (0.11) c	32.0 (2.66) d
Frequent–moderate	90.0 (10.80) c	4.56 (0.12) bc	43.3 (3.07) c
Infrequent–heavy	90.7 (15.27) bc	5.12 (0.17) a	48.6 (4.34) bc
Infrequent–moderate	129.0 (15.27) ab	4.91 (0.17) ab	55.5 (4.34) ab
Infrequent–light	160.0 (10.80) a	5.19 (0.12) a	65.4 (3.07) a
Infrequent–none	107.5 (13.22) bc	5.09 (0.15) a	52.4 (3.75) bc
P-value	0.0001	0.0001	0.0001
Contrasts[3]			
Frequent vs. infrequent	0.0109	0.0003	0.0006
Heavy vs. moderate	0.0123	0.6911	0.0213
Interaction	0.8014	0.0813	0.5532

Note: Pastures were surveyed from 2006 to 2009 in eastern South Dakota and southwestern Minnesota.
[1]SE indicates standard error of the mean.
[2]Means followed by different letters are significantly different ($P < 0.05$).
[3]Contrasts do not include infrequent—light and infrequent—none pastures.

by shorter species (Lauenroth et al. 1999). The low standard error of the grass and grasslike $\overline{C}$ indicates that the most commonly found species have similar *C* values (Northern Great Plains Floristic Quality Assessment Panel 2001). In addition, the computation of FQI is not density dependent, meaning an area could have a substantial reduction in species diversity without reducing its FQI. Grazing intensity had a significant impact on forb FQI because numerous forb species are sensitive to overgrazing (Johnson and Larson 1999).

PRIMARY LAND USE

The desire for ecosystem goods and services (i.e., an economic benefit such as beef production or a service providing habitat for flora and fauna) dictates management decisions regarding herbicide use and grazing intensity. Our data set represents the common pastureland uses in this region, and our findings of higher FQI values for forbs and for overall species on areas managed as preserves/wildlife habitat areas compared to pastures managed for livestock grazing (Table 5) was similar to previous findings. Higgins et al. (2001) surveyed 63 tallgrass prairie remnant sites in eastern South Dakota and found that private land had an FQI of 39 compared to 57 for preserves. In northeastern Kansas, Jog et al. (2006) found warm-season hay meadows had an FQI of 32 and warm-season pastures managed for livestock grazing had an FQI of 21. Landowners whose primary objective is livestock grazing tend to use herbicides for weed control more frequently and stock heavier than managers of preserves. To conserve the floristic diversity of remaining native prairie tracts, the cultural and economic incentives behind these management decisions must be understood.

Livestock producers tend to accept exotic grasses whereas managers of preserves dislike exotic grasses because they reduce native species biodiversity. Our data showing 2.1 more exotic grass species on pastures managed for livestock grazing versus areas managed as preserves/wildlife areas (Table 5) support this view. Exotic forbs are a real concern for producers and managers. Pastures that were frequently sprayed had fewer exotic forb species, and producers that managed land for livestock grazing also had fewer exotic forb species (Table 5). These data suggest that cultural factors such as "what the neighbors think," along with legal obligations to control

TABLE 4
NUMBER OF EXOTIC GRASSES AND FORBS FROM 30 NATIVE PASTURES CATEGORIZED BY HERBICIDE–GRAZING INTENSITY

	Grasses	Forbs
Herbicide–grazing intensity	$\bar{x}$ (SE[1])	$\bar{x}$ (SE)
Frequent–heavy	7.1 (0.65)	11.4 (2.43)
Frequent–moderate	7.8 (0.75)	14.3 (2.81)
Infrequent–heavy	6.0 (1.07)	19.0 (3.97)
Infrequent–moderate	6.0 (1.07)	20.3 (3.97)
Infrequent–light	5.3 (0.75)	26.2 (2.81)
Infrequent–none	4.5 (0.92)	17.3 (3.44)
P-value	0.0809	0.0942
Contrasts[2]		
Frequent vs. infrequent	0.1152	0.0545
Heavy vs. moderate	0.6990	0.5303
Interaction	0.6990	0.8115

Note: Pastures were surveyed from 2006 to 2009 in eastern South Dakota and southwestern Minnesota.
[1]SE indicates standard error of the mean.
[2]Contrasts do not include infrequent—light and infrequent—none pastures.

noxious weeds, are likely responsible for the fewer exotic forbs found on lands where livestock grazing is the primary objective.

Judicious use of herbicide application should be practiced instead of frequent broadcast applications. Fuhlendorf et al. (2009) showed that broadcast application of herbicides on Oklahoma rangeland, where forbs comprised 23% of the herbage production, did not increase grass and beef production. Their work suggests that a higher economic threshold of weedy broadleaf plants exists. Such thresholds are unknown in the Prairie Coteau Ecoregion, but historic climax-plant-community theory for this region would indicate that forbs make up approximately 5% to 15% of the plant community in terms of biomass (NRCS 2010b). The perception that broadleaf plants reduce grass production in this region may be incorrect.

Economic incentives from conservation agencies need to focus on reducing the stocking rate to a light grazing intensity in order to maintain or increase plant diversity. Such incentives exist through the Natural Resources Conservation Service's Conservation Stewardship Plan. Practices such as deferred grazing and rotational grazing with proper stocking rates pay producers

TABLE 5
NUMBER OF GRASS AND GRASSLIKE, FORB, AND OVERALL SPECIES (N), GRASS AND GRASSLIKE, FORB, AND OVERALL MEAN COEFFICIENT OF CONSERVATISM ($\bar{C}$), AND GRASS AND GRASSLIKE, FORB, AND OVERALL FLORISTIC QUALITY INDEX (FQI) FROM 30 NATIVE PASTURES

	Grass and grasslike species			Forb species			Overall species		
Primary land use	N $\bar{x}$ (SE)[1]	$\bar{C}$ $\bar{x}$ (SE)	FQI $\bar{x}$ (SE)	N $\bar{x}$ (SE)	$\bar{C}$ $\bar{x}$ (SE)	FQI $\bar{x}$ (SE)	N $\bar{x}$ (SE)	$\bar{C}$ $\bar{x}$ (SE)	FQI $\bar{x}$ (SE)
Preserve/wildlife habitat	23.3 (1.99)	4.90 (0.13)	23.4 (1.13)	114.9 (8.09)	5.20 (0.13)	55.4 (2.73)	138.1 (9.38)	5.16 (0.10)	60.2 (2.70)
Livestock grazing	20.4 (1.62)	4.80 (0.11)	21.4 (0.92)	57.2 (6.61)	4.36 (0.11)	32.8 (2.23)	77.7 (7.66)	4.50 (0.08)	39.3 (2.20)
P-value	0.2697	0.5789	0.1826	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

Note: Pastures were surveyed from 2006 to 2009 in eastern South Dakota and southwestern Minnesota.
[1]SE indicates standard error of the mean.

TABLE 6
NUMBER OF EXOTIC GRASSES AND FORBS FROM 30 NATIVE PASTURES CATEGORIZED BY PRIMARY LAND USE

	Grasses	Forbs
Primary land use	$\bar{x}$ (SE)[1]	$\bar{x}$ (SE)
Preserve/wildlife habitat	5.1 (0.52)	23.8 (1.86)
Livestock grazing	7.2 (0.42)	13.1 (1.52)
P-value	0.0041	0.0001

Note: Pastures were surveyed from 2006 to 2009 in eastern South Dakota and southwestern Minnesota.
[1]SE indicates standard error of the mean.

who qualify (NRCS 2010a). These payments are necessary to offset economic drivers to graze heavy. Dunn et al. (2010) reported that the net profit from grazing mixed-grass prairie at three different range-condition classes was significantly greater at good and low to fair range conditions compared to excellent range condition in western South Dakota, because excellent range condition could not be stocked as heavily. Thus, ranchers have no economic incentive to improve rangeland, but it also means there should be no incentive to overstock rangeland that is currently in good condition. Smart et al. (2010) showed, using data from Hart et al. (1998), that greater efficiencies occur at heavy stocking rates and optimum returns per hectare were between moderate and heavy stocking. Therefore, if society desires the benefits of improved range condition (higher plant diversity, quality wildlife habitat, etc.), then lower stocking rates must be incentivized (Dunn et al. 2010).

On the other hand, managers of preserves/wildlife production areas should be aware of the benefits of using livestock to apply periodic disturbances. Pastures that were infrequently sprayed with herbicide and lightly grazed had the highest species richness and highest $\overline{C}$ and FQI (Tables 1–3). As long as grazing is kept at a light intensity (<25% utilization of annual herbage production) and applied at the right time, it can be a useful tool to reduce competition of exotic cool-season grasses.

In summary, floristic quality assessments provided useful insight into the effects of past management practices, such as grazing intensity and herbicide application. Floristic quality index values for grasses and grasslike plants were less affected by herbicide use and grazing intensity than those for forbs. Lightly grazed pastures had higher FQI values and greater species richness than pastures that were grazed moderately, heavily, or ungrazed. Frequent use of herbicides reduced FQI values for forbs to a much greater extent than it did for grasses. Finally, pastures managed as preserves/wildlife production areas had higher FQI values than pastures managed for livestock grazing. If conservation is aimed at improving the floristic quality of remaining native prairies in this region, economic incentives should be promoted to reduce stocking rates and encourage judicious use of herbicides.

ACKNOWLEDGMENTS

The authors would like to thank the reviewers of the earlier version of this manuscript. This project was supported by a Graduate Student NCR-SARE grant (GNC08-098).

REFERENCES

Casler, M.D., and I.R. Carlson. 1995. Smooth bromegrass. In *Forages*, vol. 1: *An Introduction to Grassland Agriculture*, ed. Barnes et al., 313–24. Iowa State University Press, Ames.

Dunn, B.H., A.J. Smart, R.N. Gates, P.S. Johnson, M.K. Beutler, M.A. Diersen, and L.L. Janssen. 2010. Long-term production and profitability from grazing cattle in the northern mixed grass prairie. *Rangeland Ecology and Management* 63:233–42.

Fuhlendorf, S.D., D.M. Engle, C.M. O'Meilia, J.R. Weir, and D.C. Cummings. 2009. Does herbicide weed control increase livestock production on non-equilibrium rangeland? *Agriculture, Ecosystems and Environment* 132:1–6.

Harker, K.N., V.S. Baron, D.S. Chanasyk, M.A. Naeth, and F.C. Stevenson. 2000. Grazing intensity effects on weed populations in annual and perennial pasture systems. *Weed Science* 48:231–38.

Hart, R.H., M.J. Samuel, P.S. Test, and M.A. Smith. 1988. Cattle, vegetation, and economic responses to grazing systems and grazing pressure. *Journal of Range Management* 41:282–86.

Hickman, K.R., and J.D. Derner. 2007. Blackland tallgrass prairie vegetation dynamics following cessation of herbicide application. *Rangeland Ecology and Management* 60:186–90.

Higgins, J.J., G.E. Larson, and K.F. Higgins. 2001. Floristic comparisons of tallgrass prairie remnants managed by different land stewardships in eastern South Dakota. In *Proceedings of the 17th North American Prairie Conference: Seeds for the Future, Roots*

of the Past, ed. N.P. Bernstein and L.J. Ostrander, 21–31. North Iowa Area Community College, Mason City, IA, July 16–20, 2000.

Jog, S., K. Kindscher, E. Questad, B. Foster, and H. Loring. 2006. Floristic quality as an indicator of native species diversity in managed grasslands. *Natural Areas Journal* 26:149–67.

Johnson, J.R., and G.E. Larson. 1999. Grassland plants of South Dakota and the northern Great Plains. B566. South Dakota State University, Brookings, SD.

Lauenroth, W.K., D.G. Milchunas, J.L. Dodd, R.H. Hart, R.K. Heitschmidt, and L.R. Rittenhouse. 1999. Effects of grazing on ecosystems of the Great Plains. In *Ecological Implications Of Livestock Herbivory in the West*, ed. Vavra, M., W.A. Laycock, and R.D. Pieper, 69–100. 2nd ed. Society for Range Management, Denver.

Masters, R.A., R.N. Stougaard, and S.J. Nissen. 1994. Leafy spurge (*Euphorbia esula*) control with fall-applied imazapyr, imazaquin, and imazethapyr. *Weed Technology* 8:58–63.

Masters, R.A., K.P. Vogel, and R.B. Mitchell. 1992. Response of central plains tallgrass prairie to fire, fertilizer, and atrazine. *Journal of Range Management* 45:291–95.

Mousel, E.M., and A.J. Smart. 2007. Monitoring rangeland and pastures: A rancher's approach. South Dakota Cooperative Extension FS940.

Northern Great Plains Floristic Quality Assessment Panel. 2001. Floristic quality assessment for plant communities of North Dakota, South Dakota (excluding the Black Hills), and adjacent grasslands. Northern Prairie Wildlife Research Center Online, Jamestown, ND. http://www.npwrc.usgs.gov/resource/plants/fqa/index.htm (accessed January 26, 2001).

NRCS (National Resource Conservation Service). 2010a. Conservation Stewardship Program. USDA-NRCS. http://www.nrcs.usda.gov/programs/new_csp/csp.html (accessed April 25, 2011).

NRCS (National Resource Conservation Service). 2010b. Ecological site description of loamy rangeland. Electronic Field Office Technical Guide, USDA-NRCS. http://efotg.nrcs.usda.gov/references/public/SD/R102AY010SD_Loamy.pdf (accessed April 25, 20110.

Samson, F.B., and F.L. Knopf. 1996. Prairie conservation: Preserving North America's most endangered ecosystem. Island Press, Washington, DC.

SAS Institute. 2009. SAS Online Document, version 9.2. SAS Institute, Cary, NC.

SDSU (South Dakota State University). 2007. South Dakota rangeland and pasture grazing records. South Dakota Cooperative Extension EC923.

Smart, A.J., J.D. Derner, J.R. Hendrickson, R.L. Gillen, B.H. Dunn, E.M. Mousel, P.S. Johnson, R.N. Gates, K.K. Sedivec, K.R. Harmoney, J.D. Volesky, and K.C. Olson. 2010. Effects of grazing pressure on efficiency of grazing on North American Great Plains rangelands. *Rangeland Ecology and Management* 63:397–406.

South Dakota Department of Agriculture. 2009. South Dakota weed and pest program reports. State noxious weeds. Pierre, SD. http://sdda.sd.gov/Ag_Services/Plant-Protection/PDF/2009W&Prpt.pdf. (accessed April 25, 2011).

Swink, F.A., and G.S. Wilhelm. 1979. *Plants of the Chicago Region*, 3rd ed. Morton Arboretum, Lisle, IL.

Swink, F.A., and G.S. Wilhelm. 1994. *Plants of the Chicago Region*, 4th ed. Indiana Academy of Science, Indianapolis.

Vinton, M.A., and E.M. Goergen. 2006. Plant-soil feedbacks contribute to the persistence of *Bromus inermus* in tallgrass prairie. *Ecosystems* 9:967–76.

Weaver, J.E., and T.J. Fitzpatrick. 1934. The prairie. *Ecological Monograph* 4:109–295.

Wedin, D.A., and D. Tilman. 1996. Influence of nitrogen loading and species composition on the carbon balance of grasslands. *Science* 274:1720–23.

Great Plains Research 21 (Fall 2011):191–201

PERSISTENT PLACE-BASED INCOME INEQUALITY IN RURAL NEBRASKA, 1979–2009

David J. Peters

304 East Hall
Iowa State University
Ames, IA 50011-1070
dpeters@iastate.edu

ABSTRACT—This article addresses a current gap in the inequality literature by identifying demographic and economic factors that best explain persistent income inequality across $N = 817$ nonmetropolitan block groups in Nebraska between 1979 and 2009. Over one-half of rural places in Nebraska have average levels of income inequality, one-quarter have persistently low inequality, and one-fifth of places have persistently high levels of income inequality. Results of multinomial logistic regression suggest that persistently high-inequality places in rural Nebraska tend to be smaller, more urbanized, more ethnically diverse, more wealthy, more specialized in high-skill and low-skill industries, and have experienced fast growth in urbanization, incomes, and professional services. By contrast, low-inequality places tend to be larger, less urban, less diverse, less well educated, less wealthy, less engaged in the labor force, and have experienced population declines and slower growth in urbanization, educational attainment, and incomes.

Key Words: income inequality, regional economics, rural development, subcounty geographies, economic restructuring

INTRODUCTION

Until the 1980s, the United States experienced a period of rising incomes and relatively equal income distributions that began shortly after the Second World War (McGranahan 1980). Over the past three decades, however, incomes have begun to level off and income distributions have become more unequal (Gottschalk and Smeeding 1997). Even during the economic boom on the late 1990s, when Americans became more prosperous as a whole, income inequality remained high and actually increased (Hammond and Thompson 2006). As a result of these trends, social scientists began to document the causes of rising income inequality. The bulk of this analysis has been focused on the national and state levels, and most of the conclusions from these studies hold true across most states (Lynch 2003; Partridge and Rickman 2006). What this body of research has not addressed, however, is the place-based aspects of rising income inequality. That is, most of the existing literature has focused on trends on the national and state levels, and has largely ignored trends at smaller-scale geographies, such as counties or places.

There is a need to better understand the dynamics of income inequality across time and space in order to see how economic inequality is concentrated. Previous research has clearly demonstrated that inequality and poverty persists in the United States across regions over time (Morrill 2000; Lobao and Saenz 2002; McLaughlin 2002; Lobao 2004; Weber et al. 2005; Partridge and Rickman 2006). This body of work has demonstrated that inequality and poverty can be explained by differences in economic structures, individuals, natural resources, geography, and history. However, there have been almost no empirical studies specifically looking at the spatial distribution of income inequality across smaller geographic places (Levy and Murnane 1992; Weber et al. 2005; Lobao and Hooks 2007).

Recent advances in geographic information systems now allow researchers to address these questions more fully. The purpose of this analysis is to examine, using data from 1979 and 2009, which demographic and economic correlates of inequality best explain persistent income inequality across places in nonmetropolitan Nebraska. The analysis is unique in terms of space, using subcounty census block groups to approximate places. It is unique in terms of time, using geographically corrected subcounty data from 1979 and 2009. It is unique in terms of approach, demonstrating that changes in economic structure from an industrial to postindustrial economy

Manuscript received for review, July 2010; accepted for publication, February 2011.

result in different levels of inequality. This article offers a purely empirical look at persistent income inequality in a single state in the Great Plains. Thus, the results are suggestive rather than definitive, and are seen as a first step at a larger-scale analysis across all states. Nonetheless, this analysis contributes to filling an existing gap in the inequality literature by explaining the causes of persistent income inequality across places.

LITERATURE REVIEW

A number of studies have demonstrated that place matters in understanding inequality, and a comprehensive review of this work is presented by Weber et al. (2005). The majority of these studies take a labor market approach to understanding inequality and poverty, which incorporates both individual and structural approaches within a spatial context (Cotter 2002; McLaughlin 2002; Lobao et al. 2007). These studies generally attempt to understand county-level inequality in terms of different demographic characteristics, family structure components, geographic locations, industrial compositions, and a host of other labor market factors (Lobao et al. 1999; Levernier et al. 2000; Crandall and Weber 2004; Partridge and Rickman 2006). A review of this work is presented below.

In terms of geography, most studies of inequality use states as the unit of analysis. However, a number of studies have examined income inequality at the county level (e.g., McLaughlin 2002; Hammond and Thompson 2006). In many ways, counties are ideal units of analysis to study inequality because their boundaries are relatively stable over time, there is a wide array of data available at that scale, and they are an appropriate "meso" unit between neighborhoods and states. However, recent work has emphasized the need for more subcounty analyses to see if the relationships between inequality and various socioeconomic factors hold across geographic scales (Irwin 2007; Lobao and Hooks 2007). The only study to examine subcounty inequality to date is by Wheeler and La Jeunesse (2008), who looked at inequality by block group in metropolitan areas.

In addition, a majority of the inequality studies reviewed here include some type of control for metropolitan residence. The findings indicate that small metropolitan and suburban counties have lower inequality compared to nonmetropolitan counties. Several studies have also explicitly incorporated spatial statistics into their analyses (Crandall and Weber 2004; Partridge and Rickman 2005, 2006). This work finds that high inequality counties are spatially clustered, and high adjacent inequality exerts a strong positive effect on local inequality.

In terms of demographic structure, the literature unanimously supports the finding that higher levels of educational attainment reduce inequality, especially high school and associate's degrees. A strong relationship is also found between greater numbers of single-headed families with children and high area inequality, especially among those headed by females. The impact that minority populations have on inequality is less clear in the literature. Most studies show that larger populations of non-African-American minorities tend to increase local inequality. However, the findings for African-American populations are mixed. Nation-scale studies show that African-American populations are associated with lower rates of inequality (Levernier et al. 2000; Partridge and Rickman 2005, 2006) while nonmetropolitan studies find increases in inequality (Lobao et al. 1999; McLaughlin 2002). Most of the analyses also look at the effect of age structure, and generally find that younger persons, under age 24, tend to increase local inequality, while older persons, over age 64, tend to reduce inequality.

In terms of economic conditions, one of the strongest findings is that current inequality is highly dependent on previous inequality, indicating that inequality is path dependent. The majority of studies reviewed here shows that increases in labor force participation rates lead to lower inequality rates at the county level, especially for women. As one would expect, the literature also shows that higher unemployment rates lead to higher local inequality, and this effect is particularly strong for male unemployment. Several analyses include employment growth and industrial restructuring in their models explaining inequality (Levernier et al. 2000; Crandall and Weber 2004; Swaminathan and Findes 2004; Partridge and Rickman 2005). The findings demonstrate that employment growth strongly reduces local inequality, especially when counties are near metropolitan areas. Counties experiencing industrial structuring are more likely to have higher inequality, as are counties with a less-diversified industrial base (McLaughlin 2002).

A number of studies include industry employment variables to model local economic structure. One consistent finding across all studies is that employment in agriculture and natural resources tends to increase local inequality (McLaughlin 2002). Most also find that greater shares of employment in consumer services, trade, and government lead to higher local inequality (McLaughlin 2002). Higher employment in the services sector, broadly defined, has a moderate effect at increasing inequality

rates. However, the direction of this effect changes when looking at specific services industries. Partridge and Rickman (2006) found that higher-skill producer services have a strong impact at reducing poverty and inequality, while relatively lower-skill consumer services tend to increase poverty and inequality rates (Partridge and Rickman 2005, 2006). For manufacturing and transportation, two traditional rural industries, the results are also mixed. National studies show that employment in manufacturing and transportation results in lower inequality rates overall, while employment in these two sectors tends to increase inequality rates in nonmetropolitan areas.

Conceptually, the link between industrial restructuring and inequality is rooted in Bell's (1973) argument that modern capitalist societies are undergoing a shift away from a primarily goods-producing industrial economy toward a more services-producing postindustrial economy. The social polarization thesis, based in part on Bell's work, argues that change in economic structure from industrial to postindustrial has increased inequality (Sassen 1991; Hamnett 2003). According to this view, the shift toward a postindustrial economy has increased the number of higher-skill and higher-wage jobs in the financial, business, and professional services sectors. At the same time, however, this has been paralleled by growth in relatively lower-skilled and lower-wage services jobs that support postindustrial industries and serve members of this growing professional and managerial class. Observers have argued that these trends, along with declines in industrial goods-producing sectors, have reduced middle-skilled and middle-wage jobs and have resulted in growing polarization of incomes.

METHODS

In order to better understand persistent income inequality over time, this analysis uses a unique set of spatial data from the 1980 Decennial Census and the 2005–2009 American Communities Survey (ACS). Although ACS data represent average values for each year between 2005 and 2009, rather than point-in-time estimates, they are the only source of income data at the subcounty level. The units of analysis are nonmetropolitan census block groups, which are the smallest geographic unit for which the U.S. Census publishes data. Block-group geographies are "normalized" to the 2000 Census geographies to permit comparisons over time. Removed from the analysis are $N = 773$ block groups in Nebraska's core metropolitan areas of Omaha (Douglas and Sarpy Counties) and Lincoln (Lancaster County), and also $N = 1$ block group with missing data in 1980. This results in $N = 817$ rural block groups in Nebraska for analysis (see Appendix).

Income inequality is measured using Gini coefficients that are calculated across 14 income categories in each block group using census data. To correct for inflation and to equalize the number of categories for analysis, the income categories for 1979 and 2009 are combined to approximate current income levels based on the consumer price index. Using the aggregated household income in each category to calculate income inequality, rather than the number of households, avoids minimizing the effect of income earned at the top of the distribution. To estimate aggregated income, the midpoint of each income category is calculated and multiplied by the number of households.

Gini coefficients (G) measure the degree of concentration or inequality along a distribution of 14 income categories, with scores ranging from zero to one. Scores of zero indicate no concentration of income or perfect equality, and scores of one indicate total concentration of income, or perfect inequality. The formula for G is presented in equation 1, where σX is the cumulative distribution of equality values under a Lorenz curve, σY is the cumulative distribution of households by income categories, i is the current income category, and N is the number of income categories:

$$G = \left| 1 - \sum_{i=0}^{N} (\sigma Y_i + \sigma Y_{i-1})(\sigma X_i - \sigma X_{i-1}) \right| \qquad (1)$$

Since Gini coefficients do not have a meaningful scale, they are normed, or standardized, to the Nebraska mean to facilitate interpretation and are denoted sG. Standard scores of zero indicate inequality at the Nebraska average, while positive scores indicate above-average inequality (i.e., number of standard deviations above the mean) and negative scores indicate below-average inequality (i.e., standard deviations below the mean). sG scores are used to create the persistent income inequality typology.

Discrete choice models, in this case multinomial logistic regression, are used to determine which demographic and economic correlates of inequality best explain a place's membership in the persistent inequality typology. The procedure assesses the importance of the covariates, estimates the odds of group membership, and assesses the accuracy of the classification. The logistic model is presented in equation 2, where $\mathbf{L}$ is a matrix of logits, $\boldsymbol{\alpha}$ is the vector of intercepts, $\mathbf{X}$ is the matrix of demographic and economic predictors, $\mathbf{B}$ is the matrix of logistic regression parameters, and $\boldsymbol{\upsilon}$ is the vector of stochastic residuals. Note that in multinomial logistic

regression, the logits found in **L** are the natural log of the probability of place *i* being in typology category *j* over the probability of the same place being in reference category *r*.

$$\mathbf{L} = \boldsymbol{\alpha} + \mathbf{XB} + \boldsymbol{\upsilon} \qquad (2)$$

where **L** is matrix of $L_{ijr} = \text{h}\left(\frac{P_j}{P_r}\right)$

Standardized *G* coefficients in 2009 and change in *sG* from 1979 to 2009 are used to construct the discrete multinomial dependent variable with three levels. Block groups are placed in the low income inequality group if *sG* values are greater than -0.75 standard deviations below the mean in 2009 and if change in *sG* is also greater than -0.75 standard deviations below the mean. This results in a group with low inequality in 2009 that has been either stable or declining since 1979. Conversely, block groups are placed in the high inequality group if *sG* values are 0.75 standard deviations or more above the mean in 2009 and if change in *sG* is also 0.75 standard deviations or more above the mean. This results in a group with high inequality in 2009 that has been either stable or increasing since 1979. All other block groups not meeting these criteria are classified in the average inequality group.

The predictors in **X** include 30 demographic and economic covariates of income inequality, as identified in the literature. Descriptive statistics are presented in the Appendix. Data are taken from the census and are by place of residence. Demographic predictors include population (in hundreds), percentage of urban population, percentage of minority population (nonwhite or Hispanic), percentage of families that are single-headed, percentage of college-educated population (adults with a bachelor's degree or higher), labor force participation rate, and median household income (in thousands of nominal dollars). Variables for 2009 and percentage change from 1979 are included in the analysis.

Economic predictors for 2009 include percentage of working-age population employed in the following: agriculture, forestry, and mining; construction, utilities, and transportation; manufacturing; wholesale and retail trade; professional, business, and information services; administrative, real estate, and rental services; education, health, and social services; and entertainment, lodging, food, and personal services.

Changes to industry classification systems over time necessitate creation of a unique set of variables measuring change from 1979. These variables include percentage change working in agriculture, forestry, and mining; construction, transportation, communication, and utilities; manufacturing; wholesale and retail trade; finance, insurance, and real estate services; professional services; education, health, and social services; and entertainment, personal, and administrative services.

The assumptions for multinomial logistic regression are generally met, save for a few violations noted as follows. First, the relationship between the logits and the covariates shows a general linear scatter except for population and change in population. Second, dependent errors are likely in the analysis given the spatial nature of the data, which increases the likelihood of Type I error in least squares estimators. However, it is unclear from the literature what effect spatial dependence has on maximum likelihood estimators, such as those used in discrete choice models (Ward and Gleditsch 2008). Since none of these violations is expected to seriously bias the parameter estimates, no attempt is made to address these shortcomings.

RESULTS

Trends in place-based income inequality in rural Nebraska show a duality, with most places experiencing either low and declining inequality on the one hand, or high and increasing inequality on the other. Referring to Figure 1, which presents standardized *G* coefficients (*sG*), we find that 37.2% ($N = 304$) of rural places have low income inequality in 2009, and these rates have declined between 1979 and 2009. By contrast, 37.9% ($N = 310$) of rural places show the opposite trends, with high income inequality that has been increasing since 1979. Few places in Nebraska show emerging inequality (14.3% or 117 places) characterized by low and increasing rates, and fewer still show improving inequality (10.5% or 86 places) characterized by high and decreasing rates.

The first step of the analysis is to create a simple typology of persistent inequality with three levels, based on standardized *G* coefficients for 1979 and 2009. The results of the typology are presented in Table 1. The majority of rural places in Nebraska are characterized as having *average income inequality*, accounting for 54.7% ($N = 447$) of block groups in the state containing 54.8% (467,760) of the rural population. Table 1 shows that average-inequality places have Gini coefficients that are at the state mean in both 1979 ($sG = 0.003$) and 2009 ($sG = -0.009$), and that rates of growth are also average ($sG = -0.011$). However, the typology also identifies some places characterized by very high or very low inequality.

High income inequality places account for 21.9% ($N = 179$) of rural block groups in Nebraska, and 21.8% (186,265) of the state's rural population. These places saw

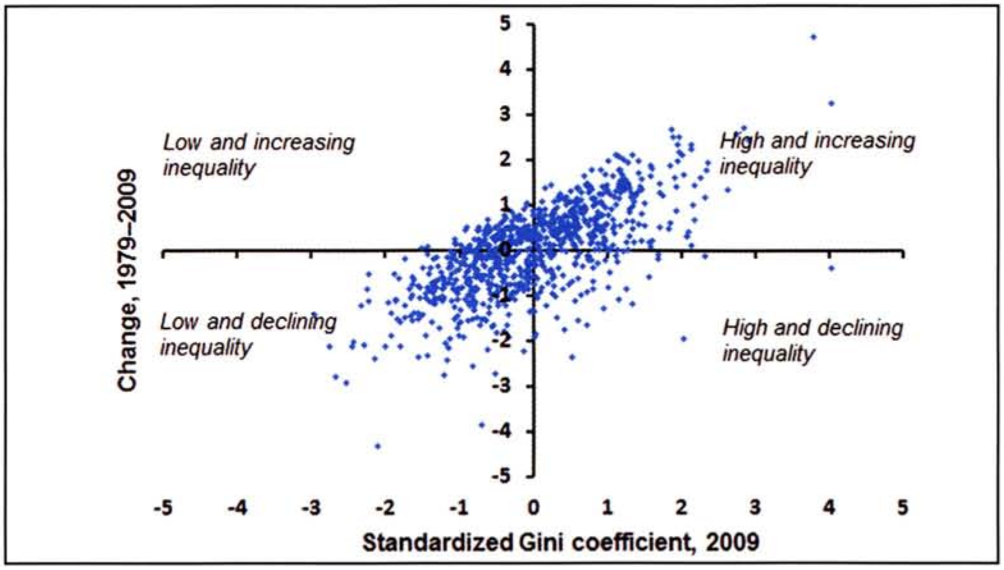


Figure 1 Trend in Gini coefficients for $N = 817$ rural Nebraska block groups, 1979–2009.

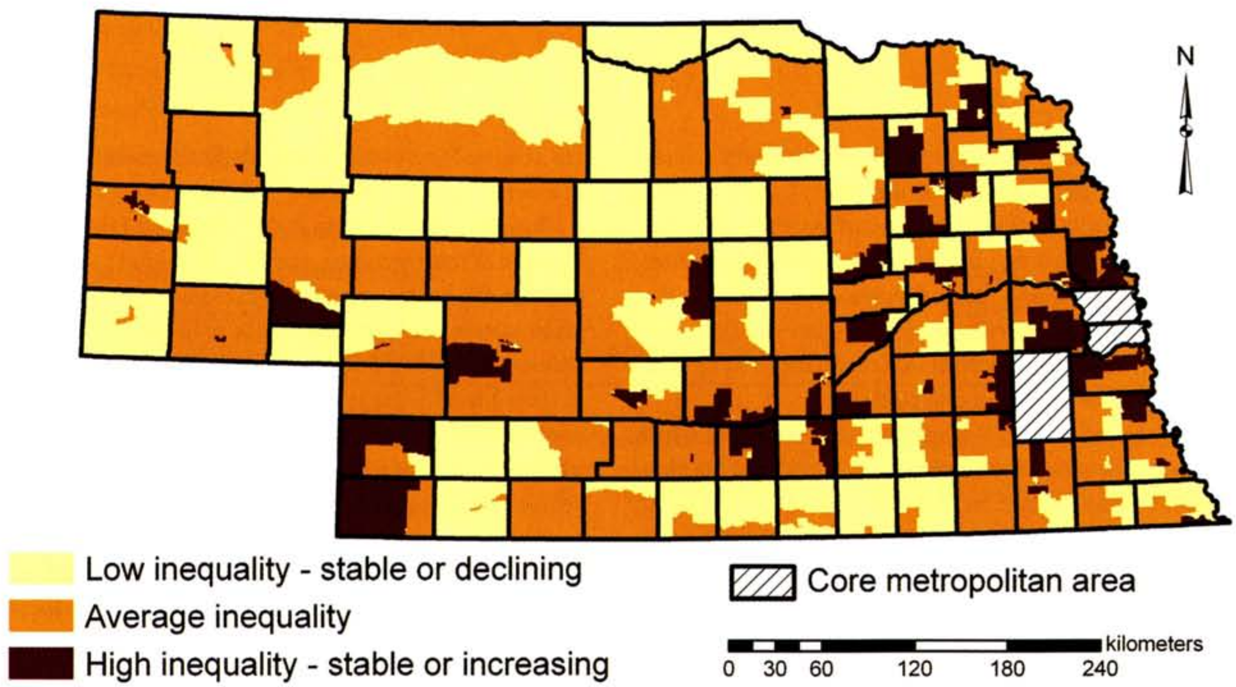


Figure 2. Persistent income inequality typology for $N = 817$ rural Nebraska block groups, 1979–2009.

rapid increases in income inequality between 1979 and 2009, rising from slightly above average ($sG = 0.302$) to very high ($sG = 1.354$) over the past 30 years (see Table 1). As shown in Figure 2, these places tend to cluster in the three general areas of the state. First, high inequality is clustered in the southwest corner of the state, where a number of recreational reservoirs and larger-scale cattle operations are located. Second, inequality is clustered in the central and northeast micropolitan areas of the state, especially in Kearney, Grand Island, and Norfolk. Third, inequality is clustered in suburban areas adjacent to the Omaha and Lincoln metropolitan areas in the eastern part of the state.

Low income inequality places account for 23.4% ($N = 191$) of rural places and populations (199,388). Block groups in this cluster saw income inequality decline from slightly below average in 1979 ($sG = -0.291$) to very low rates by 2009 ($sG = -1.247$). Geographically there is no

TABLE 1
DESCRIPTIVE STATISTICS OF INCOME INEQUALITY TYPOLOGY
FOR $N = 817$ RURAL NEBRASKA BLOCK GROUPS, 1979–2009

	Low inequality ($N = 191$)		Average inequality ($N = 447$)		High inequality ($N = 179$)	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Gini coefficient, 1979						
Nonstandardized	0.261	0.068	0.285	0.080	0.308	0.080
Standardized	-0.291	0.863	0.003	1.016	0.302	1.010
Gini coefficient, 2009						
Nonstandardized	0.425	0.043	0.543	0.043	0.673	0.056
Standardized	-1.247	0.449	-0.009	0.453	1.354	0.585
Gini coefficient change, 1979–2009						
Nonstandardized	0.164	0.077	0.259	0.081	0.365	0.086
Standardized	-0.907	0.728	-0.011	0.767	0.990	0.815

Source: 1980 Census and 2005–2009 ACS, U.S. Census Bureau.

discernable pattern for this group, but most tend to cluster in sparsely populated areas of the state. Low-inequality places are found in the Sandhills of north-central Nebraska, dominated by smaller-scale cattle operations, wheat production, and recreation areas. Another band of low-inequality places runs along the southern tier of the state, which includes recreational reservoirs and agricultural production of wheat and cattle.

The second step of the analysis is to examine which demographic and economic correlates best explain a place's membership in the high and low inequality groups, using the average group as the reference. Results of the multinomial logistic regression using socioeconomic characteristics from 2009 show the model fits the data well (see Table 2). The deviance χ^2 goodness-of-fit test fails to reject the null hypothesis that the model adequately reproduces the observed data (χ^2_D = 1104.879, $p = 0.99$), and the null model χ^2 test rejects the null hypothesis that the model fits as well as the intercept-only model ($\chi^2_N = 532.995, p < 0.001$). Pseudo-$R^2$, which measures the degree of fit between the observed and implied data, also indicates a good fitting model ($pR^2 = 0.554$). The model is adequate at correctly classifying high- and low-inequality places. About one-half of low-inequality places (107 of 191, or 56.0%) and high-inequality places (97 of 179, or 54.2%) are correctly classified, with misclassifications into the average group. Predicted values are assigned to a case if the predicted probability of being in a certain group exceeds $P > 0.7$.

Results of the models are presented in Tables 2 and 3. For ease of interpretation, the odds ratios (ψ) are discussed because the scales are standardized across measurement units, unlike the logits (b), whose scale is not meaningful. Odds ratios are best described as the percentage change in the odds of being in the low (or high) inequality group, compared to being in the average inequality group, given a one-unit change in the predictor variable. Logits are the change in the logistic distribution given a one-unit change in the predictor variable.

A number of demographic and economic variables are significant at explaining membership in the *low-inequality* group, compared to the average-inequality reference group. In terms of demographic structure, places in the low-inequality group tend to have higher populations ($b = 0.116, \psi = 12.3$) than those found in average-inequality places. Although larger in population, these areas have smaller urban populations ($b = -0.021, \psi = -2.1$), fewer college graduates ($b = -0.063, \psi = -6.1$), and fewer minorities ($b = -0.019, \psi = -1.9$). Low-inequality places also have much lower median household incomes ($b = -0.118, \psi = -11.1$) and lower rates of labor force participation ($b = -0.021, \psi = -2.1$) than average-inequality places. In terms of employment structure, no differences are found between low- and average-inequality places in rural Nebraska.

TABLE 2
PREDICTING PERSISTENT INCOME INEQUALITY BY SOCIOECONOMIC FACTORS FOR N = 817 RURAL NEBRASKA BLOCK GROUPS, 2009

	Low income inequality membership			**High income inequality membership**		
Percentage in 2009	*b*	*Odds ratio*		*b*	*Odds ratio*	
Intercept	6.309		*	-14.885		***
Demographic covariates						
Population (in hundreds)	0.116	12.3	***	-0.127	-11.9	***
Urban population	-0.021	-2.1	***	0.014	1.4	***
Minority population	-0.019	-1.9	*	0.020	2.0	*
Single-headed families	0.019	2.0		0.010	1.0	
College-educated population	-0.063	-6.1	***	0.016	1.6	
Labor force participation	-0.021	-2.1	**	0.007	0.7	
Median household income (in thousands)	-0.118	-11.1	***	0.125	13.3	***
Economic covariates						
Agriculture, forestry, mining	0.009	0.9		0.048	4.9	
Manufacturing	-0.025	-2.5		0.049	5.0	
Construction, transportation, utilities	-0.043	-4.2		0.071	7.4	*
Wholesale and retail trade	-0.004	-0.4		0.080	8.4	*
Professional, business, information services	0.003	0.3		0.095	10.0	**
Administrative, real estate, rental services	-0.019	-1.9		0.069	7.1	
Education, health, social services	0.014	1.4		0.087	9.1	*
Entertainment, lodging, food, personal services	-0.002	-0.2		0.080	8.3	*

Source: 2005–2009 ACS, U.S. Census Bureau.
Notes: Null χ^2 = 532.995***; deviance χ^2 = 1104.879; Nagelkerke's pseudo-R^2 = 0.554. Multinomial logistic regression used. Average income equality is the reference category. Logits (*b*) represent change in the logistic distribution given a one-unit change in the predictor. Odds ratios (ψ) represent change in the odds of being in the low (or high) group given a one-unit change in the predictor. Income not inflation adjusted. Significance: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Next, the analysis finds several factors that are significant at explaining why certain places are classified into the *high-inequality* group, compared to the average-inequality group. In terms of demographics, high-inequality places are found to have smaller populations (b = -0.127, ψ = -12.7) than average-inequality places. However, these smaller populations also tend to have more minority populations (b = 0.020, ψ = 2.0) and are more urbanized (b = 0.014, ψ = 1.4). High-inequality places are also much wealthier than average-inequality places (b = 0.125, ψ = 13.3). Reflecting these more urban and higher income places, the employment structure is more specialized in higher-skilled services industries. Compared to average-inequality areas, high-inequality places tend to have more employment in professional and business services (b = 0.095, ψ = 10.0) and in education and health services (b = 0.087, ψ = 9.1). However, these areas also have employment specialization in lower-skill services, such as entertainment, lodging, food, and personal services (b = 0.080, ψ = 8.3). In addition, larger employment shares in construction, transportation, and utilities also distinguished between high- and average-inequality clusters (b = 0.071, ψ = 7.4).

In addition to examining how 2009 base values impact persistent income inequality, a second model is estimated to ascertain what effect socioeconomic change between 1979 and 2009 might have on persistent inequality. The results of the change model show only modest fit

TABLE 3
PREDICTING PERSISTENT INCOME INEQUALITY BY CHANGE IN SOCIOECONOMIC FACTORS FOR $N = 817$ RURAL NEBRASKA BLOCK GROUPS, 1979–2009

	Low income inequality membership			High income inequality membership		
Change from 1979 to 2009	*b*	*Odds ratio*		*b*	*Odds ratio*	
Intercept	0.381			-4.629		***
Demographic covariates						
Population (percentage change)	-0.012	-1.2	**	0.004	0.4	
Urban population	-0.019	-1.9	***	0.019	1.9	***
Minority population	0.002	0.2		0.010	1.0	
Single-headed families	0.026	2.7	**	0.004	0.4	
College-educated population	-0.053	-5.2	***	0.020	2.0	
Labor force participation	-0.006	-0.6		-0.010	-1.0	
Median household income (percentage change)	-0.004	-0.4	**	0.012	1.2	***
Economic covariates						
Agriculture, forestry, mining	-0.003	-0.3		0.037	3.8	
Manufacturing	-0.018	-1.8		0.007	0.7	
Construction, transportation, communication, utilities	-0.003	-0.3		0.021	2.1	
Wholesale and retail trade	-0.004	-0.4		0.045	4.6	
Finance, insurance, real estate services	-0.014	-1.4		0.056	5.7	
Professional services	-0.029	-2.9		0.137	14.6	***
Education, health, social services	0.015	1.5		0.044	4.5	
Entertainment, personal, administrative services	0.000	0.0		0.028	2.8	

Source: 1980 Census and 2005–2009 ACS, U.S. Census Bureau.
Notes: Null $\chi^2 = 297.306$***; deviance $\chi^2 = 1340.569$; Nagelkerke's pseudo-$R^2 = 0.353$. Multinomial logistic regression used. Average income equality is the reference category. Logits (*b*) represent change in the logistic distribution given a one-unit change in the predictor. Odds ratios (ψ) represent change in the odds of being in the low (or high) group given a one-unit change in the predictor. Income not inflation adjusted. Significance: **$p < 0.01$; ***$p < 0.001$.

(see Table 3). The deviance χ^2 ($\chi^2_D = 1340.569$, $p = 0.99$) and the null model χ^2 ($\chi^2_N = 297.306$, $p < 0.001$) all show good fit. However, the pseudo-R^2 is modest ($pR^2 = 0.353$), and only 27.2% of low-inequality places and 41.9% of high-inequality places are classified correctly.

Compared to average-inequality places, the *low-inequality* group had faster declines in population since 1979 ($b = -0.012$, $\psi = -1.2$), and slower growth in urban populations ($b = -0.019$, $\psi = -1.9$), college-educated populations ($b = -0.053$, $\psi = -5.2$), and median household incomes ($b = -0.004$, $\psi = -0.4$). Low-inequality places also saw faster growth in single-headed families compared to average ($b = 0.026$, $\psi = 2.7$). By contrast, *high-inequality* places had faster than average growth in urban populations ($b = 0.019$, $\psi = 1.9$) and median household incomes ($b = 0.012$, $\psi = 1.2$) since 1979. Further, these places experienced very fast employment growth in professional services over the past three decades ($b = 0.137$, $\psi = 14.6$), where all other groups saw declines (see Table 3).

DISCUSSION AND CONCLUSION

This article offers a long-term yet current look at persistent place-based income inequality in rural Nebraska. Analysis of block-group data between 1979 and 2009 identifies four key findings. The first finding is

that most rural places in Nebraska have average or low levels of income inequality over time, indicating that persistently high inequality is not a widespread problem in the state. Over one-half of rural places have average levels and nearly one-quarter have persistently low levels of inequality. Most low-inequality places are found in more sparsely populated areas clustered in the north-central and southern parts of the state. However, the analysis also finds that nearly one-fifth of rural places in Nebraska have persistently high levels of income inequality. High inequality is clustered in the southwestern recreational and cattle areas of the state, and also in the state's micropolitan areas.

The second key finding is that high-inequality places have smaller yet more urban and ethnically diverse populations that have grown over the past 30 years. By contrast, low-inequality places have larger yet less urban and diverse populations that have experienced population declines since 1979. Previous research has found that higher inequality is associated with less urban and more diverse populations, so this finding for Nebraska only partially supports the literature.

The third key finding is that high-inequality places in rural Nebraska have better socioeconomic outcomes than low-inequality places. Places with high inequality have much higher and faster-growing incomes. Conversely, low-inequality places have lower and slower-growing incomes, lower labor force participation rates, and lower numbers of college graduates. This finding for Nebraska runs counter to what has been found in the literature, which documents poorer socioeconomic outcomes for higher-inequality places.

The fourth key finding is that high-inequality places are generally more specialized in services employment compared to average- and low-inequality places. Employment in both higher-skill and lower-skill services industries (e.g., professional services and leisure services, respectively) is markedly larger in places with more inequality. Further, high-inequality places also saw very fast growth in professional services jobs over the last three decades. This finding strongly supports the social polarization thesis (Sassen 1991), which argues that the postindustrial economy increases inequality as it creates large numbers of professional services jobs while at the same time creating large numbers of low-skill services jobs.

In summary, these findings suggest that successful economic development efforts in rural Nebraska are likely to result in increased income inequality at the local level. Many state and local agencies in Nebraska appropriately direct their rural development efforts at diversifying the employment base away from traditional sectors (such as agriculture and manufacturing) and toward services industries, and they also work to stabilize and grow populations in rural Nebraska. While such development efforts undoubtedly have a positive impact at reducing poverty and increasing general economic well-being, the unintended consequences of these efforts is increased inequality. Thus, economic development efforts should also include strategies that seek to employ the least employable by removing common barriers, such as lack of child care and transportation, and mismatch of skills (Partridge and Rickman 2006).

ACKNOWLEDGMENTS

The author would like to thank the editor and reviewers for their valuable comments. Financial support was provided by both the Iowa and Nebraska Agricultural Experiment Stations.

REFERENCES

Bell, D. 1973. *The Coming of Post-Industrial Society.* Basic Books, New York.

Cotter, D.A. 2002. Poor people in poor places: Local opportunity structures and household poverty. *Rural Sociology* 67:534–55.

Crandall, M.S., and B.A. Weber. 2004. Local social and economic conditions, spatial concentrations of poverty, and poverty dynamics. *American Journal of Agricultural Economics* 86:1276–81.

Gottschalk, P., and T. Smeeding. 1997. Cross-national comparisons of earnings and income inequality. *Journal of Economic Literature* 35:633–87.

Hammond, G., and E. Thompson. 2006. Convergence and mobility: Personal income trends in U.S. metropolitan and non-metropolitan regions. *International Regional Science Review* 29:35–63.

Hamnett, C. 2003. *Unequal City: London in the Global Arena.* Routledge, London.

Irwin, M.D. 2007. Territories of inequality: An essay on the measurement and analysis of inequality in grounded place settings. In *The Sociology of Spatial Inequality*, ed. L.M. Lobao, G. Hooks, and A.R. Tickamyer, 85–109. SUNY Press, Albany.

Levernier, W., M.D. Partridge, and D.S. Rickman. 2000. The causes of regional variations in U.S. poverty: People or place based? *Journal of Regional Science* 40:473–97.

Levy, F., and R. Murnane. 1992. U.S. earnings levels and earnings inequality: A review of recent trends and proposed explanations. *Journal of Economic Literature* 30:1333–81.

Lobao, L.M. 2004. Continuity and change in place stratifications: Spatial inequality and middle range territorial units. *Rural Sociology* 69:1–30.

Lobao, L.M., and G. Hooks. 2007. Advancing the sociology of spatial inequality: Spaces, places, and the subnational scale. In *The Sociology of Spatial Inequality*, ed. L.M. Lobao, G. Hooks, and A.R. Tickamyer, 29–61. SUNY Press, Albany.

Lobao, L.M., G. Hooks, and A.R. Tickamyer. 2007. Introduction: Advancing the sociology of spatial inequality. In *The Sociology of Spatial Inequality*, ed. L.M. Lobao, G. Hooks, and A.R. Tickamyer, 1–25. SUNY Press, Albany.

Lobao, L.M., J. Rulli, and L.A. Brown. 1999. Macrolevel theory and local-level inequality: Industrial structure, institutional arrangements and the political economy of redistribution, 1970 to 1990. *Annals of the Association of American Geographers* 89:571–601.

Lobao, L.M., and R. Saenz. 2002. Spatial inequality and diversity as an emerging research area. *Rural Sociology* 67:497–511.

Lynch, R. 2003. Estimates of income and income inequality in the U.S. and each of the 50 states, 1988–1999. *Journal of Regional Science* 43:571–87.

McGranahan, D. 1980. The spatial structure of income distribution in rural regions. *American Sociological Review* 45:8–12.

McLaughlin, D.K. 2002. Changing income inequality in nonmetropolitan counties, 1980 to 1990. *Rural Sociology* 67:512–33.

Morrill, R. 2000. Geographic variation in change in income inequality among U.S. states, 1970–1990. *Annals of Regional Science* 34:109–30.

Partridge, M., and D. Rickman. 2005. High poverty nonmetropolitan counties in America: Can economic development help? *International Regional Science Review* 28:415–40.

Partridge, M., and D. Rickman. 2006. *The Geography of American Poverty: Is There a Need for Place-Based Policies?* Upjohn Institute, Kalamazoo, MI.

Sassen, S. 1991. *The Global City: New York, London, and Tokyo*. Princeton University Press, Princeton, NJ.

Swaminathan, H., and J.L. Findes. 2004. Policy interventions and poverty in rural America. *American Journal of Agricultural Economics* 86:1289–96.

Ward, M., and K.S. Gleditsch. 2008. *Spatial Regression Models*. Quantitative Applications in the Social Sciences, no. 07-155. Sage Publications, Thousand Oaks, CA.

Weber, B., L. Jensen, K. Miller, J. Mosely, and M. Fisher. 2005. A critical review of rural poverty literature: Is there truly a rural effect? *International Regional Science Review* 28:381–414.

Wheeler, C., and E. La Jeunesse. 2008. Trends in neighborhood income inequality in the U.S., 1980–2000. *Journal of Regional Science* 48:879–91.

APPENDIX

SOCIOECONOMIC DESCRIPTIVE STATISICS FOR N = 817 RURAL NEBRASKA BLOCK GROUPS, 1979–2009

Percentage in 2009	**Mean**	**SD**	**Change from 1979 to 2009**	**Mean**	**SD**
Demographic covariates					
Population (in hundreds)	10.45	0.47	Population (percentage change)	-3.91	32.06
Urban population	43.25	47.31	Urban population	42.56	46.96
Minority population	10.09	14.63	Minority population	6.78	12.56
Single-headed families	16.62	12.15	Single-headed families	8.03	11.22
College-educated population	18.68	9.07	College-educated population	7.30	7.95
Labor force participation	79.92	20.85	Labor force participation	4.81	18.68
Median household income (in thousands)	44.73	13.33	Median household income (percentage change in nominal dollars)	203.30	83.16
Economic covariates					
Agriculture, forestry, mining	10.83	12.19	Agriculture, forestry, mining	-10.61	10.22
Manufacturing	12.74	10.09	Manufacturing	-0.55	8.02
Construction, transportation, utilities	13.92	7.73	Construction, transportation, communications, utilities	0.81	8.19
Wholesale and retail trade	15.58	8.19	Wholesale and retail trade	-4.70	8.20
Professional, business, information services	7.82	5.42	Finance, insurance, real estate services	1.16	4.06
Administrative, real estate, rental services	2.94	3.13	Professional services	-0.39	3.35
Education, health, social services	21.37	8.33	Education, health, social services	6.51	7.96
Entertainment, lodging, food, personal services	11.07	6.61	Entertainment, personal, administrative services	7.26	7.10
Gini coefficients					
Gini, 1979	0.284	0.079			
Gini, 2009	0.544	0.095			
Change in Gini, 1979–2000	0.260	0.106			

Source: 1980 Census and 2005–2009 ACS, U.S. Census Bureau.
Note: Income not inflation adjusted.

Great Plains Research 21 (Fall 2011):203–14

FUTURE PARTICIPATION IN THE CONSERVATION RESERVE PROGRAM IN NORTH DAKOTA

Lorilie M. Atkinson

Natural Resources Conservation Service
U.S. Department of Agriculture
Center, ND 58530

and

Rebecca J. Romsdahl and **Michael J. Hill**

Department of Earth System Science and Policy
University of North Dakota
4149 University Avenue
Grand Forks, ND 58202-9011
rebecca.romsdahl@und.edu

ABSTRACT—The purpose of this study was to gauge the impact of agriculture and energy policies on conservation practices through a survey of conservation reserve program (CRP) contract holders in a selected Prairie Pothole Region of North Dakota—Burleigh, Kidder, and Stutsman Counties. The survey results showed that 48% of respondents are considering returning CRP acres to annual crop production once the contract expires. The largest influence on post-CRP land use was the market prices for production of annual crops. Respondents also identified lack of knowledge of conservation programs as a large hurdle to participation. This may indicate a need for improved communication from program information sources such as the Farm Service Agency and the Natural Resource Conservation Service, from where most contract holders get their information. These findings also provide interesting insight into the motivation and decision-making process surrounding conservation programs, in particular continued participation in the CRP. By understanding the main motivation and considerations for conservation participation (market prices, cost-sharing opportunities, and expected cost of production), federal conservation programs will be able to maximize conservation efforts, which will benefit landowners and resources alike.

Key Words: Conservation Reserve Program, Prairie Pothole Region, North Dakota, agriculture policy

INTRODUCTION

The Conservation Reserve Program (CRP) was a revolutionary conservation program established by the 1985 Food Security Act (Farm Bill). Initially, farmers enrolled land deemed marginal, or highly erodible, and established a persistent cover crop (mainly grasses) to prevent soil erosion in exchange for compensation, an annual rent payment as well as cost sharing and technical assistance to establish cover (FSA 2008). The responsibility of administering this program is spread across several agencies within the U.S. Department of Agriculture (USDA), namely the Farm Service Agency (FSA) and the Natural Resource Conservation Service (NRCS). These agencies are charged with the responsibility of compensation and compliance as well as cooperation between state and federal levels. The dual purpose of the CRP was to address ecosystem conservation issues by removing marginal (highly erodible) cropland from production for an extended period and by providing subsidy payments (Johnson and Clark 2001; Ruhl et al. 2007). This focus on commodity supply limitation explains the high concentration of enrolled CRP acres in the Great Plains, as this is one of the most agriculturally productive regions in the nation.

Approximately 7% of North Dakota's 44 million acres (17.8 million hectares) of land is enrolled in the CRP. A significant proportion of the CRP land is located in the Prairie Pothole Region. The entire Prairie Pothole

Manuscript received for review, August 2010; accepted for publication, December 2010.

Region (PPR) of North America covers 300,000 square miles (77,000,000 hectares) and contains 83 wetlands per square mile (GAO 2007). The PPR in North Dakota is considered the heart of the world's largest grassland and is extremely productive for both agriculture and wildlife (Neimuth et al. 2007; EPA 2009). Ducks Unlimited estimates that since 2002 the North Dakota counties of the PPR have lost 88,000 acres (35,748 hectares) of native prairie (Ness 2008). As of February 2008, 78% of North Dakota CRP contracts were reenrolled or extended; however, only 34% of those acres were in the PPR (FSA 2008).

Beginning in 2007, the imminent loss of CRP acres became apparent to farmers, cattlemen, and agricultural, conservation, and environmental organizations alike. According to data available from the UDSA, from September 2007 to August 2008, CRP acres fell by the largest margin in program history—2.1 million acres (0.9 million hectares) (USDA 2008). North Dakota was expected to lose 250,000 CRP acres (101,171 hectares) in 2007 to contract expirations; the actual number was over 400,000 acres (161,880 hectares)—over 12% of all North Dakota CRP acres. In 2012 alone, over 800,000 CRP acres (323,748 hectares) are set to expire, twice as many as in 2007.

This increased loss of CRP acres can be attributed to high commodity prices, high cash rents, and greater demand for cropland to produce more biofuels (Wilson 2008). As these contracts expire, landowners face several options. If commodity prices stay high, most CRP acreage could return to crop production, leading to increased soil erosion, water quality issues, and other environmental impacts. The unpredictable nature of yearly crop prices as well as changes in federal agriculture and energy policies affect the contract holders' land use decisions.

Anecdotal evidence supports the general conclusion that the Northern Plains, especially North Dakota, is experiencing more conversion from grassland to cropland than previously noted (Stubbs 2007). Information about how many acres are being converted, and where the land is located, can loosely be gathered from existing federal and state data sources. However, identification of forces influencing the land conversion is limited and warrants further investigation.

This study focused on identifying landowner attitudes and beliefs that influence conservation versus production land use. The objectives for this study included (1) determining the main factors that influence post-CRP land use decisions, (2) determining the main management issues related to these land use decisions, and (3) identifying contract holders' environmental and conservation perceptions.

THE SURVEY

Identification of Survey Area

The focus on North Dakota was chosen because of the regional emphasis on PPR conservation and high participation rate in the CRP (Bangsund and Hodur 2004; Ducks Unlimited 2008). Three North Dakota counties, Burleigh, Kidder, and Stutsman (Fig. 1, shaded gray), were identified for the survey interests based on the following criteria: (1) location within the state's PPR, (2) having 10% to 20% of cropland enrolled in CRP, and (3) high annual CRP acre loss by county.

A large percentage of CRP acreage in these three counties expired in 2007 (almost 90,000 acres [36,420 hectares] collectively); however, a larger acreage loss is expected in 2012, with a combined loss across the three counties of over 100,000 acres (40,470 hectares). While this survey analysis focuses on the CRP acreage loss through 2012, examination of future expiration schedules reveals continued cause for concern. According to figures provided by the NRCS, Kidder County is expected to have over 33,000 acres (13,355 hectares) expire in 2017. In the same year, North Dakota is anticipated to lose over 367,000 acres (148,520 hectares). Burleigh and Stutsman Counties will experience sizeable conservation acreage loss in 2019.

Survey Design and Implementation

The study was approved by the Institutional Review Board at the University of North Dakota. An adaptation of Dillman's total design method (Dillman et al. 2007) was used to implement the mail survey targeted to CRP contract holders within the three-county survey area. Paper questionnaires were sent to the identified survey population in cooperation with the USDA North Dakota Agricultural Statistics Service Field Office (NDASS).

The questionnaire design was derived from a switchgrass survey by Jenson et al. (2007) and from three farmer surveys, by Hua et al. (2004), Janssen et al. (2008), and Roberson (2008), modified to focus on this study's objectives. The survey included sections on (1) conservation participation, (2) views on environmental and conservation issues, (3) CRP participation, (4) interest and knowledge in renewable energy production, and (5) farm and respondent demographics. The survey questions included open-ended essay responses, close-ended, multiple choice (one answer or multiple answers), and rating (Likert) scale questions. A summary of survey variables used in this project are illustrated in Table 1.

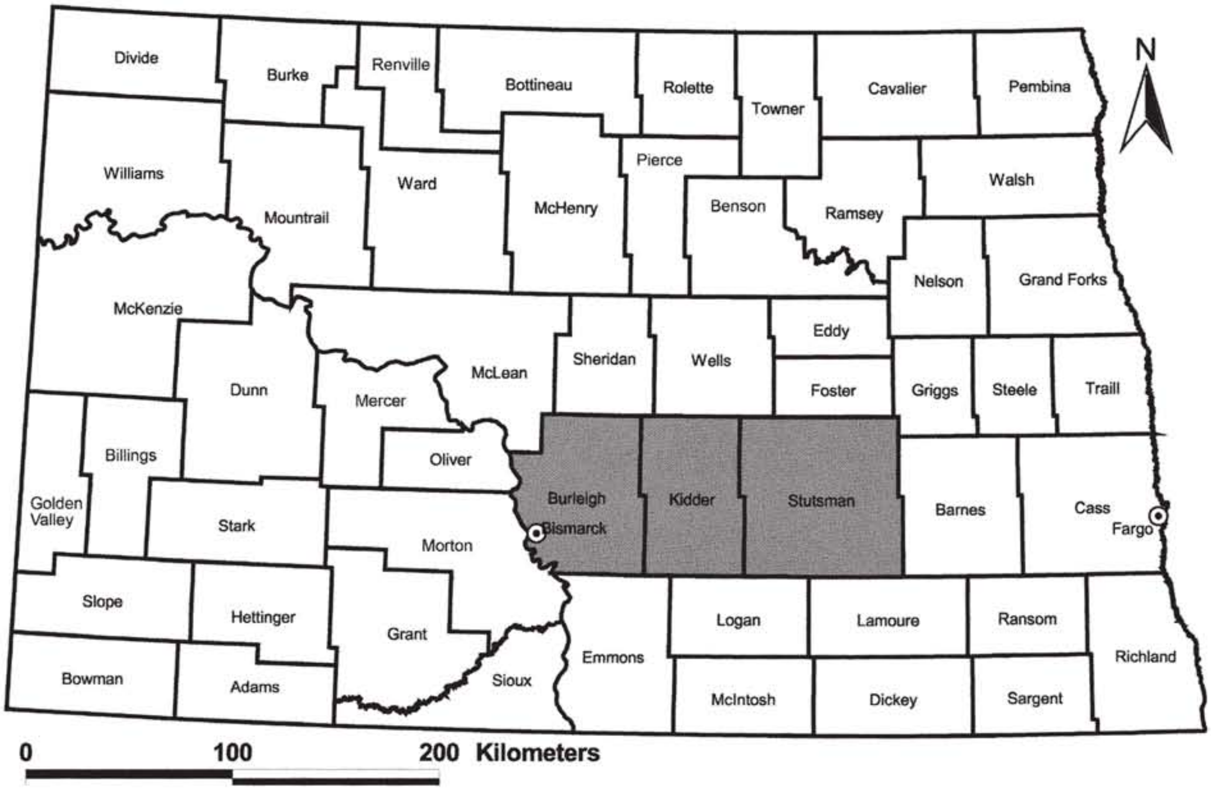


Figure 1. Counties in survey area: Burleigh, Kidder, and Stutsman (shaded gray). Map source: www.censusfinder.com.

A survey population of 1,300 CRP contract holders in the three counties was identified by the NDASS. As a statistical agency of the USDA, the NDASS collects agriculture census data and statistics for the state of North Dakota, making it an expedient way to identify the CRP contract holders within the study area. However, due to privacy issues, NDASS is not able to share personal information, such as addresses, from these databases with outside organizations. Instead, a contract agreement was established between NDASS and the primary investigator. NDASS generated a population pool of all CRP contract holders in Burleigh, Kidder, and Stutsman Counties and then printed and mailed the survey produced by the investigator. This ideal cooperation allowed for a thorough, convenient, and fast application of the survey to the target audience while protecting their anonymity. The questionnaires were mailed during the week of May 4, 2009. A postcard reminder was sent two weeks later. Survey responses were directed to the author for data collection and analysis.

Data Analyses

After the survey results were collected, all responses were entered into SurveyMonkey, an online survey site that acted as a data organization and management tool. It provides a secure, private database that allows for browsing of individual responses and questions and can be easily shared with research advisors. SurveyMonkey also had the added features of self-generated reporting and analysis tools such as filtering and cross-tabulations as well as compatibility to Microsoft Excel and other statistical software such as SPSS for further analysis.

Analyses of the data were conducted using SurveyMonkey and SPSS version 16. To gauge representativeness, characteristics of survey respondents were compared with two attributes from the 2007 U.S. Census of Agriculture state (ND) census: age and gender. Discrepancies can be attributed to the differences in the survey design and to the smaller and more focused survey size of the North Dakota CRP survey.

RESULTS

The study received 316 completed surveys out of 1,284 successful contacts, a 25% response rate. This is a satisfactory response level given the challenges to encouraging survey participation and the difficult weather conditions when the survey was sent; snowstorms in April 2009 and

TABLE 1
BREAKDOWN OF SURVEY VARIABLES AND QUESTION

Variable	Section	Category	Focus/Assessment	Scale
Dependent	Farm and landowner characteristics	Gender, age, years farming, farm size, education, and county residency	What are landowner demographics? Levels of absentee ownership?	Multiple choice
	Conservation Reserve Program	Acres, haying and grazing, contract expiration, CRP plans	How many acres are enrolled?	Open-ended
	Energy production	Crop production, switchgrass conversion	What are the obstacles to biofuel (switchgrass) production?	Open-ended
Independent	Conservation participation	Program participation, resource perception, participation barrier, source of information, conservation assistance	What conservation programs are landowners enrolled in? Perception of resource vulnerability? Barriers to conservation participations? What assistance (financial, technical, etc.) would be helpful?	Multiple choice, Likert
	Environmental/ Conservation attitudes	Importance of land, benefits and negative effects of CRP	What factors are more important for CRP enrollment? Perceived effectiveness of program?	Likert, Multiple choice
	Conservation Reserve Program	Management Influences	What factors influence land use decisions after CRP contract expiration?	Likert
	Energy production	Barrier to implementation	What are the obstacles to biofuel (switchgrass) production?	Likert

flooding in May 2009 delayed mail delivery, as county roads and streets were impassable. Due to financial and time limitations, incentives could not be offered to solicit more responses, and therefore survey success had to rely strictly on voluntary participation. These two factors likely influenced the return response rates.

A 25% response to this survey (one questionnaire and followup postcard) is acceptable. A return of 316 surveys gives a 95% confidence interval, with sampling tolerances of ±3 to 5 percentage points. Reported percentages are rounded to the nearest whole number, causing small variations in reported percentage totals (99% or 101%). Unless otherwise noted in parentheses, reported percentages are based on the total number of responses ($n = 316$).

Farm and Respondent Characteristics

Demographic Data. General demographic characteristics of survey respondents are reported in Table 2. Overall, the breakdown of gender across counties was 83% male, 17% female ($n = 282$). The response distribution by gender of landowners surveyed was similar to the 2007 North Dakota Agriculture Census data by county in which there were predominantly more male landowners (see Table 2). Male to female contract holders occur in an almost 5 to 1 ratio. The majority of female contract holders are 65 years or older; by contrast the majority of male contract holders are 45 to 64 years of age. The age distribution of survey respondents was 5% age 25–44, 44% 65 years or older, and 51% age 45–64 ($n = 285$), which aligns closely with the 2007 North Dakota Agriculture Census data.

Survey respondents have a relatively high level of education. Nearly one-half are college graduates or post graduates, with one-fourth of all others attending some college (Table 3). Less than 10% of respondents had less than a high school diploma.

Farm Information. The average acreage of CRP contracts for the three-county survey area is 227 acres (89.8

TABLE 2
SELECT DEMOGRAPHIC (AGE AND GENDER) CHARACTERISTICS OF NORTH DAKOTA CRP SURVEY RESPONDENTS

County	North Dakota Agricultural Census data Principal operator		Survey data Respondent		North Dakota Agricultural Census data Average age
	Male	Female	Male	Female	
Burleigh	890 (87%)	136 (13%)	62 (82%)	14 (18%)	56.8
Kidder	510 (86%)	80 (14%)	58 (85%)	10 (15%)	58.2
Stutsman	881 (85%)	162 (15%)	96 (82%)	21 (18%)	57.7
Gender	**25–44 years**	**45–64 years**	**65 years or over**	**Total**	
Female	1	18	28	47	
Male	12	126	94	232	

Source: North Dakota Tri-County CRP Survey, May–June 2009 and 2007, North Dakota Agriculture Census.

TABLE 3
DISTRIBUTION OF SURVEY RESPONDENTS' EDUCATION

Education	Percentage (%)	$n = 280$
Some high school or less	7	21
High school graduate	20	55
Some college	25	70
College graduate	29	80
Post graduate	19	54

Source: North Dakota Tri-County CRP Survey, May–June 2009.

hectares), slightly lower than reported (283 acres [114.5 hectares]) in the North Dakota CRP survey (Hodur et al. 2002), but above the average reported for the Northern Plains (178 acres [72.0 hectares]) (Allen and Vandever 2003). Three-fifths of respondents have been farming for over 30 years ($n = 272$). Sixty-nine percent of respondents indicated they were living in the same county as the CRP contract county. Of the remaining 31% in outside counties, 35% of those were out-of-state residents. In another study, Hodur et al. (2002) found 87% of landowners are North Dakota residents, and 61% lived in the survey county. Most CRP acres are contracted by respondents owning farms of 1,000 acres (404.9 hectares) or less (55%, $n = 280$) (Table 4). According to the 2007 North Dakota Agriculture Census, the average farm acreages by county are Burleigh, 857; Kidder, 1,277; and Stutsman, 1,144 acres (346.8, 493.0, and 516.8 hectares, respectively). The same general trend was seen in the survey responses between counties as well (Fig. 2), with more Kidder County farms in the size category 501–1,000 acres (203.0–404.7 hectares) than there were in Burleigh and Stutsman Counties, where most farms were in the size category of 1–500 acres (0.4–202.3 hectares).

Conservation Participation

At the time of the survey, 29% of respondents indicated that part of or their entire CRP contract had expired; 72% currently had active CRP contracts ($n = 280$). When asked about participation in farm conservation programs, 96% indicated having been enrolled in CRP ($n = 246$). The absence of 100% CRP participation in response to this survey question could be attributed to the fact that the

TABLE 4
SURVEY RESPONDENTS' FARM DEMOGRAPHIC DATA

Farm size (acres)	Percentage of respondents (%)	$n = 280$
1–500	32	90
501–1,000	23	65
1,001–1,500	10	28
1,501–2,000	12	33
2,001–3,000	9	26
3,001–4,000	4	10
4,001–5,000	4	11
5,000+	6	17

Years farming	Percentage of respondents (%)	$n = 272$
9 or less	11	30
10–19	14	39
20–29	15	41
30–49	36	98
50+	24	64

Source: North Dakota Tri-County CRP Survey, May–June 2009.

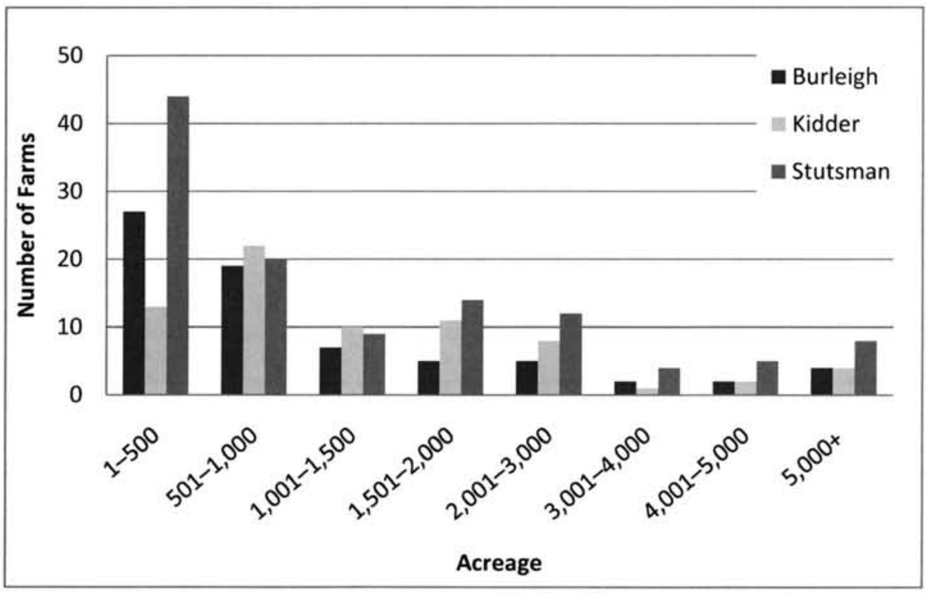


Figure 2. Survey respondent' farm acreage by county. Source: North Dakota Tri-County CRP Survey, May–June 2009.

current CRP contract had expired by the time the survey reached the respondent, or to respondents' interpretation of the question. A question on participation in other conservation programs was included in order to assess possible connections between programs. Participation in conservation programs other than CRP was low across the board, with no program garnering more than 15% participation ($n = 258$) (Fig. 3).

Overwhelmingly, respondents indicated that their source of information for conservation programs is through the Farm Service Agency (79%, $n = 223$). Approximately 40% ($n = 258$) of respondents indicated getting conservation information from the Natural Resource Conservation Service, other farmers and neighbors, media, university-based Extension Service, and Soil Conservation Districts.

When asked about perceived threats to resources, wetlands and native grasses were overwhelmingly perceived as *not threatened* (49% and 34%; $n = 266$ and 271, respectively). Respondents considered the CRP as

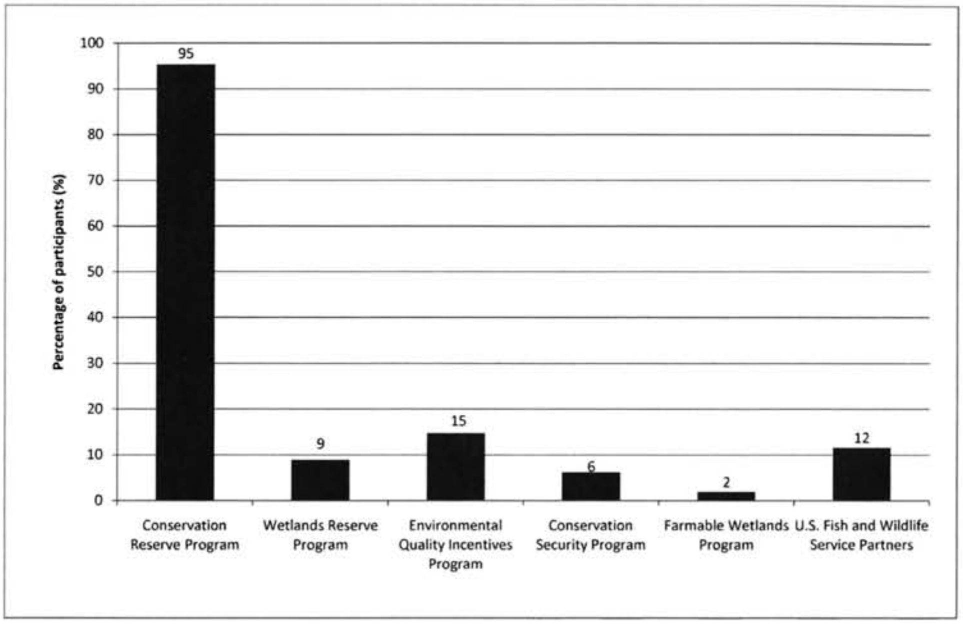


Figure 3. Participation in farm conservation programs. Source: North Dakota Tri-County CRP Survey, May–June 2009.

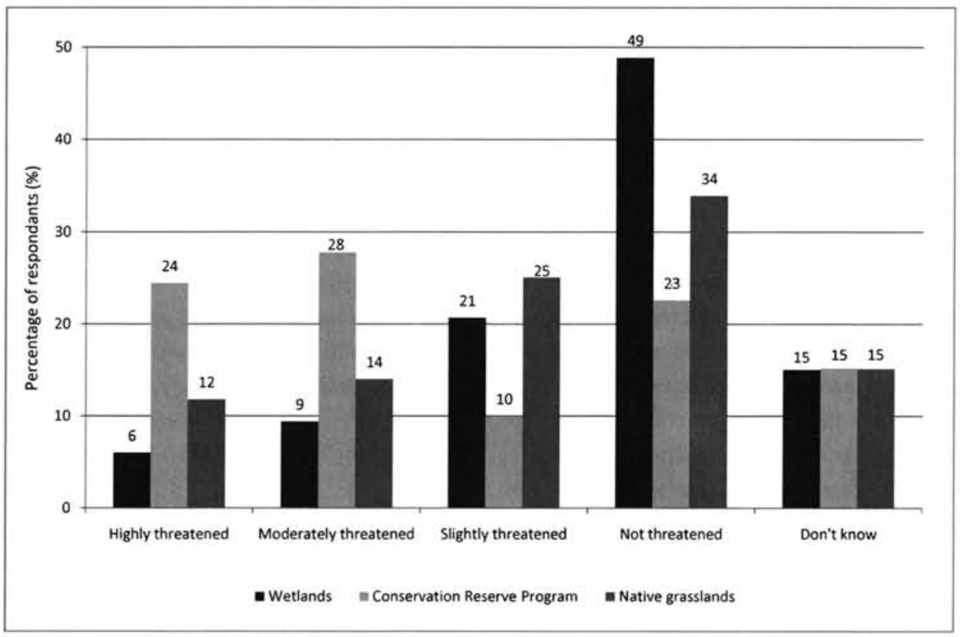


Figure 4. Farmer's views on environmental issues. Source: North Dakota Tri-County CRP Survey, May–June 2009.

moderately to *highly threatened* (n = 270) (Fig. 4). This is an interesting dichotomy, especially given the close relationships between these three features in this region. It is the combination of grassland and wetland that provides the Prairie Pothole Region with an ideal habitat for wildlife, especially waterfowl (GAO 2007; Gleason et al. 2008). If one feature is threatened, by definition all features are threatened. The CRP preserves both of these habitat structures, but native grasslands and wetlands have been increasingly targeted for intensive farming practices due to high commodity prices.

When asked about possible barriers to implementing conservation programs (Table 5), over half of respondents (52% to 69%) *agreed* or *strongly agreed* with a variety of

TABLE 5
PERCENTAGE OF RESPONDENTS WHO AGREE OR STRONGLY AGREE REGARDING THE POSSIBLE BARRIERS TO IMPLEMENTING CONSERVATION PROGRAMS

Please indicate your level of agreement with the following statement:		Respondents who agree or strongly agree (%)	Average score[a]
The program does not offer enough money to be of interest.	$n = 279$	69	2.12
There is too much bureaucracy associated with applying.	$n = 277$	65	2.16
Landowners do not want government working on their land.	$n = 276$	52	2.45
The landowner may not qualify for the programs that would be of most interest.	$n = 275$	59	2.32
The landowner may not be aware of the relevant programs.	$n = 274$	61	2.42

Source: North Dakota Tri-County CRP Survey, May–June 2009.
[a]Likert scale question where 1 = strongly agree, 2 = agree, 3 = no opinion, 4 = disagree, 5 = strongly disagree. There was no significant difference between the average score of the responses.

barriers ($n = 281$). For example, 69% ($n = 279$) *agreed* or *strongly agreed* that the program does not offer enough money to be of interest, indicating this as one of the top barriers. The statement *landowners do not want government working on their land* garnered the least concern of all the statements, and may explain the high level of existing and ongoing participation in federal conservation programs in these counties.

When asked about the value of financial or technical assistance (Table 6), 63% ($n = 269$) said establishment of cover crop to prevent soil erosion would be somewhat or very useful, followed by creation or improvement of wildlife habitat (58%, $n = 270$). Almost half the respondents indicated either payments to restore, protect, or enhance wetlands, or assistance with development of renewable fuels from crops, would be useful. Assistance in transition to organic production, protection of working easements, and carbon sequestration were favored the least (23%, 24%, and 36% [$n = 270$, 269, and 266], respectively).

Land Management Factors

The most significant factor in land management decisions was *land as a source of income*, which was considered to be *very* or *moderately important* ($n = 278$) in over 75% of responses. This corresponds with a 2006 High Plains (Colorado, Kansas, Nebraska, New Mexico, Oklahoma, and Texas) landowner survey where 86% of respondents indicated that their land as a source of income was *very* or *moderately important* (Witter 2006). The next most significant factors were *the means of passing on rural life* (55% indicating *very important*) and *a source of land and water resources* (46% indicating *very important*) ($n = 274$ and 271) (see Fig. 5). A lower percentage of respondents identified land as *a source of hunted* (31%, $n = 277$) and *nonhunted* (21%, $n = 273$) *wildlife* and as *a source of outdoor recreation* (20%, $n = 273$) as *very important* to influencing land management decisions.

Witter (2006) indicates that High Plains respondents characterized only one item, *source of income*, as very important. This indicates respondents in the North Dakota survey place a comparatively high value on wildlife and recreation opportunities. While land as *a source of income* plays a large role in management decisions, environmental issues are also an important component in decision making.

Conservation Reserve Management

Forty-eight percent of respondents hayed their CRP acres within the last five years under emergency provisions ($n = 279$). Under these same conditions, only 24% had hayed within the last year, which may be due to restrictive haying and grazing boundaries set forth by the FSA. Eighty-eight percent of respondents had not grazed CRP acres ($n = 284$), reinforcing the predominance of cropland over pasture in these three counties. Twenty-four percent of respondents in the 2003 National CRP Survey reported haying CRP acres at least once during emergency conditions (Allen and Vandever 2003). Compared across the nation, the Northern Plains utilizes the CRP acres for designated emergency haying and grazing more frequently than any other region (Allen and Vandever 2003).

TABLE 6
PERCENTAGE OF RESPONDENTS WHO WOULD FIND FINANCIAL OR TECHNICAL ASSISTANCE VERY USEFUL OR SOMEWHAT USEFUL

Type of assistance		**Respondents who answered very useful or somewhat useful (%)**	**Average score[a]**
Development of renewable fuels from crops or wood fiber	$n = 268$	49	2.54
Creation or improvement of wildlife habitat	$n = 270$	58	2.49
Payment to restore, protect, or enhance wetlands	$n = 271$	49	2.67
Establishment of cover crops to prevent soil erosion	$n = 269$	63	2.39
Improvement of water quality through nutrients or manure managements	$n = 272$	41	2.93
Transition from conventional to organic production	$n = 270$	24	3.38
Protection of working farm land through easements	$n = 269$	23	3.26
Carbon sequestration on farm land	$n = 266$	36	2.89

Source: North Dakota Tri-County CRP Survey, May–June 2009.
[a] Likert scale question where 1 = very useful, 2 = somewhat useful, 3 = uncertain, 4 = not very useful, 5 = no use at all. There was no significant difference between average scores of the responses.

Future CRP Plans

Survey respondents were asked about possible future plans for their enrolled CRP acres. In this question, they were given the option to select all responses being considered; therefore the sum of percentages exceeds 100%. Almost half (48%, $n = 247$) of respondents indicated they may return CRP acres to annual crop production after their contract expires. Thirty-one and fifteen percent, respectively, are considering keeping CRP acres in grass for hay production, or to prevent soil erosion. Twenty-nine percent of respondents have no plans or indicated uncertainty about future plans after their CRP contract expires (Fig. 6).

In deciding future land use, 43% of respondents indicated market prices for production after CRP expiration and 30% indicated the expected cost of planting and harvesting are *very important* ($n = 275$). Availability of cost-sharing for wildlife and expected sale price of land were considered *not important*, by 30% and 33% of respondents, respectively ($n = 275$).

DISCUSSION

Survey respondent demographics provide an interesting picture of rural life in these three counties and may play an important role in considering future conservation policies in the area. In general, smaller farms with older than average landowners are the most common participants in land retirement programs, and are more reliant on nonfarm sources of income (Lambert et al. 2006). This trend was observed in the tri-county survey as well. The majority of survey respondents were male, ages 45 and above, and indicated having farmed for over 30 years. This follows the general trend of land retirement programs attracting mature landowners. Given the average age of landowners in these three counties in the mid- to late 50s, their pending retirement is a relevant factor in consideration of expanding or reenrolling acres.

If North Dakota landowners continue the trend of moderate-sized farms (under 1,000 acres [404.9 hectares]), and there is every indication that this is likely, continued participation in the CRP seems assured. However, the future of landownership in the state is speculative given the aging rural population. The 2008 Farm Bill provided incentives to sell land to young or disadvantaged farmers and offered other financial assistance to support beginning farmers. How this will impact North Dakota landownership and conservation participation remains to be seen. High education levels are also relevant, as research has indicated these individuals are more interested in conservation programs (Onianwa et al. 1999).

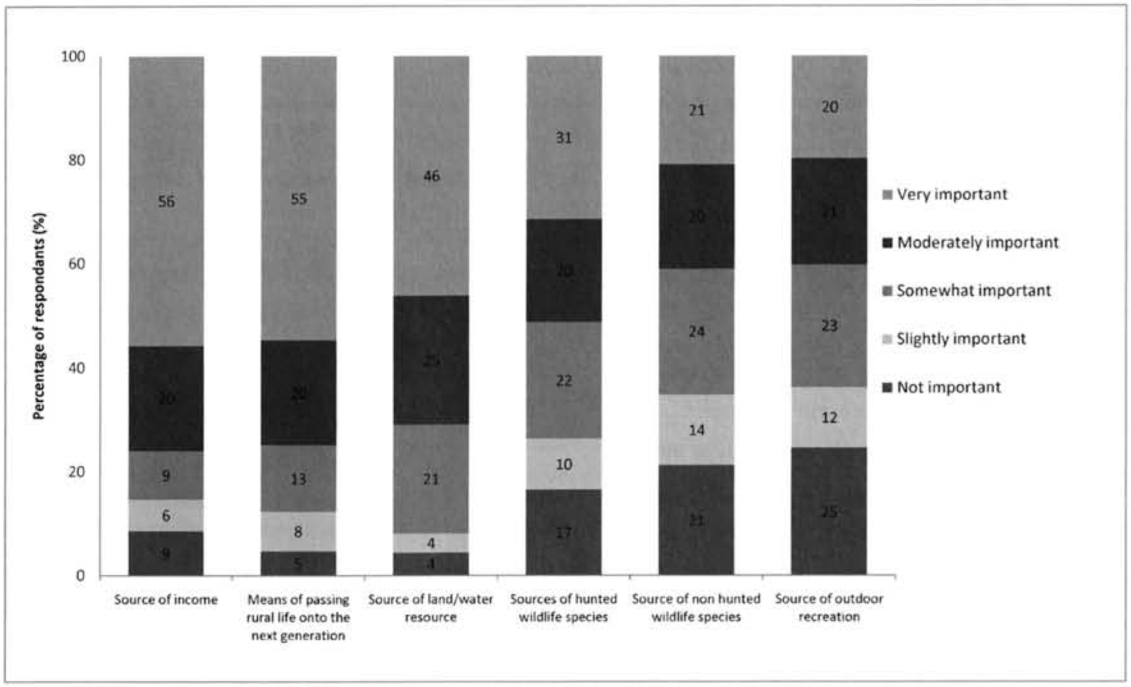


Figure 5. Importance of land on management decisions. Source: North Dakota Tri-County CRP Survey, May-June 2009.

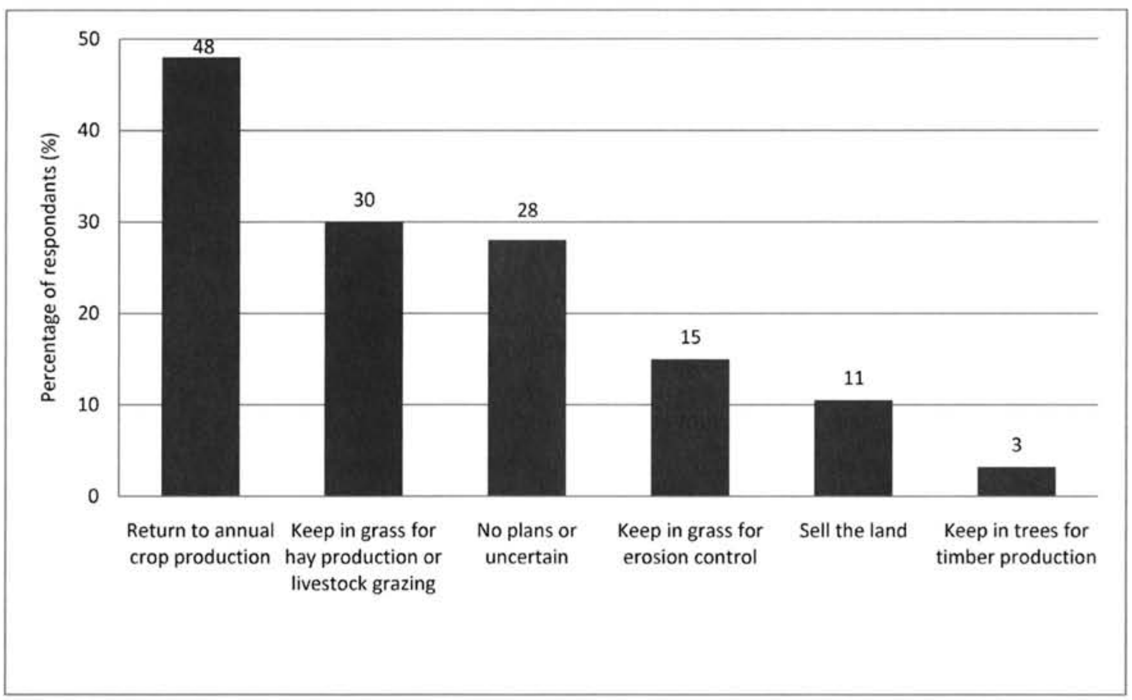


Figure 6. Land use options after CRP contract expires (Source: North Dakota Tri-County CRP Survey, May-June 2009).

The responses to a question about vulnerable ecosystems revealed a split in perception. The majority of respondents indicated a belief that CRP was *moderately* or *highly threatened*. However, contrary to published biological research, an overwhelming percentage of contract holders feel that native grasslands are *not threatened*. This may indicate that contract holders clearly discriminate between native grasslands such as National Wildlife Refuges, National Grasslands, and other preserved areas outside the agricultural production system, and CRP lands which may be private remnants, hayfields, and actively sown grassland regarded as part of the agricultural production system. The relationship between perceptions of conservation and production status for grasslands, depending upon ownership and land use context, requires further investigation and analysis.

At the time of the survey (May 2009), 72% of the respondents still had active CRP contracts. Survey respondents identified many positive aspects associated with CRP; however, nearly half of the respondents indicated they were considering returning CRP acres to annual crop production once the contract expires. This contradiction is further explained by the survey responses identifying market prices for annual crop production as having the largest influence on post-CRP land use decisions. This is a deciding factor to focus on for analyzing future CRP participation.

Over half of the respondents identified barriers to implementing conservation programs. For example, respondents noted that blanket policies did not fit every farm and called for more localized control. Survey respondents also requested increased interaction with USDA staff for information on plant species, vegetation management, and maintenance of wildlife habitat. CRP contracts that are not competitive with land rental rates and the challenges posed by government bureaucracy are significant drivers of decline in conservation acres.

Along with market forces, a lack of knowledge of conservation programs plays a large role in participation. Additional communication efforts from the leading agencies, the Farm Service Agency and the Natural Resources Conservation Service, should be a priority, as this is where respondents get their information about programs. Increased availability of information, both in terms of accessibility and in terms of relevance, clarity, and completeness of content may help to increase conservation participation. This may also indicate where other programs could be promoted to increase conservation efforts. Programs such as the Environmental Quality Incentives Program (EQIP), Conservation Security Program (CSP), and Farmable Wetlands Program (FWP) are working-land conservation programs. An increase in acreage enrollment in these programs could play a large role in a transition from long-term land retirement programs and would provide an ecological compliment to crop production. The survey results support the need for more aggressive outreach by federal and state agencies to address these bureaucratic and communication issues.

CONCLUSIONS

The conservation reserve program remains popular in this region, especially among more mature landowners with smaller acreage. The popularity of working-lands conservation programs also continues to increase and will likely play a larger role in the future, along with land retirement conservation programs. Findings from this survey provide insights into the motivation and decision-making processes of landowners in regard to conservation programs, specifically, continued participation in the CRP. Results indicate that landowners value both the revenue and ecological benefits provided by their land. Although the financial importance of land supports the need for more competitive CRP contract rental rates, the equivalent ranking of diverse economic and environmental resources indicates that conservation decisions are not based solely on financial incentives. This helps explain why the CRP has been and continues to be a popular program, providing stable farm income, securing natural resources, and maintaining wildlife habitat. Successful conservation programs will need to include all these considerations in order to garner attention and participation into the future.

ACKNOWLEDGMENTS

The authors would like to thank the staff, faculty, and students of the University of North Dakota Department of Earth System Science and Policy for their contributions to this research. The authors would like to acknowledge the North Dakota Agriculture Statistics Service for survey collaboration and the staff of the Natural Resources Conservation Service Grand Forks Field Office and Scott Stephens of the Ducks Unlimited Great Plains Regional Office for technical assistance and data. The Agricultural Research Service provided funding for this study. The authors would also like to thank two anonymous reviewers for their time and valuable comments during the review process.

REFERENCES

Allen, A.W., and M.W. Vandever. 2003. *A National Survey of Conservation Reserve Program Participants on Environmental Effects, Wildlife Issues, and Vegetation Management on Program Lands.* U.S. Geological Survey, Biological Science Report 2003-0001.

Bangsund, D.A., and N.M.J.L.L. Hodur. 2004. Agricultural and recreational impacts of the Conservation Reserve Program in rural North Dakota, USA. *Journal of Environmental Management* 71:293–303.

Dillman, D.A., J.D. Smyth, and L.M. Christian. 2007. *Internet, Mail and Mixed-Mode Surveys: The Tailored Design Method.* Wiley, Hoboken, NJ.

Ducks Unlimited. 2008. Ducks Unlimited says CRP loss over next four years may be more than five million acres. January 28, 2008.

Environmental Protection Agency (EPA). 2009. Prairie Potholes. http://water.epa.gov/type/wetlands/potholes.cfm. Accessed January 13, 2009.

Farm Service Agency (FSA). 2008. Conservation *Reserve Program Summary and Enrollment Statistics.* Farm Service Agency, Washington, DC.

Government Accountability Office (GAO). 2007. Prairie Pothole Region: At the current pace of acquisitions, the U.S. Fish and Wildlife Service is unlikely to achieve its habitat protection goals for migratory birds. GAO-07-1093. Report to the Subcommittee on Interior, Environment, and Related Agencies, Committee on Appropriations, House of Representatives.

Gleason, R.A., M.K. Laubhan, and J.N.H. Euliss. 2008. Ecosystem services derived from wetland conservation practices in the United States Prairie Pothole Region with an emphasis on the U.S. Department of Agriculture Conservation Reserve and Wetlands Reserve Programs. U.S. Geological Survey, Professional Paper 1745. Reston, VA.

Hodur, N.M., F.L. Leistritz, and D.A. Bangsund. 2002. Local socioeconomic impacts of the Conservation Reserve Program. 16 pp. *Agribusiness and Applied Economics*, Report 23640. Fargo, ND.

Hua, W., C. Zulauf, and B. Sohngen. 2004. Ohio farmers' conservation decision: 2004 survey results. Ohio State University, Agricultural, Environmental and Development Economics Report AEDE-RP-0045-0: 20 pp. Ohio State University, Columbus, OH.

Janssen, L., N. Klein, G. Taylor, E. Opuku, and M. Holbeck. 2008. Conservation Reserve Program in South Dakota: Major findings from 2007 survey of South Dakota CRP respondents. Economics Research Report 2008-1. South Dakota State University, Brookings, SD.

Jensen, K., C.D. Clark, P. Ellis, B. English, J. Menard, M. Walsh, and D.D.L.T. Ugarte. 2007. Farmer willingness to grow switchgrass for energy production. Biomass & Bioenergy 31:773–81.

Johnson, J.B., and R.T. Clark. 2001. The Conservation Reserve Program: 2002 Farm Bill policy options and consequences. The Farm Foundation, Oak Brook, IL.

Lambert, D., P. Sullivan, R. Claassen, and L. Foreman. 2006. *Conservation-Compatible Practices and Programs: Who Participates?* Economic Research Service Report No. 14.

Neimuth, N.D., F.R. Quamen, D.E. Naugle, R.E. Reynolds, M.E. Estey, and T.L. Shaffer. 2007. Benefits of the Conservation Reserve Program to grassland bird populations in the Prairie Pothole Region of North Dakota and South Dakota. Prepared for the Univted States Department of Agriculture Farm Service Agency Reimbursable Fund Agreement OS-IA-04000000-N34. Bismark, ND.

Ness, E. 2008. Preserving Prairie Pothole. Forest Carbon Portal. http://www.forestcarbonportal.com/content/preserving-prairie-potholes. Accessed January 13, 2009.

Onianwa, O., G. Wheelock, and S. Hendrix. 1999. Factors affecting conservation practice behavior of CRP participants in Alabama. *Journal of Agribusiness* 17:149–60.

Roberson, T.D. 2008. Assessing farmer support for conservation programs in the Farm Bill. Master's thesis, Nicholas School of the Environment and Earth Sciences. Duke University, Durham, NC.

Ruhl, J.R., S.E. Kraft, and C.L. Lant. 2007. *The Law and Policy of Ecosystem Services.* Island Press, Washington, DC.

Stubbs, M. 2007. Land conversion in the Northern Plains. Congressional Research Service, RL-33950.

U.S. Department of Agriculture (USDA). 2008. CRP Contract Summary and Statistics. http://fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=rns-css. Accessed January 23, 2009.

Wilson, R. 2008. CRP R.I.P? *North Dakota Outdoors*, 4–9. June 2008.

Witter, D.J. 2006. High Plains landowner survey 2006: Farmers, ranchers, and conservation. Playa Lakes Joint Venture, Mishawaka, IN.

Great Plains Research 21 (Fall 2011):215-30

A MODEL OF HUMAN SCALE TESTED ON RURAL LANDSCAPE SCENES

Richard K. Sutton

Department of Agronomy and Horticulture and the Program in Landscape Architecture
University of Nebraska–Lincoln
Lincoln, NE 68583-0915
rsutton1@unl.edu

ABSTRACT—Landscapes such as the Great Plains have been described as lacking human scale. This study developed a quantitative model of human scale and compared it with viewers' perceptions of visual structure. Visual structure was selected from the physical features of Otoe County, NE, forming boundaries, found as ground textures, vegetative screens, and topographic breaks and was depicted in photographs of landscape scenes. The model used and tested nine classes of scale based on grain and extent of the photos rated by viewers against those from the model. Viewers identified boundaries representing grain and extent that were synthesized into a viewer-perceived scale class. Good agreement with the proposed model occurred at four smaller scales but deteriorated as scale increased. Larger-scale scenes appear to offer more opportunities for the viewer to select closer or farther visual boundaries, thus changing their interpretation of scale.

Key Words: grain, extent, visual structure, landscape structure, visual assessment

INTRODUCTION

Scale connects humans to their environment. Absolute scale (Fig. 1) relates "the size of any object to a definitely designated standard" and relative scale (Fig. 2) refers to "the size [comparison] . . . between landscape components and their surroundings" (Grinde and Kopf 1986:329). Both types of scale interest an array of researchers: landscape ecologists (Meentemeyer and Box 1987; Wiens 1989, 1992; Turner et al. 1991; Allen et al. 1993), archeologists (Lock and Molyneaux 2006), geographers (Harvey 1968; Montello 1993, 2001), psychologists (Coeterier 1996; Schyns and Oliva 1994; Henderson and Hollingsworth 1999), and landscape architects (Fabos et al. 1975; Zube et al. 1975; Toth 1988; Stiles 1994; Swaffield 2005; Swaffield and Primdahl 2006).

The perceived quality of the landscape has been studied for nearly 40 years (Daniel 2001), and interest in perception quality has included some interest in scale effects. Landscape quality studies support environmental assessments mandated by the U.S. National Environmental Policy Act (NEPA 1969). In 2000 the European Landscape Convention also bolstered assessment of rural landscapes and aesthetic quality (Déjeant-Pons 2007). Some investigators mention scale in connection with landscape structure and its impact on quality of life (Zube et al. 1982; Gobster 1993; Coeterier 1994; Eaton 1997; Nassauer 1997; Sutton 1997; Bhakuni 2000; Tveit et al. 2006; Gobster et al. 2007).

Manuscript received for review, February 2010; accepted for publication, May 2011.

Human perception and experience of landscape are important because we, as the dominant species on most of the earth, rely on our perceptions and experiences in making judgments about the existing landscape structure, function, and future changes. These judgments affect decisions regarding use and management of landscapes (Fedorwick 1993; Nassauer 1995; Sutton 1997; Gobster et al. 2007). For example, Thorne and Huang (1991) proposed modifying landscape structure in a rural New York watershed only to the extent that changes did not degrade the wildlife habitat and block scenic views.

Humans are biological and ecological creatures as well as cognitive, social, and intellectual. We respond to the structure and scale of landscapes, and thus are affected by the structure and scale of landscapes. Scale is a feature of the landscape, a component of visual organization, and an interactive process, all of which engage human beings and relay information about our ambient environment.

Researchers have developed no explicit models of human scale, although Montello (1993) has verbally described a model. This study proposes a model aimed at measuring and understanding attributes of the human

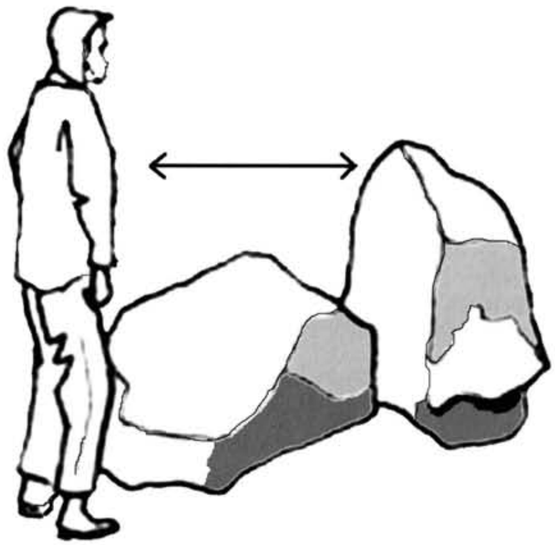


Figure 1. Absolute scale compares the rock to the human body as a standard (after USFS 1973).

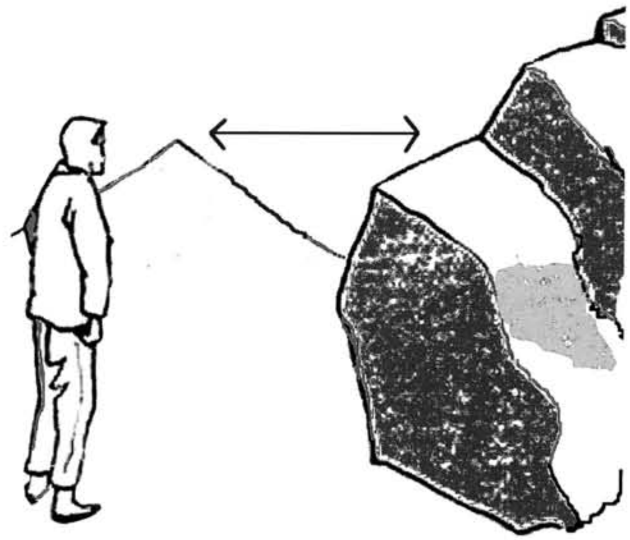


Figure 2. Relative scale compares a landscape feature to its landscape surroundings (after USFS 1973).

scale as affected by the structure of a portion of the Great Plains agricultural landscape.

Scale

Forman and Godron (1986:15) state that scale is "the level of spatial resolution perceived or considered," while Allen and Hoekstra (1992:4) declare that "scale independent entities do not change their qualities when perceived at different scales." While these ideas seem contradictory, human scaling of landscapes appears to use both. Scale relates the size of objects, but because of the optics of the human eye, the apparent size of objects diminishes with distance, and it is easy to interchange clues about size (Fig. 3) with clues about distance (Iverson 1985; Coeterier 1994). Therefore human scale also applies to perception of relative distance. Montello (1993) verbally described a hierarchy of four human scales: (1) *figural scale*, smaller than a human and containing objects manipulated by them; (2) *vista scale*, as viewed from one point; (3) *environmental scale*, which requires movement and multiple viewpoints to understand it; and (4) *geographic scale*, which can only be assessed indirectly via maps or remotely sensed media. Ahl and Allen (1996) have explained spatial scale as hierarchical and rather like a fishnet. Everything not captured by the net is merely background. That is, the smallest thing captured is a function of the size of the mesh, and the largest thing, of the size of the net. This mesh size is the grain, whereas the size of the net is the extent. Observers of a landscape in Montello's vista scale cast their view rather like a net, but in the process of perception likely make a decision about what constitutes the smallest space in which they reside. The visible landscape beyond (to as far as one can see) would then become the viewer's extent.

The process is similar to fishing with a net, except for two potentially conflicting differences: (1) not every observer may use the same size grain, and (2) the very structure of boundaries in the landscape works to suggest a grain and an extent. Landform, vegetative walls, or breaks in surface texture can trigger a boundary designation, and if one focuses upon the grain, then the extent becomes background (Fig. 4). Two basic features that affect scale are landscape structure and what humans interpret from this space as visual structure.

Landscape Structure

Forman and Godron (1986:595) define landscape structure as "the distribution of energy, materials and species in relation to the sizes, shapes, numbers, kinds and configurations of landscape elements." Landscape structure, then, becomes the arrangement, organization, and physical juxtaposition of fixed biological, abiotic, and cultural entities. For example, most dominant in the rural landscape are vegetation, landform, and land cover. Scale becomes a way to describe the relative size and distances inherent in landscape structure.

Landscape structure as a fixed pattern becomes similar to Gibson's (1986) "invariant structure." Invariant structure operates as a limit or boundary. Examples

Figure 3. Scale relates the size of objects. These hay bales diminish with distance and imply scale.

Figure 5. Horizons, topographic breaks, and vegetation represent invariant structure.

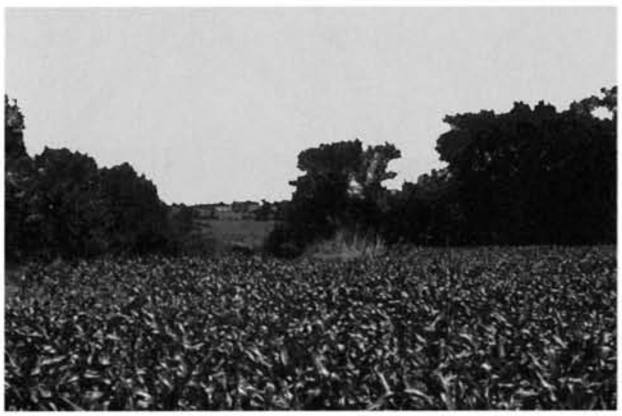


Figure 4. Boundaries parse the rural landscape.

of invariant structure are horizons, vertical topographic breaks, and vegetation barriers (Fig. 5). Such structure contains, halts, or slows the flow of species, energy, nutrients (Forman and Godron 1986), and information (Cadenasso et al. 2003; Wiens 2005). Visible information for humans is a critical aspect of the informational theory of landscape preference (Kaplan and Kaplan 1989).

For the landscape ecologist, physical processes such as erosion, and ecological processes such as species succession, respond to structure over space and time. Yet if we take the idea of landscape structure further to examine how humans act on and react to landscapes, then structure is a basis for studies of <u>both</u> visual and ecological processes (McCarthy 1979; Lyle 1985; Gibson 1986; Barrett and Bohlen 1991; Thorne and Huang 1991). Thus, when humans visually perceive, consider, and act on the structure of a landscape, it is transformed into visual structure. Gobster et al. (2007:960) call this "perceptible structure" and they include other senses besides sight.

Visual Structure

Visual structure is an anthropocentric construct representing a viewer's interpretation of arrangement, importance, and meaning of landscape structure. Visual structure is tied to a place and arises from landscape structure, yet it obviously does not occur without an observer. So, visual structure could be examined as aggregations of basic human perceptions and responses.

Schauman and Pfender (1982:107) and Schauman (1988a, 1988b) describe visual structure as "the range of landscape spatial conditions: from those that offer unlimited but undefined views to those that offer no vista or where all views are blocked." Implicit in their definition are humans who see visual structure from a viewpoint (Montello 1993). Gibson (1986) describes this activity as gaining "perspective structure." Visual structure, just as Gibson's (1986:75) perspective structure, "contains information about the potential observer, not about the environment as the invariants do." The viewpoint or the motion of a roving observer controls incoming information about the environment. Using visual structure places the observer in the system.

The viewer responds to the scale of a scene. For example, a major component of human perception is the mind's ability to imagine and cognize. In those, scale has been recognized as a component (Kosslyn 1994). But perception and cognition, like visual structure, must be based on or triggered by something physical. According to Gibson (1986:284), the "invariants [of physical structure] display a world with nobody in it and the perspective displays where the observer is in that world. . . . To the extent that the invariants are detected, all observers will perceive the same world." To the extent that landscape structure is

selected, interpreted, and scaled by an observer, a visual structure appears.

GRAIN AND EXTENT

By identifying structural boundaries, we can use the concepts of grain and extent to examine human scale.

Boundaries

In both the landscape structure and visual structure of a particular place, scale can be identified as a combination of grain and extent (also sometimes called resolution and scope) (Schneider 1994; Kosslyn 1994). Regarding visual structure, grain is the smallest area of interest to the observer (i.e., the mesh size of the net); extent defines all else that can be seen beyond, thus offering a context for grain (i.e., the size of the net). The observer, however, decides what to focus on and what to call grain and extent.

Boundaries mark an edge or contrast between contiguous land areas (Schauman 1988b). Cadenasso et al. (2003) propose a theory of boundary functioning categorizing impacts on movements across open space into: (1) type of flow, (2) patch contrast, and (3) boundary structure. Boundaries represent structural constraints on visual information, separating surfaces and defining what is perceivable of the landscape spaces. Thus, these spaces become visual entities or wholes determined by the homogeneity of surfaces (often the ground plane) (Brown 1994) (Fig. 6). One unique aspect of landscape as a visual phenomenon arises in the variability in the composition and location of its boundaries. Boundaries that are longest, tallest, and most dense have the greatest power to constrain our visual information, enclose a space, and most strongly fix its perceived grain (Schauman 1988b; Hammitt 1988). Tveit et al. (2006) describe these as a "grain space." The relative order of the assessed strength of a boundary is linked, first, to how tightly any given homogeneous space or grain holds together visually to form a whole, and second, to the relative importance of the boundaries delimiting it (Fig. 7). Topographic breaks, vegetative barriers, and ground pattern represent basic classes of landscape boundaries found in rural landscapes.

The viewer determines a boundary's importance because boundaries vary in their capacity to hold attention and filter information. One becomes aware of the larger landscape beyond a primary space stretching to other visible but less dominant boundaries in the distance. Distant boundaries would then most likely form the context, or extent. Distant boundaries also suggest visual relationships between a primary space of interest and other larger ones that could be selected from those that encompass it.

Figure 6. Fields planted to the same crop and treated with the same conservation techniques display homogeneity of surface.

Figure 7. The grassed waterway slices through this field. Does it possess enough visual strength to overcome the field as a "space grain"?

To illustrate what grain and extent mean in relation to visual structure, imagine a person at some point in a landscape (see Figs. 8 and 9). Figure 8 is reproduced from the Elmwood, NE, quadrangle (USGS 1966) and depicts a planimetric view of a landscape's topographic structure. Projected on this map is a portion of the limits to a stationary observer's vision cone looking northwest from the designated viewpoint. Figure 9 shows what might be interpreted about the landscape's boundaries moving sequentially out from his or her location. (The boundaries for each corresponding horizontal limit of view in Fig. 9 are marked by letters and are shown and noted similarly in Fig. 8).

First, it is likely that the viewer might unconsciously and quickly expand his or her focus to a visual boundary—one that offered enough contrast, density, and

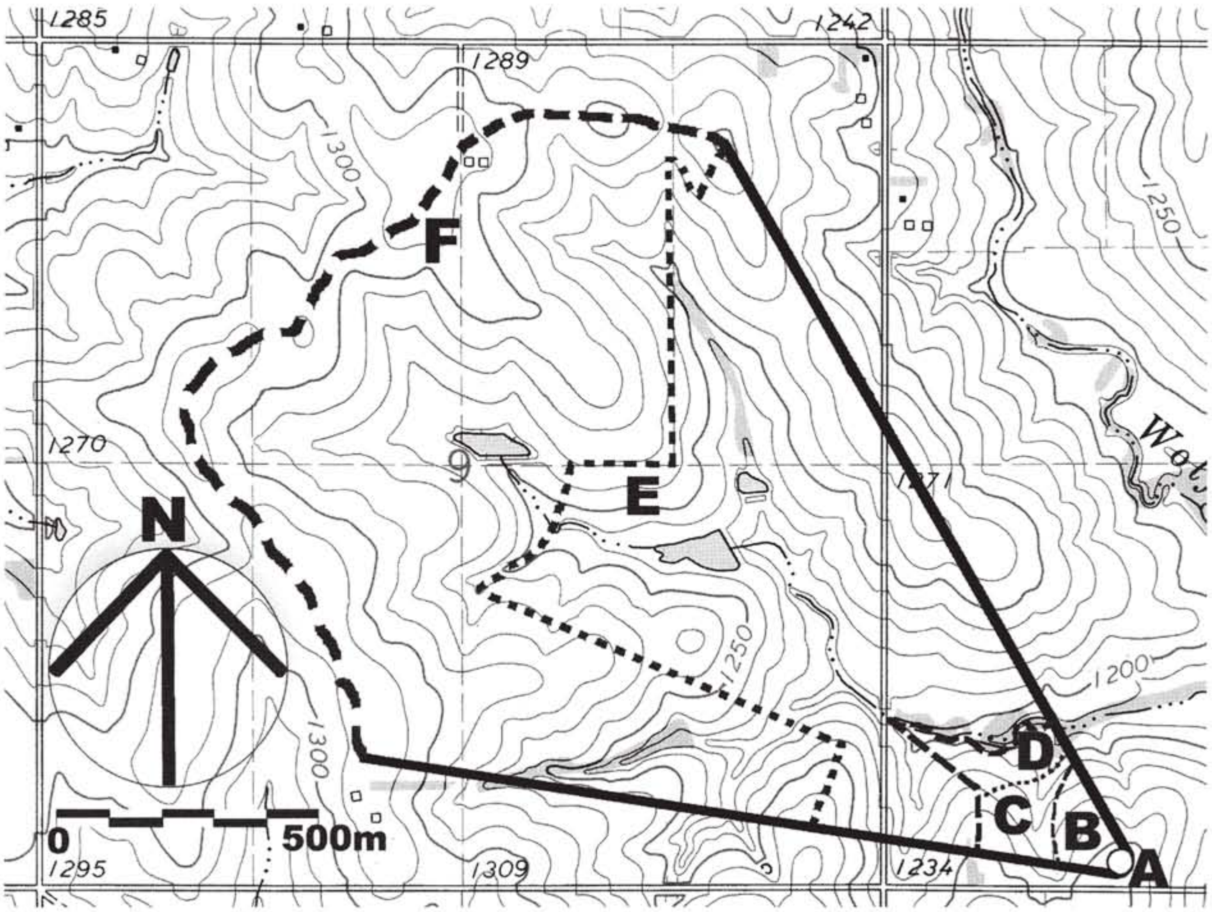


Figure 8. Planimetric view of landscape structure and a cone of vision are shown for a rural scene (USGS 1966). Boundaries are labeled as Boundary A through Boundary F and correspond to the landscape scenes in Figure 9.

enclosure to stop the eye and stabilize the focused view, say, to one such noted as boundary B. That is, the viewer would "scale up" to fit the grain suggested by the landscape structure. Continuing outward to boundary C, we see boundary B nested within it. So arranged hierarchically, the cornfield's stubble edge (B) is more easily seen and understood, because a true boundary's structure shows the differences between areas. The arc shown in each scene represents an imaginary border (A) of an arbitrary circular plot surrounding the viewpoint.

As we continue to deconstruct what is seen from the observer's viewpoint and move out through boundaries D, E, and F, we can see the roles that landscape structure, formed from breaks in the topography and barriers of vegetation, play in revealing and enclosing the visual landscape. The viewer may look outward through a series of nested landscape spaces quickly collapsing the view inward and expanding it again outward several times. At the completion of this process, the view will have become fixed in the viewer's mind, and one of the boundaries will dominate. It could be the horizon (boundary F), the riparian vegetation (boundary D), or the edge of the corn stubble (boundary B). The viewer will have settled upon a primary boundary; thus other perceived boundaries beyond form its context. The primary boundary defines the viewer's grain; boundaries more distant than the dominant one are a measure of the viewer's extent. Thus, for purposes of understanding the visual landscape's scale, we must consider both grain and extent.

Distance of View

Measures of grain and extent make it possible to quantify scale. Researchers have often employed distance of view (DOV) as a variable to describe a scene's scale (Hull and Buhyoff 1983; Gimblett et al. 1985; Gobster 1987; Ruddell et al. 1989). In these studies, DOV defines the distance a viewer could see. There is no accounting for a viewer affixing on a range of boundaries. Modification of the DOV to where the viewer identifies boundaries would

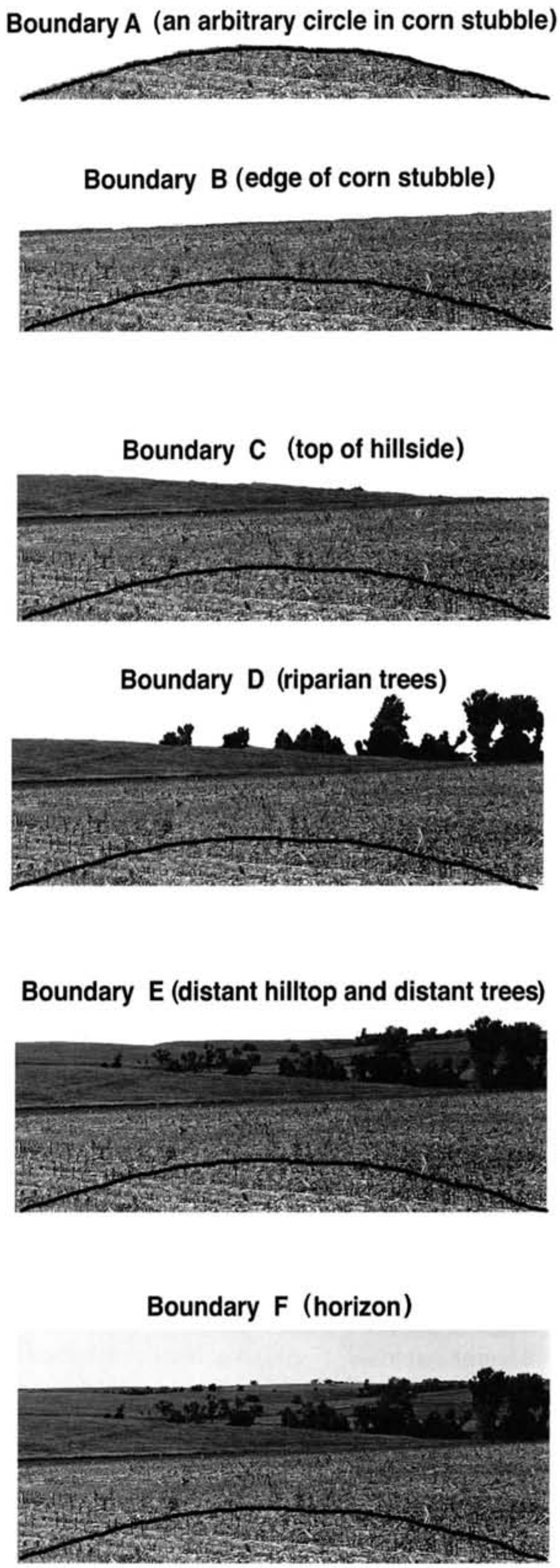


Figure 9. Deconstruction and delimitation of a view based on nested boundaries moving out from a viewpoint. Boundary locations, A through F, can be seen in Figure 8.

Figure 10. The horizon, distant tree lines, and ridges not only parse the landscape and visually structure this scene but also provide context that gives the view a sense of extent.

be a better indicator of scale, especially relative scale. It would convey more information about the observer's interpretation, and once marked on a photo, it could readily be measured in the field or from maps or aerial photographs. However, neither DOV, nor distance of view to a primary boundary (DOV-prime), alone determines scale. We also need a measure of extent, without which no reliable determination of a scene's context is possible. Boundaries identified by the viewer beyond DOV-prime can be used to determine the degree of nesting of grain within a given context (Fig. 10). This nested relationship between DOV-prime and number of boundaries beyond becomes relative, contextual, and hierarchical.

A MODEL RELATING LANDSCAPE AND VISUAL STRUCTURE WITH SCALE

Physical landscape structure can be defined as:

$$\textit{Landscape structure} = f(\textit{Boundaries}), \qquad (1)$$

where in rural landscapes,

$$\textit{Boundaries} = f\textit{Horizon} + (\textit{Topographic breaks} + \textit{Vegetative barriers} + \textit{Textural surfaces}). \qquad (2)$$

Vegetative boundaries occur as changes in land cover, enclosing walls, or overhead canopies. Large masses are readily identified whether near or far. Topographic breaks vary in size but are easily recognized even at a distance, for example, the horizon. Textural surfaces of the ground plane weakly define edges.

Although these boundaries are fixed and measurable physical elements, they are still open to interpretation

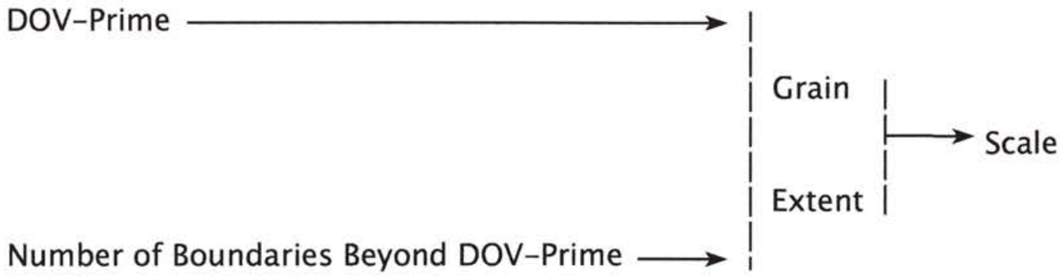


Figure 11. Hierarchical interaction of landscape structure components and modeled as scale.

(see Fig. 9). When viewers select a boundary, they select a scale where

$$Scale = f(Grain + Extent). \quad (3)$$

Grain and extent relate and interpret landscape structural boundaries. Scale can be defined by its grain and extent cued by boundaries that form its context.

Grain and extent can be delimited in sample photographic scenes of the landscape by two visual structure variables: (1) distance of view to the critical, viewer-identified primary boundary (DOV-prime) and (2) the number of boundaries identified beyond the DOV-prime in the scene by the viewer (Fig. 11).

Thus, we have the relation

$$Grain = f\ (DOV\text{-}prime). \quad (4)$$

Extent sets the context for grain and can be measured by the number of viewer-identified boundaries beyond the viewer-identified primary boundary (i.e., the more boundaries beyond the primary boundary, the greater the perceived extent):

$$Extent = f\ (Number\ of\ viewer\text{-}identified\ boundaries\ beyond\ DOV\text{-}prime). \quad (5)$$

Again, just as for grain, other factors are involved, such as the prominence of the horizon and orientation of the boundaries to the viewer. Where the existing boundaries cross perpendicular to the view, a greater extent is possible because the viewer sees more potential boundaries. Where boundaries tend to be parallel to the direction of view, the boundaries do not function as effectively as edges but function as visual corridors. Visual corridors tend to expand one's distance of view and thus increase the perceived scale of a landscape, just as a drainage corridor links and more closely connects nutrient flows in a landscape. Likewise, a prominent horizon means less enclosure increasing the likelihood of viewing at larger scale.

MATERIALS AND METHODS

Using the model in Figure 11, the author compared selected grains and extents present in photographs of rural scenes to determine how well the selected scales agreed with those determined by the viewers.

The materials used as stimulus sets were color slides and black-and-white photographs of rural landscape scenes. Landscape boundaries depicted in the scenes were measured in the field and from aerial photographs. The scenes were selected to represent the nine scale classes in a 3-by-3 matrix consisting of three levels of grain and three levels of extent (Table 1). They were photographed

TABLE 1
NINE ASSIGNED SCALE CLASSES FOR VARIOUS MODEL GRAIN AND EXTENT LEVELS

Grain[1]	Extent[2,3]	Scale class
$X_{DOV\text{-}prime} < 30$ m	$X_b \leq 1$	1
30 m $\geq X_{DOV\text{-}prime} \leq 400$ m	$X_b \leq 1$	2
$X_{DOV\text{-}prime} > 400$ m	$X_b \leq 1$	3
$X_{DOV\text{-}prime} < 30$ m	$1 \geq X_b \leq 2$	4
30 m $\geq X_{DOV\text{-}prime} \leq 400$ m	$1 \geq X_b \leq 2$	5
$X_{DOV\text{-}prime} > 400$ m	$1 \geq X_b \leq 2$	6
$X_{DOV\text{-}prime} < 30$ m	$X_b > 2$	7
30 m $\geq X_{DOV\text{-}prime} \leq 400$ m	$X_b > 2$	8
$X_{DOV\text{-}prime} > 400$ m	$X_b > 2$	9

[1] $X_{DOV\text{-}prime}$ is the distance to the boundary identified as primary.
[2] Less than 1 occurs where no boundaries occur beyond the primary one (DOV-prime).
[3] X_b is the total of viewer-identified boundaries beyond the one identified as primary.

Figure 12. Landscape scenes representing scale classes collected in Otoe County, Nebraska.

in the same rural Otoe County, NE, watershed during two weeks in June (Fig. 12). Representative samples of scenes from the scale classes are shown in Figure 13. To control potential researcher bias, a panel of experts reviewed a set of 100 landscape scenes to corroborate designated scale classes represented by grain and extent and their interaction scale.

Expert Panel

The expert panel consisted of two landscape architects and two geographers familiar with visual assessments and rural landscapes. They were given background readings on grain and extent that were discussed before viewing the sample scenes. Panelists were not informed about the grain and extent levels or of the scale classes used in taking specific photos. Each panel member was asked to sort the randomized stack of the 100 scenes into three separate piles representing large, medium, and small grain. The 100 scenes were then reshuffled, and panelists were asked a second time to place them into three piles representing large, medium, or small extent. Each scene's identification number and sort level were recorded. The panel suggested eliminating 34 scenes that did not fit the proposed scale classes, and it reclassified seven. Elimination occurred for several reasons: (1) the scene portrayed a corridor effect; (2) scenes were ambiguous across a range of boundary types (Fig. 14); (3) densities of boundaries were not consistently interpreted; and (4) the scenes had been misclassified.

Respondent Sampling

Respondents for the next procedure were university students and residents of rural areas and small towns near the area photographed. The University of Nebraska–Lincoln Institutional Review Board approved questions and procedures (IRB 93-9-22). The students were members of planning, architecture, geography, horticulture, and natural resources classes, and the residents were members of civic and school groups and garden club. Often groups exhibit characteristics that might influence their responses as a whole. So, groups were compared to check for unusual members by demographic variables collected from all respondents, including group identifier, age, gender, and a self-rating about knowledge, interest, and experience of the eastern Nebraska rural landscape. Purcell and Lamb (1984) found such data could be used to account for unusual variability in scene responses. The demographic variables were normally distributed across all respondents and across all groups.

Respondents first received instructions. Then black-and-white reproductions of the scenes were given to the respondents for marking during simultaneous projection of a color slide of the same scene. Next, they viewed one "warm-up" scene to clarify questions about the procedure. That clarification was followed by projection of a 27-scene slide set created by drawing and displaying at random three scenes from each of the nine scale classes. Three-hundred forty-eight respondents from 24 groups were asked to identify, mark, and rank the importance

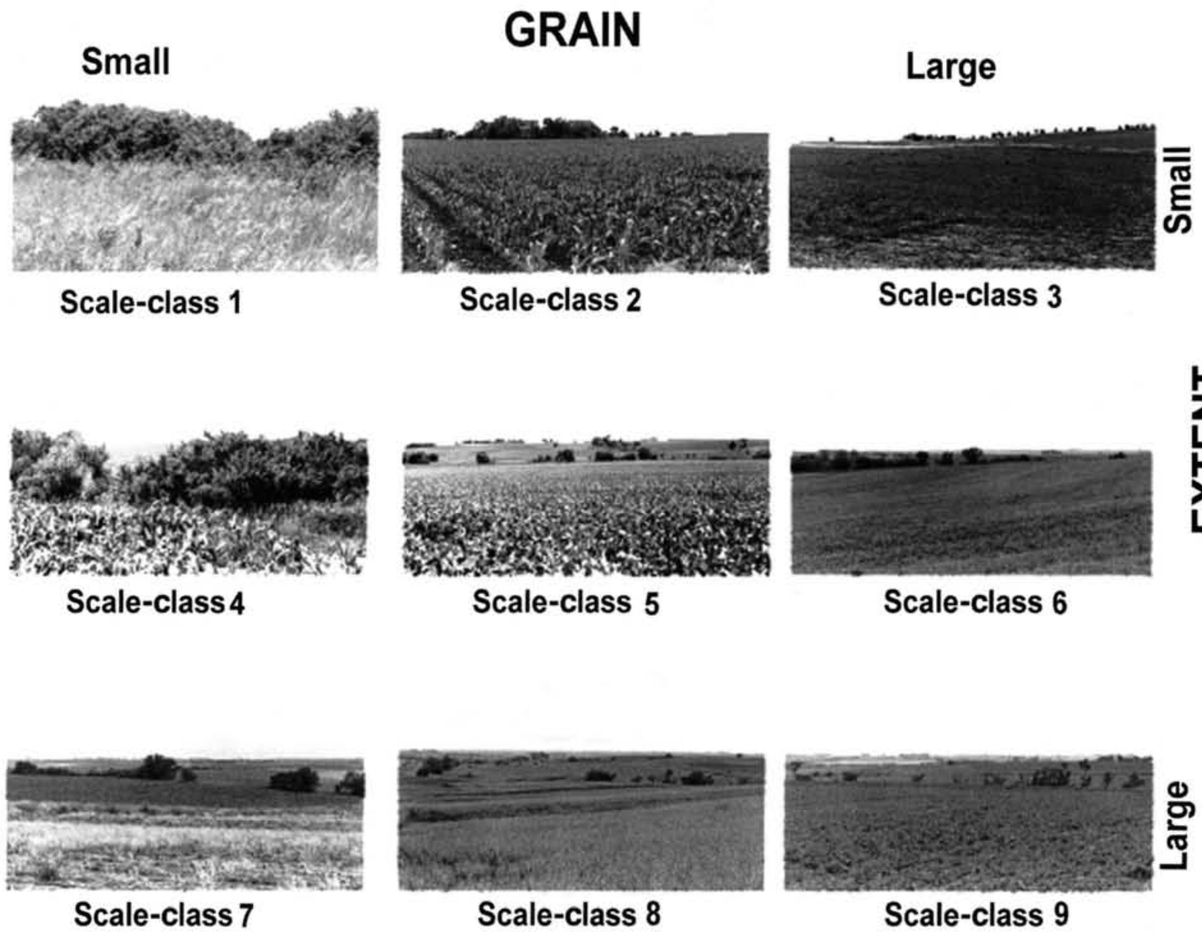


Figure 13. Examples of some landscape scenes used to depict various scale classes.

of boundaries found in each scene on black-and-white reproductions printed four to a page. First, respondents marked the boundaries of each succeeding space as one's view moved into the landscape depicted in the scene. After drawing the boundaries, respondents ranked them 1, 2, 3, 4, or 5, based on what they felt was the importance that each boundary exhibited in defining the boundary of a landscape scene's most important space or area, with 1 being most important. Over 9,000 responses were tabulated (Table 2).

RESULTS AND DISCUSSION

The respondents' scale classification for each scene was synthesized by comparing their perceived DOV-prime (grain size) and number of boundaries they marked beyond the DOV-prime (extent). These were aggregated as a variable called perceived scale class (P-scale) and then cross-tabulated and compared with the scale class set by the researcher (i.e., the model). Respondent-perceived scale classes were compared to those designated by the model using an appropriate categorical statistical program, Procedure CATMOD (SAS Institute 1990), with contrasts to test for statistically significant relationships. If the model of scale class derived from grain and extent perfectly matched those perceived by the respondents, the corresponding P-scale correspondence would be 100%.

Figure 15 delineates all scale-class versus P-scale designations and shows several trends. The P-scale distributions with the exception of 7, 8, and 9 do not appear to be normal curves. Larger classes such as 5, 8, and 9 did not have good correspondence between the P-scale class and the researcher-designated scale class. However, in most others a plurality of respondents' P-scale class agreed with the researcher-designated scale class. There was no significant difference between scale class 4 and P-scale 4.

Figure 14. A "corridor" effect frames distant landscape features, cuts across boundaries, and reduces the visual scale of a scene.

TABLE 2
NUMBERS OF RESPONSES PER SCALE CLASS

Scale class	Count
1	1,174
2	1,160
3	803
4	1,166
5	1,006
6	713
7	1,170
8	1,056
9	1,148
Total	9,396

For scale class 1 scenes (Fig. 16), more than 40% of respondents agreed with the model (Fig. 15A). The next closest level, at 32%, represents responses shifted up one extent level to scale 4. P-scale 1 versus P-scale 4 had a chi-square of 1,044 and $p < 0.0001$. Though scale class 1 scenes were selected to have a structure of small grain and extent, the viewers appear to have seen a closer primary boundary and thus increased the extent. Interestingly, no respondents saw the scenes as containing large grains found in scales 3, 6, and 9, and only a few found the grain larger, which would move their responses into P-scales 2, 5, or 7.

For scale class 2 scenes (Fig. 17), 60% of the respondents agreed with the model scale class (Fig. 15B). P-scale 2 versus P-scale 5 had a chi-square of 107 and $p < 0.0001$. Like the preceding class, a similar shift up in extent level occurred to P-scale 5 with about 30% of respondents.

For scale class 3 scenes (Fig. 18), 50% of respondents agreed with the model (Fig. 15C). The next closest level, at 25%, was shifted down one extent level to P-scale 2. P-scale 3 versus P-scale 2 had a chi-square of 59.5 and $p < 0.0001$. Though scale class 3 scenes were selected to have a structure of large grain and small extent, some viewers appeared to have seen a closer primary boundary but did not perceive increased extent by noting boundaries beyond the one designated most important. A similar though dampened trend was found in the first two scale classes where about 12% of respondents shift up one extent level. Few respondents saw the scenes as containing the small extents found for scale classes 1, 4, or 7.

For scale class 4 scenes (Fig. 19), 38% of respondents agreed with the model (Fig. 15D). This was followed closely by the P-scale 7 level, at 36%, in an apparent repeat of the pattern of shifting up one extent level in scale classes 1 and 2. P-scale 4 versus P-scale 7 had a chi-square of 0.27 and $p < 0.6121$, and therefore were not significantly different. Though scale class 1 scenes were selected to have a structure of small grain and extent, the viewers appeared to have seen a closer primary boundary and thus increased the extent. However, no respondents saw the scenes as containing large grains found in scale class 9, and few found them for scale classes 2, 3, 5, or 6. Perception of grain size is apparently very stable at this scale.

For scale class 5 scenes (Fig. 20), only 17% of the respondents agreed with model (Fig. 15E), and like the preceding one, scale class 5, the respondents had a similar shift up in distribution of responses in extent level to P-scale 8. However, 35% of the respondents saw larger grain size in the scene and selected P-scale 6. P-scale 5 versus P-scale 6 had a chi-square of 59.4 and $p < 0.0001$, but in the opposite direction. Some, 17% of respondents, saw smaller extent and larger grain, thus moving their responses to scale class 3. These two trends may be the result of selecting a larger, more distant DOV-prime that subsumes a boundary and reduces extent to P-scale 3. Likewise, 10% of respondents saw more extents and thus selected P-scale 8, and 15% selected P-scale 9 (15%). Few respondents saw other P-scale classes, and none saw small grain and extents of P-scale 1.

For scale class 6 scenes (Fig. 21), only 27% of respondents agreed with the model (Fig. 15F). The next closest levels were at 24% for P-scale 3 and 19% for P-scale 9. P-scale 6 versus P-scale 3 had a chi-square of 1.44

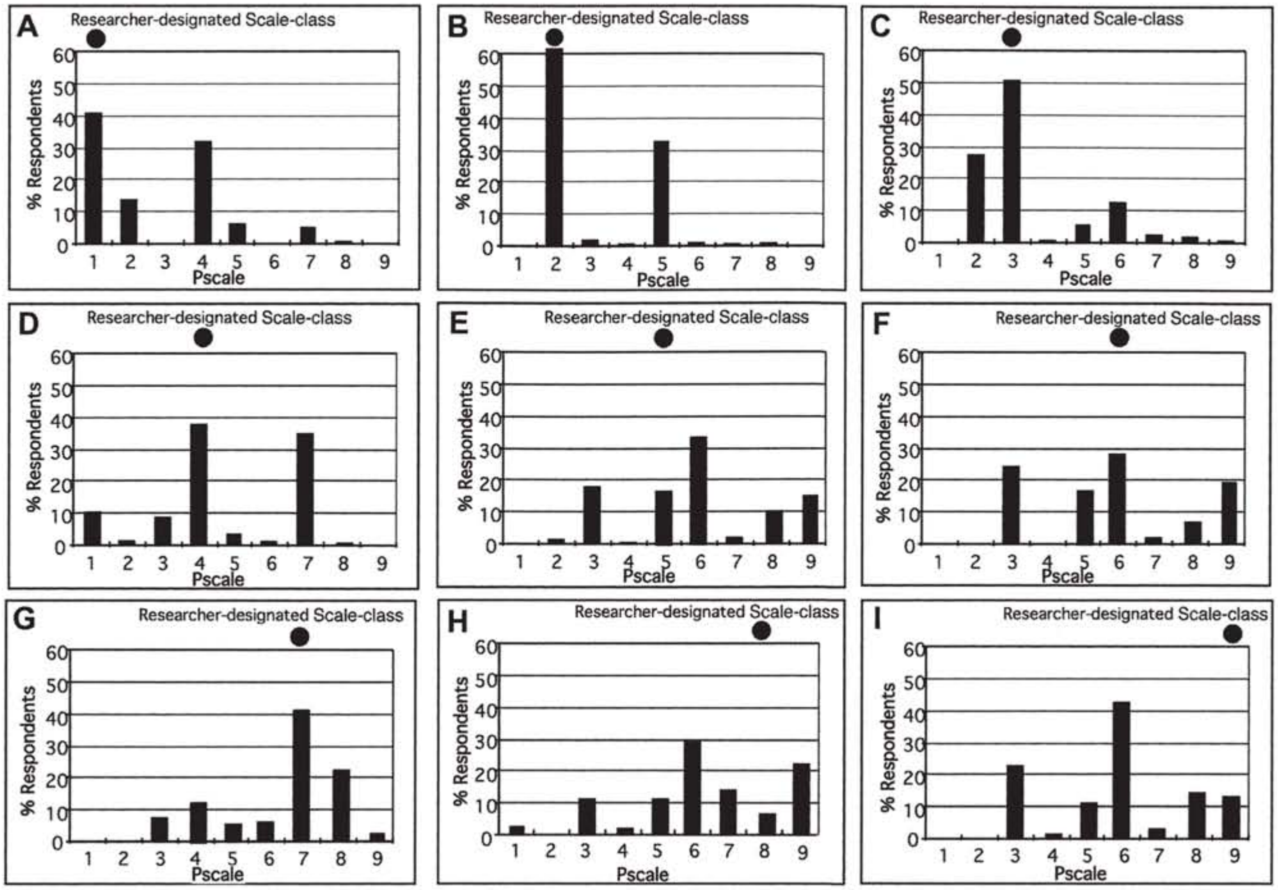


Figure 15A–I. Percentage of respondents' perceived scale (P-scale) classes versus researcher-designated scale class used in the human-scale model.

and $p < 0.23$. Thus, there is not a significant difference between responses of P-scale 6 and P-scale 3. Though scale class 6 scenes were selected to have a structure of large grain and moderate extent, some viewers shifted down one extent level. This would have happened if the viewer designated a DOV-prime farther into the scene. Larger grains potentially offer more choices for defining boundaries. Few respondents saw the scenes as containing small extents found for scale classes 1, 4, or 7. None saw moderate grain with small extent present for scale class 2. A trend similar to that found in the first two scale classes showed about 19% of respondents shifting up in extent level to P-scale 9.

For scale class 7 scenes (Fig. 22), over 40% of the respondents agreed with the model (Fig. 15G). Twenty-two percent of respondents shifted up in extent and saw P-scale 8. No viewers saw small extent or grain sizes. A few saw scale classes 3, 4, 5, 6, or 9. P-scale 7 versus P-scale 8 had a chi-square of 64.9 and $p < 0.0001$.

For scale class 8 scenes (Fig. 23), only 6% of the respondents agreed with the model's (Fig. 15H) designated moderate grain and large extent. P-scale 8 versus P-scale 6 had a chi-square of 191 and $p < 0.0001$, but in the wrong direction. Few viewers saw small extent or grain sizes in scale classes 1, 2, or 4. However, over 10% of the viewers saw P-scales 3, 5, 6, 7, or 9. As with scale class 5, there appears to be more choice of boundaries to select as the primary one, and this factor decreased grain size or increased extent level.

For scale class 9 scenes (Fig. 24), many respondents either dropped a grain level to scale class 8 or dropped an extent level to scale class 6, different from the model (Fig. 15I). P-scale 9 versus P-scale 6 had a chi-square of 650.7 and $p < 0.0001$, but in the wrong direction. For this scene, 23% saw the large grain but only a limited extent, the horizon. No respondents saw these scenes as small grained or limited in extent. P-scales 1 and 2 had no responses and P-scales 4, 5, and 7 less than 4% each.


Figure 16. Example scene of scale class 1


Figure 17 Example scene of scale class 2.


Figure 18. Example scene of scale class 3.

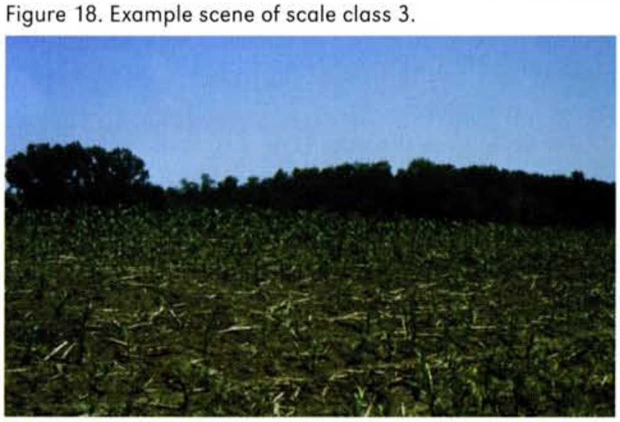


Figure 19. Example scene of scale class 4.


Figure 20. Example scene of scale class 5.


Figure 21 Example scene of scale class 6.


Figure 22. Example scene of scale class 7

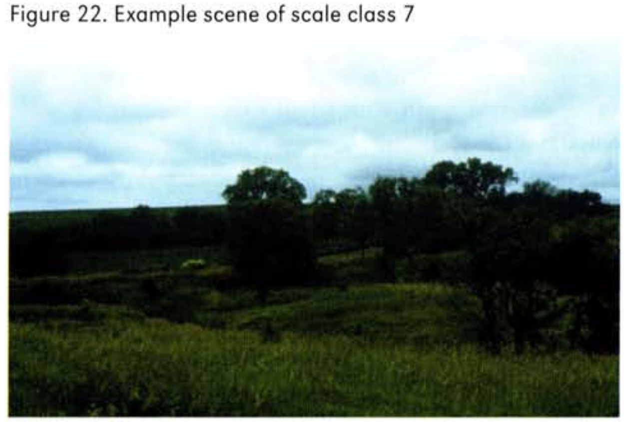


Figure 23. Example scene of scale class 8.

Figure 24. Example scene of scale class 9.

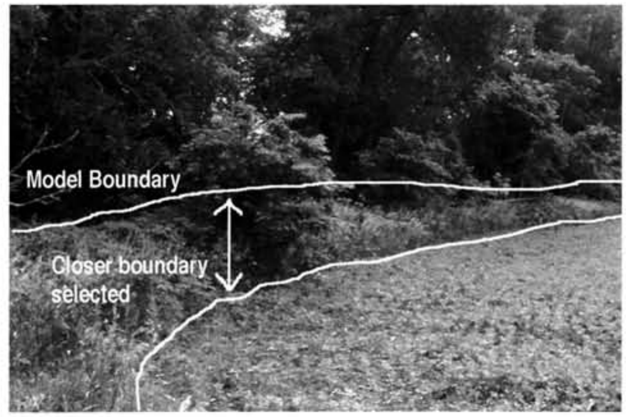


Figure 25. The foreground effect occurs when a closer boundary is selected as most important.

CONCLUSIONS

Relationships between the model and perceived scale in Figures 15A–I suggest that scalar characteristics, grain, and extent can be described and tied to a human scale. Significantly more respondents agreed on close, defined spaces shown in scenes from scale classes 1, 2, 3, and 7. However, Figures 15E, 15H, and 15I also indicate that we humans may have a limit to our visual scaling ability. This limit may dampen our perception of and connection to distant boundaries in space. The agreement between P-scale classes and scale classes 1, 2, 3, and 7 suggests the restrictions from enclosure and from the view beyond were successful in constraining responses. However, as extent or extent and grain increase, the opportunity for different interpretations also increases and predictability wanes. At the middle ranges of grain and extent found in scale classes 5, 6, 8, and 9, many respondents simply did not perceive large, distinct differences.

In management of landscape resources and their visual consequences, Litton (1968) has noted the importance of what he called "middle ground views." The middle ground links close and distant impressions of a landscape. This study suggests that as viewers' attention moves from fore- to middle to background views (a process that is tantamount to scaling), their ability to recognize changes in the landscape diminishes. The visual structure and associated human-scale responses to middle-ground landscape as detected in the model may also fall into a class of middle-number systems. Allen and Hoekstra (1992) note that middle-number systems often defy prediction because they contain too many variables to model and too few to average.

Generally, it appears that smaller-scale changes in landscapes do make a difference in the similarity of some human responses. Humans may tend to restructure the pattern of the landscape partially to satisfy those responses and thus not include a scale of structure appropriate for other organisms. Therefore, if changes in landscape do not account for our penchant for a human scale, then such schemes may fail to gain acceptance.

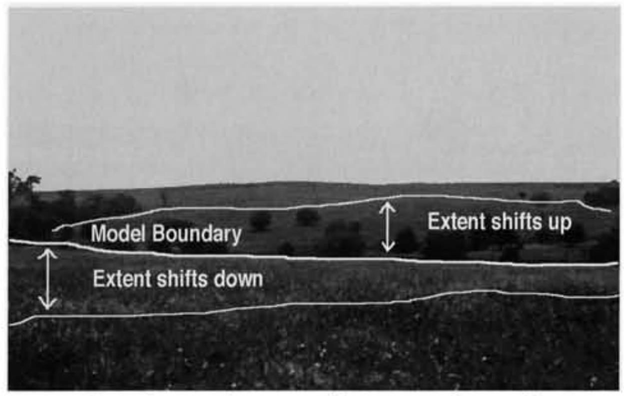


Figure 26. Mid-ground extent effects come from selecting a closer boundary.

To summarize what was found:

- Good agreement with the model occurred with P-scale in scale classes 1, 2, 3, and 4. Disagreement with the model can be called a "foreground effect," where extent shifts up due to seeing a closer boundary because the foreground is too variable. Ground textural differences likely come into play (Fig. 25).
- Fair agreement with the model occurred with P-scale in scale class 6. Disagreement with the model can be called a "mid-ground extent effect," where extent shifts up due to selecting a closer boundary or shifts down due to selecting a more distant boundary (Fig. 26).
- Good agreement with the model occurred with P-scale in scale class 7. Disagreements with the model could

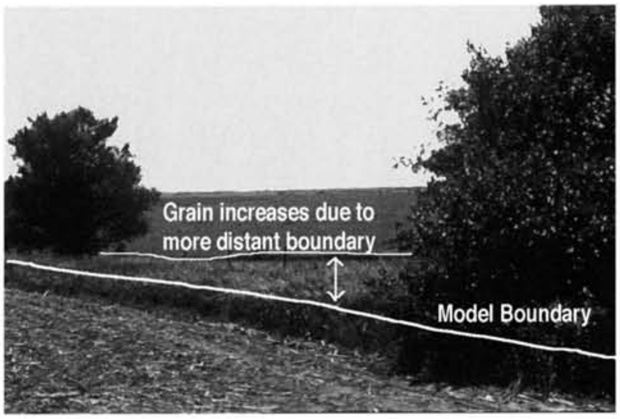


Figure 27. Mid-ground grain effects occur when grain shifts up.

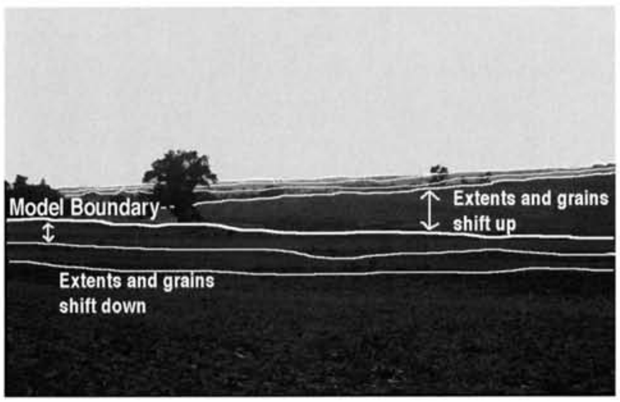


Figure 28. The background effect occurs from a complex interaction of grain and extent.

be called a "mid-ground grain effect," where grain shifts up due to selecting a farther boundary since more boundaries are available, possibly due to ground textural differences (Fig. 27).

- Poor agreement with the model occurred with P-scale in scale classes 5, 8, and 9. It is likely due to what could be called "background effects," where complex interaction of both mid-ground extent and mid-ground grain effects probably occurred. Here the variety of scene grains and extents makes prediction harder (Fig. 28).

This study suggests that plans for major manipulations in rural landscapes, such as clearing or planting windbreaks and hedgerows, consolidating fields, building new roads, siting rural electrical transmission lines, and creating riparian buffers, among others, are subject to the filter of human response to scale. This filter is implicit in visual preference studies that are a part of documentation in major environmental impacts. It is quite possible that a portion of visual preference assigned to the quality of landscape results from our predilection for human scale.

ACKNOWLEDGMENTS

This paper was substantially improved by the comments of two anonymous reviewers. Joan Nassauer, Steve Rodie, Gary Bentrup, and Dave Mortenson commented on earlier drafts. Ann Parkhurst and Steve Westerholt provided help with parsing data and analyzing statistics.

REFERENCES

Ahl, V., and T.H.F. Allen. 1996. *Hierarchy Theory: A Vision, Vocabulary, and Epistemology*. Columbia University Press, New York.

Allen, T.H.F., and T. Hoekstra. 1992. *Toward a Unified Ecology*. Columbia University Press, New York.

Allen, T.H.F., A.W. King, B.T. Milne, A. Johnson, and S. Turner. 1993. The problem of scaling in ecology. *Evolutionary Trends in Plants* 7:3–8.

Barrett, G., and P.J. Bohlen. 1991. Landscape ecology. In *Landscape Linkages and Biodiversity*, ed. W. Hudson, 149–61. Island Press, Washington, DC.

Bhakuni, K. 2000. Resource quest in the Himalayan scenery. *IALE Bulletin* 18:1.

Brown, T.C. 1994. Conceptualizing smoothness and density as landscape elements in visual resource management. *Landscape and Urban Planning* 30:49–58.

Cadenasso, M.L., S.T.A. Pickett, K.C. Weaver, and C.G. Jones. 2003. A framework for a theory of ecological boundaries. *BioScience* 53:750–58.

Coeterier, J.F. 1994. Cues for the perception of the size of space in landscapes. *Journal of Environmental Management*. 42:333–47.

Coeterier, J.F. 1996. Dominant attributes in the perception and evaluation of the Dutch landscape. *Landscape and Urban Planning* 34:27–44.

Daniel, T.C. 2001. Whither scenic beauty? Visual landscape quality assessment in the 21st century. *Landscape and Urban Planning* 54:267–81.

Déjeant-Pons, M. 2007. The European Landscape Convention. *Landscape Research* 31:363–84. DOI: 10.1080/01426390601004343.

Eaton, M. 1997. The beauty that requires health. In *Placing Nature: Culture and Landscape Ecology,* ed. J. Nassauer, 85–108. Island Press, Washington, DC.

Fabos, J.G., W.G. Hendrix, and C.G. Greene. 1975. Visual and cultural components of the landscape resource assessment model of the METLAND study. In *Landscape Assessment,* ed. E.H. Zube, R.O. Brush and J.G. Fabos, 319–43. Dowden, Hutchinson, and Ross, Stroudsburg, PA.

Fedorowick, J.M. 1993. A landscape restoration framework for wildlife and agriculture in the rural landscape. *Landscape and Urban Planning* 27:7–17.

Forman, R.T.T., and M. Godron. 1986. *Landscape Ecology*. Wiley, New York.

Gibson, J.J. 1986 [1979]. *The Ecological Approach to Visual Perception*. Lawrence Erlbaum Associates, Hillsdale, NJ.

Gimblett, H.R., R.M. Itami, and J.E. Fitzgibbon. 1985. Mystery in an information-processing model of landscape preference. *Landscape Journal* 4:87–95.

Gobster, P. 1987. Properties of aesthetic preference for rural landscapes. PhD diss., University of Wisconsin–Madison.

Gobster, P., 1993. The aesthetic experience of forest ecosystems. In *Sustainable Ecological Systems: Implementing An Ecological Approach to Land Management*, ed. W.W. Covington and L.F. DeBano, 246–55. USDA-USFS General Technical Report, RM 237 July 12–15, Flagstaff, AZ.

Gobster, P., J. Nassauer, T. Daniel, and G. Fry. 2007. The shared landscape: What does aesthetics have to do with ecology? *Landscape Ecology* 22:959–72.

Grinde, K., and A. Kopf. 1986. Illustrated glossary. In *Foundations for Visual Project Analysis*, ed. R. Smardon, J. Palmer, and J. Felleman, 307–34. Wiley, New York.

Hammitt, W.E. 1988. Visual and management preferences of sightseers. In *Visual Preferences of Travelers along the Blue Ridge Parkway*, ed. F.P. Noe and W.E. Hammitt. Scientific Monograph Series No. 18. USDI-NPS. U.S Government Printing Office, Washington, DC.

Harvey, D.W. 1968. Pattern, process, and the scale problem in geographical research. *Transactions of the Institute of British Geographers* 45:71–78.

Henderson, J.M., and A. Hollingworth. 1999. High-level perception. *Annual Review of Psychology* 50:243–71.

Hull, R.B. IV, and G.J. Buhyoff. 1983. Distance and beauty: A non-monotonic relationship. *Environment and Behavior* 15:77–91.

Iverson, W.D. 1985. And that's about the size of it: Visual magnitude as a measurement of the physical landscape. *Landscape Journal* 4:14–22.

Kaplan, R., and S. Kaplan. 1989. *The Experience of Nature: A Psychological Perspective*. Cambridge University Press, Cambridge, UK.

Kosslyn, S.M. 1994. *Image and Brain*. MIT Press, Boston.

Litton, B.R. 1968. *Forest Landscape Description and Inventories: A Basis for Land Planning and Design*. USDA Forest Service Research Paper PSW-49, Berkeley, CA.

Lock, G.R., and Molyneaux, B. 2006. *Confronting Scale in Archaeology: Issues of Theory and Practice*. Springer-Verlag, New York.

Lyle, J. 1985. *Design for Human Ecosystems*. VNR, New York.

McCarthy, M.M. 1979. Complexity and valued landscapes. In *Our National Landscape*, ed. R. Smardon and G.H. Elsner, 235–40. USFS General Technical Report PSW-35, Berkeley, CA.

Meentemeyer, V., and E.O. Box. 1987. Scale effects in landscape studies. In *Landscapes, Heterogeneity, and Disturbance,* ed. M. Turner, 15–34. Springer-Verlag, New York.

Montello, D.R. 1993. Lecture notes in computer science. In *Spatial Information Theory: A Theoretical Basis for GIS,* ed. A.U Frank and I. Compari, 312–21. Springer, Berlin.

Montello, D.R. 2001. Scale in geography. In *International Encyclopedia of the Social and Behavioral Sciences,* ed. N.J. Smelser and P.B. Baltes. Pergamon, Oxford, UK.

Nassauer, J. 1995. Culture and changing landscape structure. *Landscape Ecology* 10:229–38.

Nassauer, J., ed. 1997. *Placing Nature: Culture and Landscape Ecology*. Island Press, Washington, DC.

NEPA. 1969. The National Environmental Policy Act of 1969 as amended. http://ceq.hss.doe.gov/nepa/regs/nepa/nepaeqia.htm (accessed September 27, 2010).

Purcell, A. T. and R. J. Lamb. 1984. Landscape Perception: An examination of two central issues in the area. *Journal of Environmental Management*. 19(1):31–63.

Ruddell, E.J., J.H. Gramann, V.A. Rudis, and J.M. Westphal. 1989. The psychological utility of visual penetration in near-view forest scenic-beauty models. *Environment and Behavior* 21:393–412.

SAS Institute. 1990. *SAS/STAT User's Guide*, Version 6, 4th ed. SAS Institute, Cary, NC.

Schauman, S. 1988a. Countryside and scenic assessment: Tools and an application. *Landscape and Urban Planning* 15:40–46.

Schauman, S. 1988b. Scenic value of countryside landscapes to local residents: A Whatcom County, Washington, case study. *Landscape Journal* 7:227–39.

Schauman, S., and M.B. Pfender. 1982. An assessment procedure for countryside landscapes. University of Washington Department of Landscape Architecture, Seattle.

Schneider, D.C. 1994. *Quantitative Ecology.* Academic Press, London.

Schyns, P.G., and A. Oliva. 1994. From blobs to boundary edges: Evidence for time- and spatial-scale-dependent scene recognition. *Psychological Science* 5:195–200.

Stiles, R. 1994. Landscape theory: A missing link between landscape planning and landscape design. *Landscape and Urban Planning* 30:139–49.

Sutton, R.K. 1997. Scale in the aesthetic assessment of landscapes. PhD diss., University of Wisconsin–Madison.

Swaffield, S. 2005. Landscape and public policy: Issues of scale. In *Our Shared Landscape,* ed. E. Lange and D. Miller, 109–10. Proceedings of a Conference at Ascona, Switzerland, May 2–6, 2005, Swiss Federal Institute of Technology, ITH Zurich.

Swaffield, S., and J. Primdahl, 2006. Spatial Concepts in Landscape analysis and policy: Some implications of globalization. *Landscape Ecology* 21:315–31.

Thorne, J.C., and S. Huang, 1991. Minimizing conflicts between ecological integrity and viewshed quality by using the landscape ecological aesthetic. *Abstracts of the World Congress of Landscape Ecology.* Carleton University, Ottawa, Canada.

Toth, R.E. 1988. Theory and language in landscape analysis, planning, and evaluation. *Landscape Ecology* 1:193–201.

Turner, S.J., R.V. O'Neill, W. Conley, M.R. Conley, and H.C. Humphries. 1991. Pattern and scale: Statistics for landscape ecology. In *Quantitative Methods in Landscape Ecology,* ed. M. Turner and R.H. Gardner, 17–50. Springer-Verlag, New York.

Tveit, M., A. Ode, and G. Fry. 2006. Key concepts in a framework for analysing visual landscape character. *Landscape Research* 31:229–55.

USGS (U.S. Geological Survey). 1966. Elmwood, Nebraska, Quadrangle. N4045-W9615/7.5.

Wiens, J. 1989. Spatial scaling in ecology. *Functional Ecology* 3:385–97.

Wiens, J. 1992. What is landscape ecology, really? *Landscape Ecology* 7:149–50.

Wiens, J. 2005. Toward a unified landscape ecology. In *Issues and Perspectives in Landscape Ecology,* ed. J. Wiens and M. Moss, 365–73. Cambridge University Press, Cambridge, UK.

Zube, E.H., D. Pitt, and T.W. Anderson. 1975. Perception and prediction of scenic resource values of the northeast. In *Landscape Assessment,* ed. E.H. Zube, R.O. Brush, and J.G. Fabos, 151–67. Dowden, Hutchinson, and Ross, Stroudsburg, PA.

Zube, E.H., J.L. Sell, and J.G. Taylor, 1982. Landscape perception: Research, application, and theory. *Landscape Planning* 9:1–33.

Great Plains Research 21 (Fall 2011):231–43
2011 Published by the Center for Great Plains Studies, University of Nebraska–Lincoln

ECOREGIONAL DIFFERENCES IN LATE-20TH-CENTURY LAND-USE AND LAND-COVER CHANGE IN THE U.S. NORTHERN GREAT PLAINS

Roger F. Auch and **Kristi L. Sayler**

U.S. Geological Survey
Earth Resources and Observation Science Center (EROS)
47914 252nd Street
Sioux Falls, SD 57198
auch@usgs.gov

Darrell E. Napton

South Dakota State University
Geography Department
Box 504, Scobey Hall SSB232
Brookings, SD 57007

Janis L. Taylor

SGT, Contractor to the U.S. Geological Survey
Earth Resources and Observation Science Center (EROS)
47914 252d St.
Sioux Falls, SD 57198

and

Mark S. Brooks

U.S. Geological Survey
Eastern Geographic Science Center
12201 Sunrise Valley Drive
Reston, VA 20192

ABSTRACT—Land-cover and land-use change usually results from a combination of anthropogenic drivers and biophysical conditions found across multiple scales, ranging from parcel to regional levels. A group of four Level III ecoregions located in the U.S. northern Great Plains is used to demonstrate the similarities and differences in land change during nearly a 30-year period (1973–2000) using results from the U.S. Geological Survey's Land Cover Trends project. There were changes to major suites of land-cover; the transitions between agriculture and grassland/shrubland and the transitions among wetland, water, agriculture, and grassland/shrubland were affected by different factors. Anthropogenic drivers affected the land-use tension (or land-use competition) between agriculture and grassland/shrubland land-covers, whereas changes between wetland and water land-covers, and their relationship to agriculture and grassland/shrubland land-covers, were mostly affected by regional weather cycles. More land-use tension between agriculture and grassland/shrubland land-covers occurred in ecoregions with greater amounts of economically marginal cropland. Land-cover change associated with weather variability occurred in ecoregions that had large concentrations of wetlands and water impoundments, such as the Missouri River reservoirs. The Northwestern Glaciated Plains ecoregion had the highest overall estimated percentage of change because it had both land-use tension between agriculture and grassland/shrubland land-covers and wetland-water changes.

Key Words: Northern Great Plains, land cover, land-use change, land-use tension, weather variability

Manuscript received for review, January 2011; accepted for publication, July 2011.

INTRODUCTION

The Great Plains of North America extends from south-central Canada through northeast Mexico, with a majority of the region within the United States. This region of semiarid and subhumid grasslands and shrublands is bounded by the Rocky Mountains to the west and broad transition zones on the north, south, and particularly the east, where long-term wet and dry periods may alter the best economic use of the land. Thus, the area extent of what is included in the Great Plains has been the subject of debate (Rossum and Lavin 2000).

Early definitions of the Great Plains focused upon natural vegetation and climate (Webb 1931; Borchert 1950). More recent definitions and descriptions are characterized by the region's major economy and land use (Borchert 1987; Riebsame 1990; Gutmann et al. 2005; Parton et al. 2007). Most such treatments of the Great Plains tend to view the region in its entirety and potentially miss subregional biophysical and human conditions that may substantially impact contemporary land use at a finer geographical scale. Gutmann et al. (2005:85) stated that the balance between cropland and pasture in the Great Plains remained "virtually stable" between the 1920s and 1990s, but Drummond (2007) indicated that cropland gained an estimated 5,159 km^2 from grassland/shrubland between 1973 and 1980 in just two large Level III ecoregions (Omernik 1987) that cover 324,274 km^2. The use of the scale of an individual state can also mask finer-scale area changes. Hiller et al. (2009) present a detailed accounting of agricultural land change across Nebraska's history but never identify what subregions of the state changed the most or changed the least from presettlement conditions.

The use of large-scale analysis may also generalize conditions that are important to land use in one subregion and not be a leading factor in another. Irrigated cropland is a major component of land use in the central and southern Great Plains and issues dealing with such water use are needed in any discussion of the broader region (Riebsame 1990; Parton et al. 2007). Land use in the northern Great Plains, such as in the Dakotas, relies little on irrigation, and drivers affecting irrigation elsewhere may not be a factor influencing land change in this part of the Great Plains. A similar situation arises with the impacts of urbanization within the Great Plains. Urban growth in the Colorado Front Range impacts land use in the adjacent Great Plains (Parton et al. 2003). Other metropolitan areas within the larger region may also experience similar conditions (Parton et al. 2007). Urbanization, however, is not much of an issue in the Northern Plains, and land dynamics associated with these processes have had little impact on this subregion.

Although Great Plains land use is primarily agriculturally dominated, either by crop or grazing land, and contemporary land-cover and land-use change mostly reflect these major uses, there are regional differences that include other land covers and uses (Drummond and Auch 2010). The Northern Plains has noticeable amounts of surface water, ranging from the large Missouri River reservoirs to hundreds of glacial lakes to tens of thousands of human-made livestock watering impoundments. This subregion of the Great Plains also has substantial amounts of wetland cover that differentiates it from much of the overall larger region. Changes associated with these land covers range from those that are induced by partially anthropogenic–partially interannual weather variability (i.e., farming temporary or seasonal wetlands when possible, dealing with persistently flooded former agricultural land, managing the water storage of the Missouri River reservoirs) to those that are induced much more by climatic variability (i.e., water to wetland land-cover or wetland land-cover to water). These types of changes tend to be lost in discussions about land changes in the greater Great Plains region.

One of our goals is to demonstrate that at the intermediate scale of U.S. EPA Level III ecoregions, change in amounts and types of contemporary land use and land cover occurred across a subregion of the Great Plains, driven and influenced by an interweaving of biophysical and human conditions. We chose four ecoregions found in the Northern Plains because they provide an east-to-west transect from the humid, tallgrass prairie to the semiarid shortgrass prairie. These ecoregions also provide an opportunity to compare and contrast glaciated Great Plains ecoregions with a nonglaciated ecoregion. This is different from Drummond (2007), who compared two semiarid shortgrass-prairie, nonglaciated ecoregions. The major difference in that study was the heavy irrigation in one of the ecoregions compared to the other. Our Northern Plains study examines contemporary land change across both a precipitation gradient and substantial differences in soil capacity for cropping.

Our other goal is to explore how the biophysical and human drivers change across the study period. A single anthropogenic driver may not impact even smaller regions the same across time. Human drivers heavily influence "land-use tension" (or competition among land uses) where competition is possible. Short-term climatic variability (interannual weather cycles) also produce temporal pulses that influence changes in land use and more

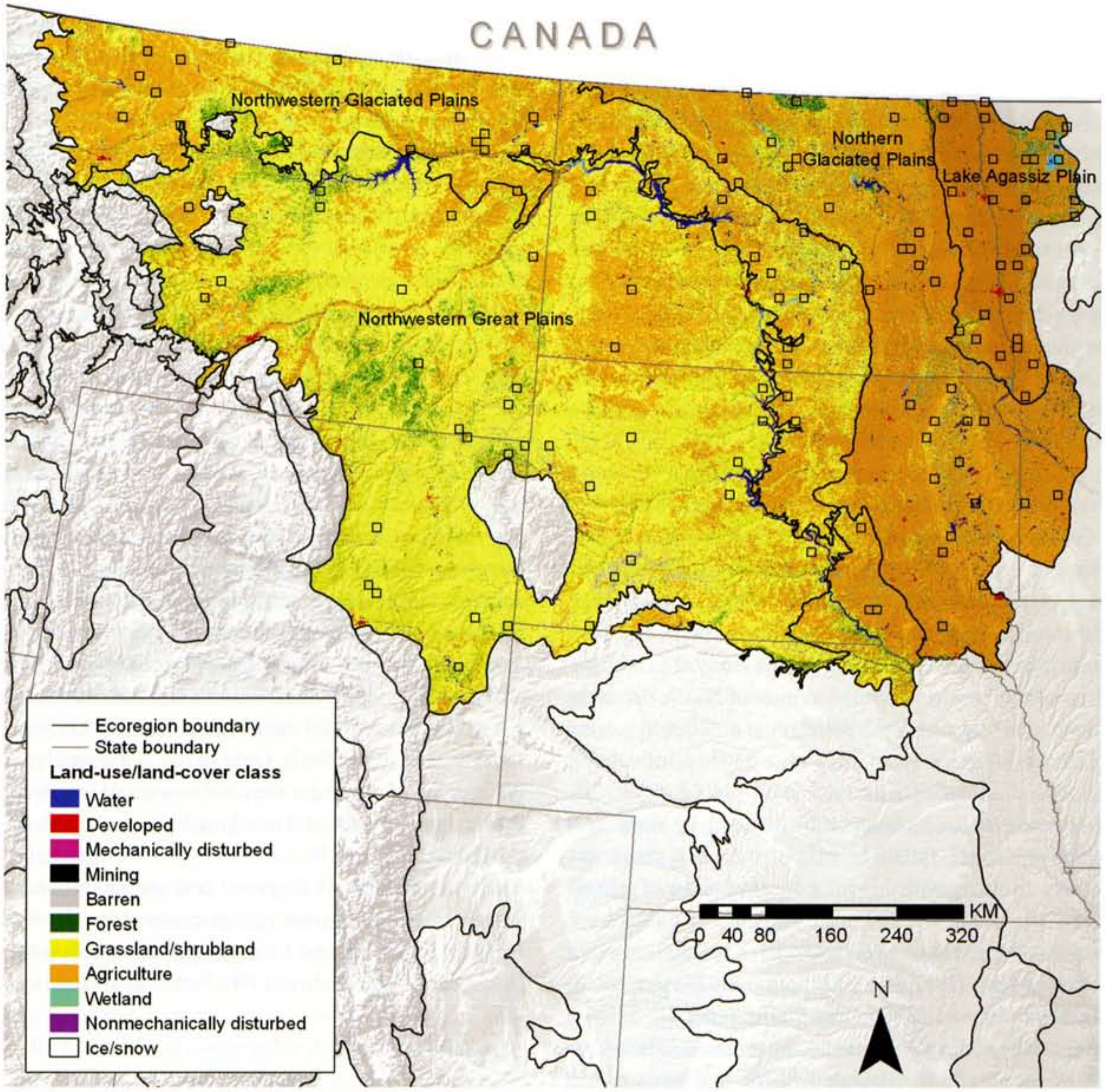


Figure 1. U.S. Northern Great Plains Level III ecoregions and land cover. The Land Cover Trends sample blocks are the hollow squares seen across the ecoregions.

directly land-cover relationships among water, wetland, agriculture, and grassland/shrubland. The Northern Plains provides a good case study in which to observe these types of land changes.

We examine recent land changes in the Northern Plains by using a number of sources. Thematic and spatial land-cover and land-use data are from the U.S. Geological Survey's Land Cover Trends project. The study period is from 1973 to 2000, the length of the Landsat satellite observation record when the Land Cover Trends project was initiated. The USGS data will be augmented with a spatial USDA soils dataset. Information about the drivers of land change in the Northern Plains will come from available literature to document the highlights of change. Together, all the sources will be woven to tell the general story of land change in the study area during the temporal period of interest.

STUDY AREA DESCRIPTION

The four northern Great Plains Level III ecoregions are the Lake Agassiz Plain, Northern Glaciated Plains, Northwestern Glaciated Plains, and the Northwestern Great Plains (Fig. 1), and include parts of six states. North

Dakota is completely within the study area, as well as nearly all of South Dakota and the eastern two-thirds of Montana. Lesser areas are found, in descending order, in northeastern Wyoming, western Minnesota, and extreme north-central Nebraska. The study area covers approximately 689,544 km^2 or about 8.9% of the conterminous United States based on ecoregion boundary area.

Elevation rises from east to west and land forms are generally rolling plains, with subregional and local differences. The Lake Agassiz Plain ecoregion has the most level terrain whereas the Northwestern Great Plains ecoregion has areas of high dissection, such as the South and North Dakota badlands and the west bank tributaries of the Missouri River. Glaciation has had major impacts on the land forms. The three eastern ecoregions were glaciated (approximately half of the study area), while the Northwestern Great Plains ecoregion was not. The Northern Glaciated Plains and Northwestern Glaciated Plains ecoregions have geologically young landscapes that have immature drainage systems. These manifest themselves in substantial numbers of wetland depressions and permanent lakes that make that part of the study area a major portion of the "prairie pothole" region of North America (Johnson and Higgins 1997; Johnson et al. 2005).

The study area's soils were also heavily influenced by glacial events. Soils derived from glacial drift, till, or from lake-basin sedimentation tend to be deep and productive. Those found in glacial outwash areas are generally thinner, with higher concentrations of gravel and sand (Bryce et al. 1998). The unglaciated plains west and south of the Missouri River tend to have shallow soils with clayey textures and lower productivity (Sayler 2010).

Precipitation in the Northern Plains generally follows a decreasing gradient from east to west. The southeastern areas of the Northern Glaciated Plains and most of the Lake Agassiz Plain have average annual precipitation amounts around or above 500 mm. The western areas of the Northwestern Great Plains and the Northwestern Glaciated Plains receive on average 300–400 mm of precipitation annually, although some pockets receive even less (PRISM Group 2010). Evaporation is about half of that found in the southern Great Plains (Owensby 2004).

The study area's natural vegetation is predominantly grassland communities, although shrublands are found in the more western parts of the region. The Lake Agassiz Plain and eastern portions of the Northern Glaciated Plains were covered with tallgrass prairie that transitioned into mixed-grass communities farther west. Shortgrass prairies are found in western sections of the Northwestern Glaciated Plains and Northwestern Great Plains ecoregions (Bryce et al. 1998; Woods et al. 2002; Chapman et al. 2001; Chapman et al. 2004; Brooks 2010). Other natural vegetation includes herbaceous wetland communities and scattered riparian forest found along the region's major rivers.

Euro-American settlement and the genesis of contemporary land use started during the second half of the 19th century and was initially completed by 1920. Settlement generally proceeded east to west, with areas having the highest annual precipitation and better soils having the longest occupation (Schell 1961; Malone and Roeder 1978; Larson 1978; Robinson 1995). Generally, glaciated land with level to undulating surfaces and deep soils provided the basis for crop agriculture and was converted to agricultural land cover. In the eastern Dakotas, grasslands remained only in localized areas where the glaciers left heavy deposits of rock, gravel, and sand. The primary use for these areas became grazing land for livestock. Ranching became the common land use as precipitation amounts diminished westward. Soil capacity for cropping, however, still played a role even in these areas, such as the western half of the Northwestern Glaciated Plains in northern Montana where alternating summer fallowing allowed for successful small-grain farming (Bryce et al. 1998; Woods et al. 2002). Only in the Northwestern Great Plains ecoregion, where the combination of low precipitation and poorer soils, did ranching become the ecoregional dominant land use (Bryce et al. 1998; Woods et al. 2002; Chapman et al. 2004). Regional land use was still adapting to the physical and human geographies of the Great Plains in 1973 and continued to do so during the study period (Riebsame 1990; Hudson 1996; Parton et al. 2005).

METHODS

The land-cover change data for this study comes from the USGS Land Cover Trends project. This research activity was initiated to better understand changes in contemporary land cover and land use at a regional scale (Loveland et al. 2002). A stratified random sampling approach was used to create statistically rigorous estimates of land-cover and land-use changes across the conterminous United States from 1973 to 2000 on an intermediate regional scale. The goal was to detect change at ±1% at an 85% confidence level (Loveland et al. 2002). A 10 km × 10 km grid was placed over the conterminous United States and samples were stratified by Omernik Level III ecoregions and randomly drawn for each of the 84 ecoregions (Omernik 1987; U.S. Environmental Protection Agency 1999; Stehman et al. 2003).

Five dates of Landsat satellite imagery (circa 1973, 1980, 1986, 1992, and 2000) were acquired for each sample "block." Each sample block was manually interpreted from the Landsat imagery using ERDAS Imagine© software. The Landsat interpretation was augmented by two dates of higher-resolution aerial photography from the early 1990s (the National Aerial Photography Program) and the early to mid-1980s (the National High Altitude Photography Program).

The interpretations were classified into 11 modified Anderson Level I land-cover and land-use classes (Anderson et al. 1976; Loveland et al. 2002). No classification scheme is purely land cover or land use but usually a mixture of both.

For this study, the most important land-cover classifications from the Land Cover Trends project are agriculture (cropland, including hay land, and intensely used pasture), grassland/shrubland (less intensely used rangeland grazing land and idled cropland planted to perennial grasses), water (permanent lakes, reservoirs, and persistent water devoid of wetland vegetation), and wetland (wetland vegetation or conditions). No formal accuracy assessment of the Land Cover Trends project's interpretations has been made, because most remote-sensing-based accuracy assessments use higher-resolution aerial photography to validate coarser-resolution satellite imagery, and we used aerial photography as part of the initial interpretations.

For this study, the data from the four Level III ecoregions of interest were combined to get the estimates of land-cover change for the overall Northern Plains, but data were also used separately to show ecoregional differences.

Data from the Natural Resources Conservation Service (NRCS) State Soil Geographic (STATSGO) database were included in the post-interpretation analysis to help better understand the change results. The crop capability index for soils that is produced within this database was intersected with the ecoregions to give a summary of the land capacity for cropping by ecoregion. The values of the index range from 1 to 8, with 1 to 4 being areas basically suitable for cultivated crops. Suitability decreases as the index increases in value. Classes 5 through 8 have increasingly more restrictions that limit their use, with the exception of pasture or grazing (Natural Resources Conservation Service 1994).

RESULTS

We estimate that 8.5% of the combined four Northern Plains ecoregions changed land cover at least once during the study period. This equates to an estimated 58,692 km^2 (±12,609 km^2) of overall change. This was less than the cumulative totaling of the four time intervals, however, as some land had more than one change during the study period but occupied the same space and thus was counted only once for overall change. The Lake Agassiz Plain had the least amount of change in both percentage and absolute area, whereas the Northwestern Glaciated Plains had the greatest percentage of change (Table 1), not only in the Northern Plains but also for the overall Great Plains (Taylor 2010). Although the Northwestern Great Plains had considerably less percentage change than its neighbor to the north and east, this ecoregion had a slightly greater absolute amount of area change because of its much larger size (Table 1).

In all four Northern Plains ecoregions, the first two time intervals saw less change than the last two intervals (Table 1), even when the percentages were normalized to annual amounts to overcome unequal temporal spans (Table 2), although the Northwestern Great Plains annualized rate returned to the pre-1986 levels during the last time interval. The ecoregions generally had greater change after 1986, yet differences in rates of change remained among them. The annualized change rate (Table 2) in the Northwestern Glaciated Plains rose considerably during the last two time intervals when compared to the first two. Change in the Northwestern Great Plains spiked in the third interval. The Northern Glaciated Plains had its highest change during the last time interval.

Ten types of change accounted for 95% of the gross change detected (where the same area could be counted more than once for change) (Table 3). Seventy-five percent of the combined gross change resulted from conversions between agriculture and grassland/shrubland land-covers. The leading land-cover change during the study period was the conversion of agriculture to grassland/shrubland. Most of this change occurred in the Northwestern Great Plains and the Northwestern Glaciated Plains ecoregions. A second set of changes involving wetland and water transitions accounted for another 13% of the combined gross change and occurred primarily in the Northern Glaciated Plains and Northwestern Glaciated Plains ecoregions. Other changes affected smaller areas and tended to be more ecoregion specific. Most of the agriculture-to-wetland, wetland-to-agriculture, and agriculture-to-water transitions occurred in the Northern Glaciated Plains. A majority of the changes between grassland/shrubland and water happened in the Northwestern Great Plains. This ecoregion was also the only one where a substantial disturbance event (wildfire

TABLE 1
ESTIMATED OVERALL PERCENTAGE OF SPATIAL CHANGE BY ECOREGION AND ABSOLUTE AREA CHANGED

Ecoregion	Percentage change (%); Area change (km²)				Overall spatial percentage change, 1973–2000; Area change (km²) (No double counting)
	1973–1980	1980–1986	1986–1992	1992–2000	
Lake Agassiz Plain	0.3 (±0.1); 101 (±34)	0.2 (±0.1); 98 (±49)	0.7 (±0.3); 278 (±119)	0.5 (±0.2); 210 (±84)	1.4 (±0.4); 569 (±163)
Northern Glaciated Plains	1.4 (±0.3); 2,003 (±429)	1.4 (±0.3); 1,949 (±418)	2.4 (±0.5); 3,330 (±694)	4.2 (±1.0); 5,846 (±1,392)	7.5 (±1.4); 10,601 (±1,979)
Northwestern Glaciated Plains	2.6 (±0.6); 4,203 (±970)	2.6 (±0.7); 4,158 (±1,119)	6.1 (±1.3); 9,830 (±2,095)	6.6 (±1.5); 10,627 (±2,415)	13.6 (±2.2); 21,853 (±3,535)
Northwestern Great Plains	2.2 (±0.7); 7,448 (±2,370)	2.0 (±0.8); 6,810 (±2,724)	3.0 (±1.2); 10,533 (±4,213)	2.7 (±1.0); 9,381 (±3,479)	7.4 (±2.0); 25,669 (±6,933)

TABLE 2
ESTIMATED ANNUAL PERCENTAGE CHANGE OF ECOREGION

Ecoregion	Percentage change, annualized			
	1973–1980	1980–1986	1986–1992	1992–2000
Lake Agassiz Plain	>0.1 (± >0.05)	>0.1(± >0.05)	0.1 (±0.05)	0.1 (± >0.05)
Northern Glaciated Plains	0.2 (± >0.05)	0.2 (± >0.05)	0.4 (±0.1)	0.5 (±0.1)
Northwestern Glaciated Plains	0.4 (±0.1)	0.4 (±0.1)	1.0 (±0.2)	0.8 (±0.2)
Northwestern Great Plains	0.3 (±0.1)	0.3 (±0.1)	0.5 (±0.2)	0.3 (±0.1)

that was classified as "nonmechanically disturbed") was identified that impacted the change statistics, although its variability was quite high (Table 3).

There were also temporal differences in the major types of changes. Agriculture had net gains from grassland/shrubland land-cover in all the ecoregions during the first time interval and in three out of four in the second time interval (Fig. 2). In the third time interval, however, this pattern was substantially reversed, and grassland/shrubland gained from agriculture. This reversal continued during 1992–2000 but at greatly reduced amounts. Net changes between wetland and water land-covers had both temporal and regional variability (Fig. 3). There was a heterogeneous mix among the ecoregions during the first and third intervals, where either wetland or water had net gains from the other depending on more subregional weather conditions. The area of water land-cover increased in all ecoregions, however, during the second and fourth time intervals, especially between 1992 and 2000 in the Northwestern Glaciated and Northern Glaciated Plains ecoregions. A somewhat similar temporal pattern can be seen in net changes between grassland/shrubland and water land-covers, with water usually gaining from grassland/shrubland but with a substantial

TABLE 3
MAJOR TYPES OF LAND COVER AND LAND USE CHANGES AND ESTIMATED AREA AFFECTED (KM^2)

Type of change	Lake Agassiz Plain	Northern Glaciated Plains	Northwestern Glaciated Plains	Northwestern Great Plains	*Northern Great Plains Combined*
Agriculture to grassland/ shrubland	297 (±134)	3,386 (±1,180)	14,688 (±3,103)	17,239 (±10,193)	**35,610 (±10,610)**
Grassland/shrubland to agriculture	104 (±56)	1,915 (±602)	9,027 (±1,947)	11,013 (±3,342)	**22,059 (±5,947)**
Wetland to water	20 (±13)	3,244 (±814)	3,172 (±1,388)	493 (±483)	**6,929 (±2,698)**
Water to wetland	10 (±6)	1,107 (±325)	1,212 (±514)	722 (±744)	**3,051 (±1,589)**
Agriculture to wetland	26 (±21)	1,356 (±758)	113 (±53)	33 (±33)	**1,528 (±865)**
Nonmechanically disturbed to grassland/shrubland	0	0	0	1,390 (±2,029)	**1,390 (±2,029)**
Grassland/shrubland to water	0	252 (±150)	159 (±110)	703 (±462)	**1,114 (±722)**
Water to grassland/shrubland	1 (±2)	14 (±11)	47 (±38)	846 (±610)	**908 (±661)**
Wetland to agriculture	28 (±33)	624 (±196)	69 (±28)	0	**721 (±257)**
Agriculture to water	5 (±5)	484 (±307)	87 (±55)	23(±19)	**721 (±257)**

reversal in the trend between 1986 and 1992 primarily in the Northwestern Great Plains and to a lesser extent in the Northwestern Glaciated Plains (Fig. 4). The Lake Agassiz Plain had almost no water and grassland/shrubland land-cover transitions.

Northern Plains ecoregions share similar physical and anthropogenic management characteristics that result in similar land covers and land-cover conversions such as grassland/shrubland to agriculture and agriculture to grassland/shrubland. Each ecoregion also has different amounts of precipitation, soils, glacial history, and settlement patterns that distinguish it from the others. The result is that Northern Plains ecoregions' land-use and land-cover changes are variations on a theme, with the amounts of different types of changes found in greater abundance in certain ecoregions or several ecoregions than in others.

DISCUSSION

The leading types of land-cover and land-use change in the study area between 1973 and 2000 can be placed within into two major suites: one that was primarily the result of the land-use tension between crop and grazing agriculture land use and the other caused by lengthy periods of wetter and drier weather. The land-cover transitions within both suites showed temporal variability because the study period was long enough to capture changes in both agriculture and weather cycles.

Land-use tension is created by the competition between or among two or more land uses, given the general biophysical conditions that result in the greatest economic gain for the landowner. Competing land uses must generate similar incomes or little tension between them would exist. The competition is typically viewed across a temporal scale where potential land change is seen as a competitive advantage, especially during times of changing or unpredictable economic conditions (Napton and Loveland in press). Land-use tension also spans spatial scales, from the regional down to the parcel level. In the U.S. Southeast, the main land-use tension is between forestry and agricultural land uses (Healy 1985; Napton et al. 2010). In the Northern Plains, the land-use tension is between crop cultivation and livestock grazing uses.

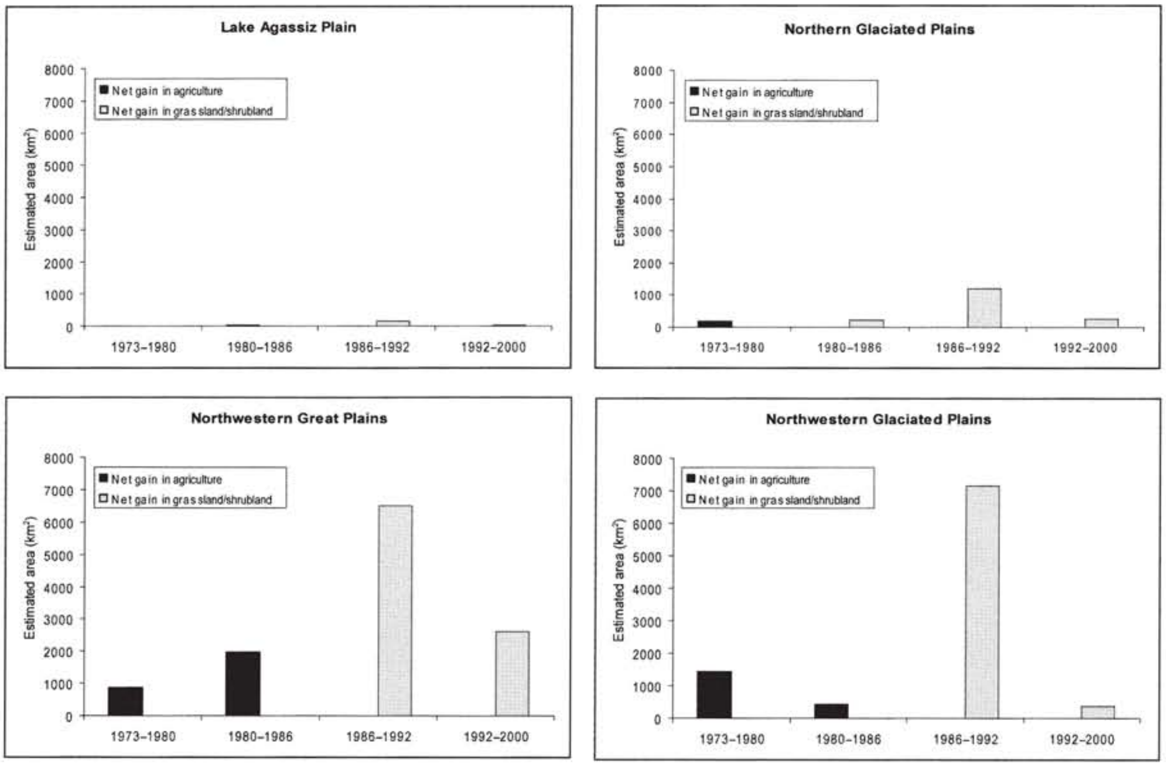


Figure 2. Estimated area of net gain in agriculture versus grassland/shrubland land-covers.

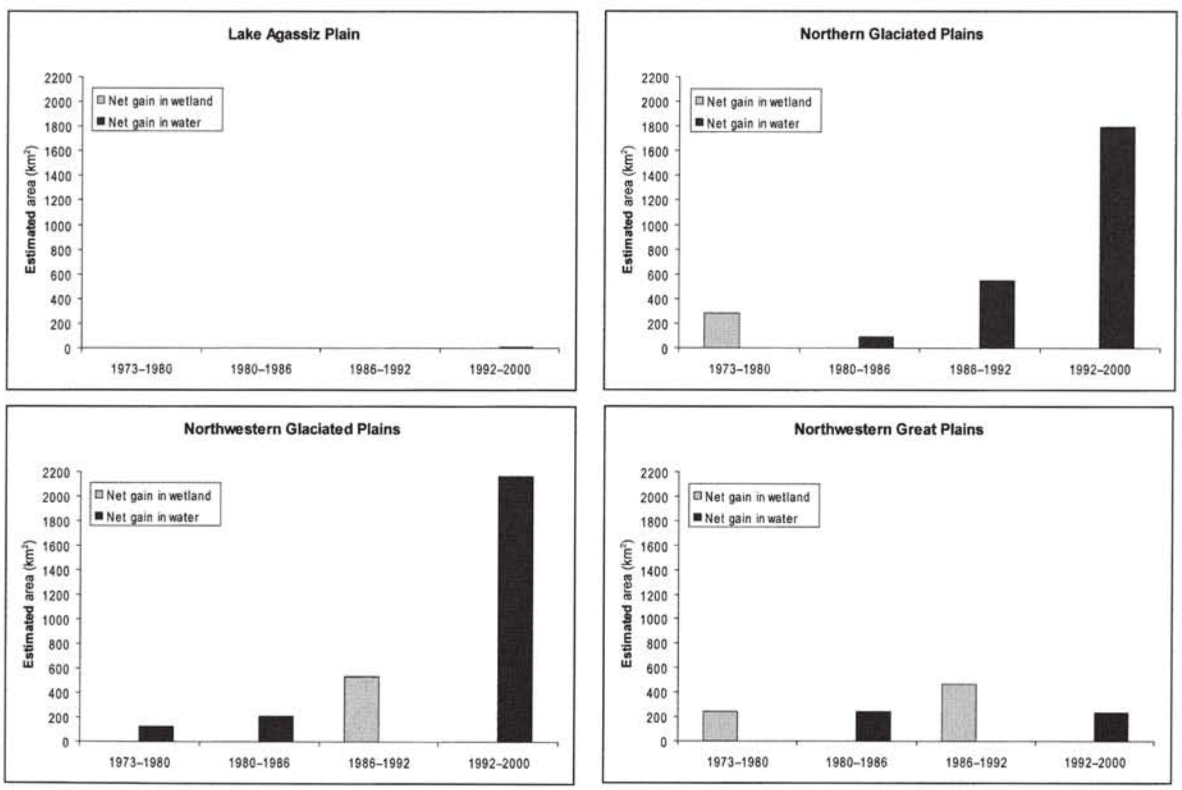


Figure 3. Estimated area of net gain in wetland versus water land-covers.

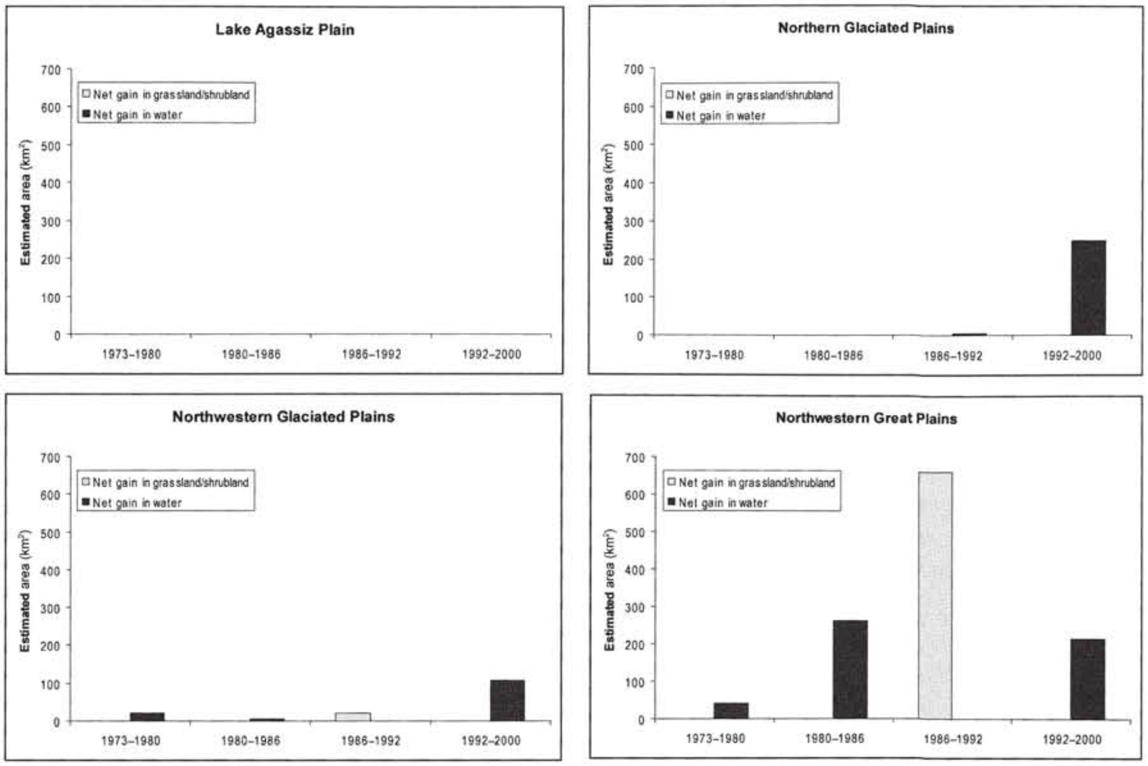


Figure 4. Estimated area of net gain in grassland/shrubland versus water land-covers.

This regional land-use tension between agriculture or grassland/shrubland land-cover use during the study period was greatly influenced by anthropogenic drivers. Grassland/shrubland-to-agriculture conversion was the leading change during the first two time intervals, especially between 1973 and 1980, when changes in drivers occurred. These altered drivers, all favoring increased cropping, included a major commodity price spike caused by foreign countries' large grain purchases, governmental policy that favored enlarged farming operations, and increasing farmland prices driven by high inflation rates (Danbom 1995; Stam and Dixon 2004; Conklin 2008:132–34). Grassland/shrubland-to-agriculture conversion was most common in the Northwestern Glaciated Plains and the Northwestern Great Plains, ecoregions that each had higher amounts of grassland/shrubland to convert because of lower overall land capacity for cropping (Fig. 5). The newly converted land had been "economically marginal" for farming (Deal 2006) until the above drivers facilitated change. Grassland/shrubland grazing land that remained unchanged in these two ecoregions may have been considered so economically marginal for cropping that even with the above drivers landowners would not convert them.

The situation was different, however, by the third time interval, as the 1980s "farm crisis" had played out with low commodity prices and substantial numbers of highly leveraged crop producers (Fig. 2). The U.S. Department of Agriculture's Conservation Reserve Program (CRP) was established in 1985 to retire highly erodible land from production (agriculture to grassland/shrubland land-cover change) and to help reverse the agricultural economy's malaise (Sullivan et al. 2004). Its implementation during the 1986 to 1992 interval is clearly seen in all the ecoregions (Fig. 2). The Conservation Reserve Program was the single greatest driver of land change in the Northern Plains during the study period.

The land-use tension between agriculture and grassland/shrubland land-covers had again changed somewhat by the end of the fourth time interval. The CRP had matured as a federal program, with less land being newly enrolled than during its heyday, although grassland/shrubland land-cover still had a net gain from agriculture (Fig. 2). New or changed drivers (improved crop types including bioengineered varieties, biofuel production, greater availability of crop insurance, and higher commodity prices) were helping to convert grassland/shrubland to agriculture in the Northern Plains (Higgins et al. 2002; Stubbs 2007). This was possibly reflected in the lower net gains of grassland/shrubland land-cover from agriculture during this interval.

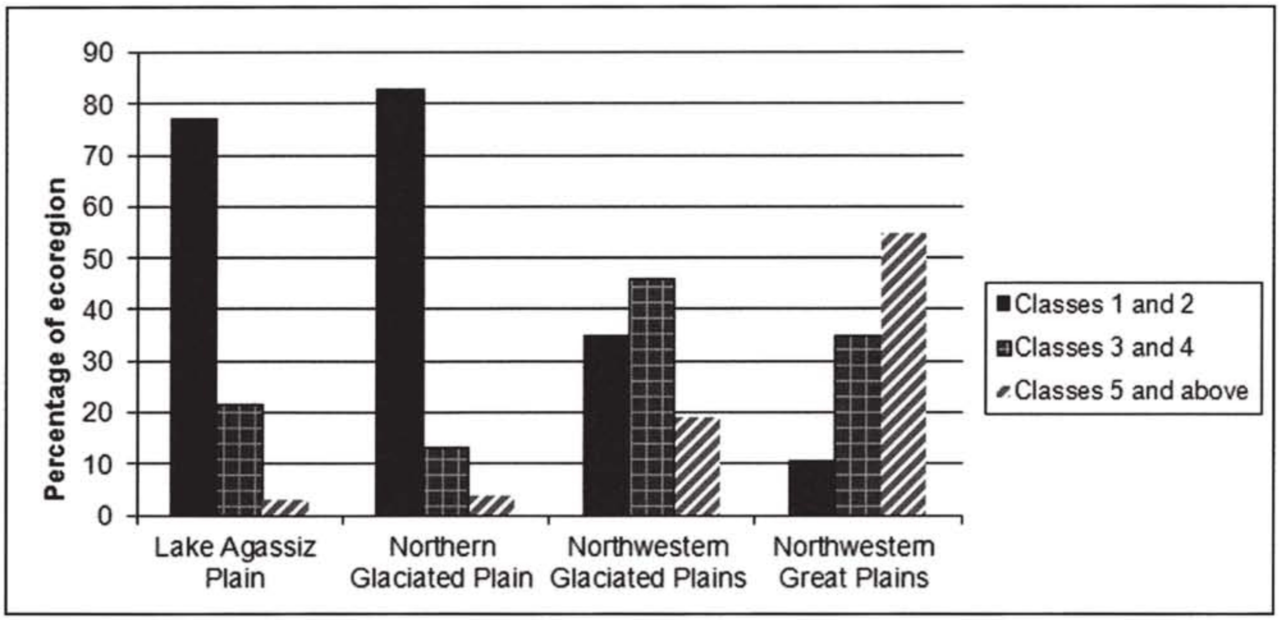


Figure 5. Percentage of ecoregion in the northern Great Plains by crop-capacity class groupings. Lands in classes 1 and 2 are best suited for crop agriculture. Lands in classes 3 and 4 are less suited for crop agriculture but still could be cropped. Lands in classes 5 and above have little to no potential for crop agriculture. Crop-capacity groupings are from the Natural Resources Conservation Service.

The other major suite of land-cover changes was primarily driven by interannual weather variability, although anthropogenic management could also be found in these changes. Most of these transitions were ephemeral in nature. Water and wetland land-covers increased and decreased because of wet and dry weather cycles with noticeable interregional variation across the time intervals. Each ecoregion gained water land-cover from wetlands, however, during the 1992 to 2000 interval because of a series of wetter years in the mid- to late 1990s. Lake Agassiz Plain had little wetland-to-water change because most of its wetlands had been drained before our study period (Aadland et al. 2005). Research by Garbrecht and Rossel (2002) concluded that the Northern Plains did have a significantly wetter decade during the 1990s, and Kirby et al. (2002), Todhunter and Rundquist (2004), Shapley et al. (2005), and the South Dakota Game, Fish, and Parks (2010) give more localized examples of how cyclic drought-and-deluge temporal spans affect land cover and land use in the study area.

Other, mostly weather-driven land-use and land-cover transitions included agriculture-to-wetland, agriculture-to-water, and grassland/shrubland-to-water land-cover transitions. Many temporary and seasonal wetlands were cropped, especially in the Northern Glaciated Plains and Northwestern Glaciated Plains, but during wetter than normal years these wetlands could not be farmed and stayed out of production (Kirby et al. 2002). Water gain from agriculture and grassland/shrubland land-covers could represent a longer-term but still cyclic change where a number of larger glacial lake basins experienced flooding during the study period. Water bodies such as Lake Thompson and Waubay Lakes in South Dakota, Devil's (Spirit) Lake in North Dakota, and numerous smaller lakes gained in size from the mid-1980s onward. These lakes may persist at larger surface areas for years (Todhunter and Rundquist, 2004; Shapley et al. 2005; South Dakota Game, Fish, and Parks 2010).

Other changes between grassland/shrubland and water may be short-term, such as those affecting the water status of impoundments that ranged in size from a single-pixel (60 × 60 m) stock dam to the great reservoirs on the Missouri River. The stock dams would be full of water during wetter or more normal precipitation years but could dry up and become vegetated during droughts. Many new stock dams were also created from grassland/shrubland land-cover during the study period. The Missouri River reservoirs' volumes fluctuated because of variable snowpack melt from the Rocky Mountains and runoff from Northern Plains watersheds. The major water-to-grassland/shrubland spike during the third interval (Fig. 4) was the result of a series of drought years both in the Rockies and the Northern Plains that substantially reduced runoff into the reservoir system (U.S. Army

Corps of Engineers 2004:8). Exposed reservoir land grew a grassland/shrubland land-cover that was flooded again when runoff returned to more normal conditions and the reservoirs refilled.

CONCLUSIONS

In conclusion, the amounts and types of change in land cover and land use in the Northern Plains depended on the various combinations of anthropogenic drivers and biophysical conditions found in the four ecoregions during the study period. The Lake Agassiz Plain experienced the least change because it had already been altered the most from its presettlement conditions (Loveland and Hutcheson 1995). This ecoregion's biophysical attributes allowed it, under the U.S. land rent theory system, to reach its "highest and best use" (Napton and Loveland in press). The greatest land-use tension was found in the ecoregions that had the highest proportion of economically marginal land where landowners could respond to changes in anthropogenic drivers. This was especially true in the Northwestern Glaciated Plains, which has the highest amounts of class 3 and 4 crop-capacity lands that could be brought into or retired from cultivation depending on the various drivers (Fig. 5). Cyclic weather variations, less linked to anthropogenic drivers, also resulted in land-cover change in the four ecoregions, especially in the remaining, less-altered core of the U.S. prairie pothole region where wetland and water land-cover conditions fluctuate regularly.

This study documents recent land-use and land-cover changes in the Northern Plains but also strives to further indentify intermediate-scale regional differences in change within the context of human and natural driving forces. Discussing how to better understand the future role of land-use change in "earth system dynamics," Lambin et al. (2001:267) said that we "must not only capture the complex socio-economic and biophysical drivers of land-use change but also account for the specific human-environment conditions under which the drivers of change operate." Our study captures the major strands of complex interplay of socioeconomic and biophysical drivers necessary to develop an enriched understanding of how human ; interact with the environment.

Land-cover and land-use change is expected to continue in the Northern Plains; our study period was just a slice of time in a longer continuum. Post-2000 land-use tension between agriculture and grassland/shrubland land-covers is underway as anthropogenic drivers continue to modify or develop, particularly in the Northwestern Glaciated Plains (Garrett-Davis 2004; Stubbs 2007). Climatic variability may continue to cause land-cover changes, especially if human-induced climatic change increases variability (Johnson et al. 2005; Millett et al. 2009). Ecoregional change variability may also continue as these regions offer their own combinations of resources and conditions to their current human inhabitants. Further monitoring and research is warranted as land-use and land-cover conditions continue to change.

REFERENCES

Aadland, L.P., T.M. Koel, W.G. Franzin, K.W. Stewart, and P. Nelson. 2005. Changes in fish assemblage structure of the Red River of the North. *American Fisheries Society Symposium* 45:293–321.

Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer. 1976. *A Land Use and Land Cover Classification System for Use with Remote Sensor Data.* U.S. Geological Survey Professional Paper 964.

Borchert, J.R. 1950. The climate of the central North American grassland. *Annals of the Association of American Geographers* 40 (3):1–49.

Borchert, J.R. 1987. *America's Northern Heartland: An Economic and Historical Geography of the Upper Midwest.* University of Minnesota Press, Minneapolis.

Brooks, M.S. 2010. Lake Agassiz Plain Ecoregion Summary. http://landcovertrends.usgs.gov/gp/eco48Report.html (accessed August 11, 2010).

Bryce, S.A., J.A. Omernik, D.E. Pater, M. Ulmer, J. Schaar, J. Freeouf, R. Johnson, P. Kuck, and S.H. Azevedo. 1998. *Ecoregions of North and South Dakota* (color poster with map, descriptive text, and photographs). U.S. Geological Survey (map scale 1:500,000), Reston, VA.

Chapman, S.S., J.M. Omernik, J.A. Freeouf, D.G. Huggins, J.R. McCauley, C.C. Freeman, G. Steinauer, R.T. Angelo, and R.L. Schlepp. 2001. *Ecoregions of Nebraska and Kansas* (color poster with map, descriptive text, summary tables, and photographs). U.S. Geological Survey (map scale 1:1,950,000), Reston, VA.

Chapman, S.S., S.A. Bryce, J.M. Omernik, D.G. Despain, J. ZumBerge, and M. Conrad. 2004. *Ecoregions of Wyoming* (color poster with map, descriptive text, summary tables, and photographs). U.S. Geological Survey (map scale 1:1,400,000), Reston, VA.

Conklin, P.K. 2008. *A Revolution Down on the Farm the Transformation of American Agriculture since 1929.* University Press of Kentucky, Lexington.

Danbom, D.B. 1995. Postscript. In *History of North Dakota*, 2nd ed., ed. E.B. Robinson, 582–92. North Dakota State University Institute for Regional Studies, Fargo.

Deal, J. 2006. The relationship between economically and environmentally marginal land. Paper presented at the American Agricultural Economics Association Annual Meeting, Long Beach, CA, July 23–26. http://ageconsearch.umn.edu/bitstream/21119/1/sp06de02.pdf (accessed August 3, 2010).

Drummond, M.A. 2007. Regional dynamics of grassland change in the western Great Plains. *Great Plains Research* 17 (Fall 2007):133–44.

Drummond, M.A., and R.F. Auch. 2010. Land cover change in the United States Great Plains, 1973–2000: Regional synthesis. http://landcovertrends.usgs.gov/gp/gpResults.html (accessed January 12, 2011).

Garrett-Davis, J. 2004. The greening of the plains. *High Country News*, August 2. http://www.headwatersnews.org/HCN.prairiefarms.html (accessed August 3, 2010).

Garbrecht, J.D., and F.E. Rossel. 2002. Decade-scale precipitation increase in the Great Plains at end of 20th century. *Journal of Hydrologic Engineering* 7 (1):64–75.

Gutmann, M.P., W.J. Parton, G. Cunfer, and I.C. Burke. 2005. Population and Environment in the U.S. Great Plains. In *Population, Land Use, and Environment: Research Directions*, ed. B. Entwisle and P.C. Stern, 84–105. Washington, DC, National Research Council.

Healy, R.G. 1985. *Competition for Land in the American South Agriculture, Human Settlement, and the Environment*. Washington, DC: Conservation Foundation.

Higgins, K.F., D.E. Naugle, and K.J. Forman. 2002. A case study of changing land use practices in the northern Great Plains, U.S.A.: An uncertain future for waterbird conservation. *Waterbirds* 25 (spec. publ. 2): 42–50.

Hiller, T.L., L.A. Powell, T.D. McCoy, and J.J. Lusk. 2009. Long-term agricultural land-use trends in Nebraska, 1866–2007. *Great Plains Research* 19 (Fall 2009):225–37.

Hudson, J.C. 1996. *The Geographer's Great Plains*. Inaugural lecture, PhD Program in Rural Geography. Department of Geography, Manhattan, KS.

Johnson, R.R., and K.F. Higgins. 1997. *Wetland Resources of Eastern South Dakota, Appendix A*. South Dakota State University, Brookings, and USGS Northern Prairie Wildlife Research Center, Jamestown, ND (July 22, 1999). http://www.npwrc.usgs.gov/resource/wetlands/sdwet/index.htm (accessed August 3, 2010).

Johnson, W.C., B. Millett, T. Gilmanov, R. Voldseth, G. Guntenspergen, and D. Naugle. 2005. Vulnerability of northern prairie wetlands to climate change. *BioScience* 55 (10):863–72.

Kirby, D.R., K.D. Krabbenhoft, K.K. Sedivec, and E.S. DeKeyeser. 2002. Wetlands in northern plains prairies: Benefitting wildlife and livestock. *Rangelands* 24 (2):22–25.

Lambin E.F., et al. 2001. The causes of land-use and land-cover change: Moving beyond the myths. *Global Environmental Change* 11:261–69.

Larson, T.A. 1978. *History of Wyoming*, 2nd ed., revised. University of Nebraska Press, Lincoln.

Loveland, T.R., and H.L. Hutcheson. 1995. Monitoring changes in United States landscapes from satellite imagery: status and future possibilities. In *Our Living Resources*, ed. E.T. Roe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, 468–73. National Biological Service, Washington, DC.

Loveland, T.R., T.L. Sohl, S.V. Stehman, A.L. Gallant, K.L. Sayler, and D.E. Napton. 2002. A strategy for estimating the rates of recent United States land-cover change. *Photogrammetric Engineering and Remote Sensing* 68 (10):1091–99.

Malone, M.P., and R.B. Roeder. 1978. *Montana, a History of Two Centuries*. University of Washington Press, Seattle.

Millett, B., W.C. Johnson, and G. Guntenspergen. 2009. Climate trends of the North American Prairie Pothole Region, 1906–2000. *Climatic Change* 93:243–67.

Napton, D.E., R.F. Auch, R. Headley, and J. Taylor. 2010. Land changes and their driving forces in the Southeastern United States. *Regional Environmental Change* 10 (1):37–53.

Napton, D.E., and T.R. Loveland. In press. Land change theory and large area land change in the United States. *Journal of Land Use Science*.

Natural Resource Conservation Service. 1994. *State Soil Geographic (STATSGO) Data Base Data Use Information*, revised. U.S. Department of Agriculture, Miscellaneous Publication, Number 1492, Appendix C.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. *Annals of the Association of American Geographers* 77 (1):118–25.

Owensby, C. 2004. Kansas State University Range Page. "Range Areas of the United States" and "Plains Grasslands." http://spuds.agron.ksu.edu/ (accessed September 7, 2010).

Parton, W.J., M. Gutmann, and W. Travis. 2003. Sustainability and historical land-use change in the Great Plains: The case of Eastern Colorado. *Great Plains Research* 13 (Spring 2003):97–125.

Parton, W.J., M.P. Gutmann, S.A. Williams, M. Easter, and D. Ojima. 2005. Ecological impact of historical land-use patterns in the Great Plains: A methodological assessment. *Ecological Applications* 15 (6):1915–28.

Parton, W.J., M.P. Gutmann, and D. Ojima. 2007. Long-term trends in population, farm income, and crop production in the Great Plains. *BioScience* 57 (9):737–47.

PRISM Group, Oregon State University. 2010. Precipitation: annual climatology (1971–2000). http://prism.oregonstate.edu/products/viewer.phtml?file=/pub/prism/us_30s/graphics/ppt/Normals/us_ppt_1971_2000.14.png&year=1971_2000&vartype=ppt&month=14&status=final (accessed August 12, 2010).

Riebsame, W.E. 1990. The United States Great Plains. In *The Earth as Transformed by Human Action*, ed. B.L. Turner II, W.C. Clark, R.W. Kates, J.F. Richards, J.T. Mathews, and W.B. Meyer, 561–75, Cambridge University Press, Cambridge, UK.

Robinson, E.B. 1995. *History of North Dakota*, 2nd ed. North Dakota State University Institute for Regional Studies, Fargo.

Rossum, S., and S. Lavin. 2000. Where are the Great Plains? A cartographic analysis. *Professional Geographer* 52 (3):543–52.

Sayler, K.L. 2010. Contemporary land cover change in the northwestern Great Plains Ecoregion. http://landcovertrends.usgs.gov/gp/eco43Report.html (accessed August 12, 2010).

Schell, H.S. 1961. *History of South Dakota*. Lincoln: University of Nebraska Press.

South Dakota Game, Fish, and Parks. 2010. Lake Thompson recreation area. http://gfp.sd.gov/state-parks/directory/lake-thompson/ (accessed August 3, 2010).

Shapley, M.D., W.C. Johnson, D.R. Engstrom, and W.R. Osterkamp. 2005. Late-Holocene flooding and drought in the northern Great Plains, USA, reconstructed from tree rings, lake sediments, and ancient shorelines. *The Holocene* 15 (1):29–41.

Stam, J.M., and B.L. Dixon. 2004. Farmer bankruptcies and farm exits in the United States, 1899–2002. U.S. Department of Agriculture, Economic Research Service, Agriculture Information Bulletin Number 788.

Stehman, S.V., Sohl, T.L., and Loveland, T.R. 2003. Statistical sampling to characterize recent United States land-cover change. *Remote Sensing of Environment* 86 (4):517–29.

Stubbs, M. 2007. Congressional Research Service, CRS Report for Congress Land Conversion in the Northern Plains. Order Code RL33950. http://www.ncseonline.org/NLE/CRSreports/07May/RL33950.pdf (accessed August 3, 2010).

Sullivan, P., D. Hellerstein, L. Hansen, R. Johansson, S. Koenig, R. Lubowski, W. McBride, D. McGranahan, M. Roberts, S. Vogel, and S. Bucholtz. 2004. *The Conservation Reserve Program Economic Implications for Rural America*. U.S. Department of Agriculture, Economic Research Service, Agricultural Economic Report No. 834.

Taylor, J. 2010. Northwestern Glaciated Plains Ecoregion Summary Report. http://landcovertrends.usgs.gov/gp/eco42Report.html (accessed August 12, 2010).

Todhunter, P.E., and B.C. Rundquist. 2004. Terminal lake flooding and wetland expansion in Nelson County, North Dakota. *Physical Geography* 25:68–85.

U.S. Army Corps of Engineers. 2004. *Summary Missouri River Final Environmental Impact Statement Master Water Control Manual Review and update*. U.S. Army Corps of Engineers Northwestern Division. http://www.nwdmr.usace.army.mil/mmanual/Summary.pdf (accessed August 3, 2010).

U.S. Environmental Protection Agency. 1999. *Level III Ecoregions of the Continental United States, Revised March 1999*. Map (map scale 1:7,500,000).

Webb, W.P. 1931. *The Great Plains*. Grosset and Dunlap, New York.

Woods, A.J., J.M. Omernik, J.A. Nesser, J. Shelden, J.A. Comstock, and S.H. Azevedo. 2002. Ecoregions of Montana, 2nd ed. (color poster with map, descriptive text, summary tables, and photographs). U.S. Geological Survey (map scale 1:1,500,000), Reston, VA.

BOOK REVIEWS

RARE: Portraits of America's Endangered Species. By Joel Sartore. Washington, DC: National Geographic Focal Point, 2010. 160 pp. Color photographs. $24.00 cloth.

As someone who tries to educate the public about wildlife, I always hope my efforts will impress upon people how important the nonhuman world is and encourage them to conduct their lives with more respect and care for the environment. One thing that became clear to me early on in my career was that speaking or writing about a plant or animal never has the impact of actually experiencing one. Observing a painted turtle basking on a log, smelling the fragrance of rose verbena, or hearing the song of a dickcissel will always trump mere words.

Short of being in the presence of a creature, a really good photograph of one can also make a lasting impression. That is something *RARE* does compellingly, with exquisite portrait photos of 68 North American species that are dwindling dangerously in numbers or have recently recovered from the brink of extinction. Included are such Great Plains natives as the lesser prairie chicken, the interior least tern, and the black-footed ferret. All creatures were photographed with either a pure white or black background, but unconventional poses surprise the reader with each turn of the page, while creative framing and layout engage the eye. It's as if we were having a friendly visit with these plants and animals in their living rooms, not watching them pose stiffly for mug shots. A mouse washes its face, a toad leaps off the page, an eagle looks the other way, a salamander raises its forefoot as if to give us a "high five," a butterfly emerges from its chrysalis.

Each portrait has only a brief paragraph of text accompanying it, but introductory essays by Joel Sartore and noted author Verlyn Klinkenborg frame the narrative well and emphasize the importance of what Aldo Leopold famously established as the first rule of intelligent tinkering: "save all the pieces."

I have a book on extinct species, illustrated with a painting of each one. While the paintings are beautiful, how much better it would be to see photos of these creatures and know they are still living somewhere. I hope every species depicted so enchantingly in *RARE,* as well as those not chosen for the book, will still be here to enchant our descendants. At a time when the Endangered Species Act is under fire from those who are apparently incapable of appreciating anything that cannot be bought or sold, it's good we have books like *RARE* to demonstrate what we may lose unless we exercise more care in our stewardship of the Earth. **Jim Mason**, *Great Plains Nature Center, Wichita, Kansas.*

Sandhill and Whooping Cranes: Ancient Voices over America's Wetlands. By Paul A. Johnsgard. Lincoln: University of Nebraska press, 2011. xx + 155 pp. Illustrations, maps, appendix, bibliography, suggested reading list, online resource list. $12.95 paper.

This charming, informative book has clearly been written by someone who truly understands and appreciates the magnificence of cranes. Indeed, *Sandhill and Whooping Cranes: Ancient Voices over America's Wetlands* is Paul Johnsgard's fourth book on the subject. The knowledge he imparts, presented from the heart, culminates almost five decades of personal observations and research on cranes. Moreover, the book features many attractive illustrations and detailed maps sketched by the author himself.

Two of four chapters offer overviews of life history, habitat preferences, behavior, phenology, and demographics of all six sandhill crane subspecies. Johnsgard emphasizes seasonal movements and distinguishing features, with great care explaining the taxonomy and distribution of these often difficult to distinguish birds. Many readers will find this extremely useful, particularly when observing cranes during migration.

Chapter three offers a brief history of endangered whooping cranes with concise summaries of past and current conservation programs established to preserve the species. Johnsgard highlights the astounding efforts and success of Operation Migration and the Whooping Crane Eastern Partnership in reintroducing an eastern migratory flock. In addition, he provides demographic and distributional information for all wild and introduced whooping crane populations.

The final chapter looks to the future of North American cranes. Johnsgard discusses current and potential threats to populations and provides baseline numbers and cautionary predictions regarding recovery plans and policies. He ends with a compelling appeal to readers to safeguard these marvelous birds.

The book contains an outstanding appendix of crane-viewing locations in which Johnsgard provides an alphabetical annotated list by state and province of refuges and wildlife areas where cranes are regularly observed, including site details, approximate dates of occurrence, and contact information. One featured location is Nebraska's Platte River, a historical focus for cranes that still boasts the largest spring assemblage of these birds globally.

Sandhill and Whooping Cranes is a scholarly work with a much-welcomed personal touch. Whether its reader is contemplating a pilgrimage to observe these wonderful birds in the wild, or merely catching up on

the state of cranes, this book will be a worthwhile acquisition. **Janice M. Hughes**, *Department of Biology, Lakehead University, Thunder Bay, Ontario.*

A Field Guide to the Amphibians and Reptiles of Nebraska. By Daniel D. Fogell. Conservation and Survey Division of the School of Natural Resources/Institute of Agriculture and Natural Resources at the University of Nebraska–Lincoln, 2010. vi + 158 pp. Maps, illustrations, photographs, glossary. $17.99 paper.

A good field guide to any wildlife group includes an identification key, quality photographs, distribution maps, and a natural history summary. The recently published *Field Guide to the Amphibians and Reptiles of Nebraska* does not fail the reader in this regard, having all of these features and more. Dan Fogell effectively presents all 62 species of amphibians, turtles, and reptiles native to Nebraska as well as four additional species of possible occurrence within the state, and all in a useful and compact guide that can be toted easily on a hike or any other field expedition.

Fogell introduces Nebraska's herpetofauna by providing a brief history of Nebraska herpetology, followed by the legal conservation status of each species within the state. For serious herpetologists and field biologists there is an identification key, which includes outstanding line drawings by Errol Hooper Jr. that make distinguishing between characteristics relatively simple. The section on species accounts includes introductions to the herpetofaunal groups within which are descriptions of the taxonomic families residing in the state, although a brief comment on the family Bufonidae (True Toads) appears to have been overlooked. Individual species accounts are presented in both an attractive and useful manner. Each account follows the same format: species description, habitat, natural history, and distribution (both continental and Nebraskan) are on the left page, while photographs and Nebraska distribution maps are on the right, making all pertinent information for each species accessible without turning pages.

Full-color photographs are of outstanding quality and include at least one image that typifies the species as well as additional images that highlight important identification features or morphological variation when necessary. Range maps are also in color and include county outlines and major streams. Distributions are based on voucher specimens, and counties where specimens have been collected are highlighted in bold red. While this map style is useful, it does not offer a true representation of the actual range of a species. The book ends with a helpful glossary, followed by a checklist for those who like to maintain "life lists." Fogell includes additional line drawings showing the names and locations of reptile scales (also provided by Errol Hooper) on the inside front cover and a larger county outline map that incorporates county names on the inside back cover.

This long-overdue updated field guide to Nebraska's herpetofauna makes a significant contribution to Nebraska herpetology. It is practical, easy to read, and should be an integral tool for every field biologist, naturalist, and aspiring herpetologist in the state. **Joseph T. Collins**, *Kansas Biological Survey, University of Kansas.*

Damselflies of Texas: A Field Guide. By John C. Abbott. Austin: University of Texas Press, 2011. xviii + 268 pp. Photographs, illustrations, maps, appendices, glossary, references, index. $24.95 paper.

Well-produced field guides are always in demand, and *Damselflies of Texas* is one such. This compact, camera-bag-friendly compendium displays each of the 77 species known to occur, or that have been historically documented, in the state. The guide's first 50 pages are introductory and full of useful detail. There follows a large section devoted to species descriptions and a set of appendices.

Gracile damselflies are normally approachable, unlike their notoriously aloof cousins the robust dragonflies. Even so, it is difficult to obtain a photograph clearly showing all the species diagnostic features. John Abbott and his scientist/illustrator colleague Barrett Anthony Klein have overcome this problem by a combination of tactics. Representative specimens are dissected and each body part is digitally scanned into a file. Through the use of Adobe Photoshop™ and its powerful layers tool, the male damselfly is reconstructed in a standard, top down format, while a series of side views depict both males and females. As with all preserved Odonata, color loss is unavoidable, and so the digital specimens are carefully retouched to match living specimens.

Families are grouped by color-coded pages, and each species is presented in a two-page summary. On the left page are images, diagnostic features, color morphs, and a pronunciation guide to the scientific name. On the opposite page is a short write-up detailing identifying marks and similar species that might cause confusion. Conservation status ratings and habitat preferences are listed, while a short discussion highlights interesting notes. At the top and on the side of the right page appear two very important details: a range map and flight periods. These pieces of information alone will help immensely with identification. The flight period on the species page is a shaded monthly histogram, but actual date ranges are found in the appendices.

In addition to individual species pages, readers will find at the end of the write-ups for larger genera a set of

micrographs showing male genitalia and female mesostigmal plates. These are important taxonomic details for separating some damselflies that are similar in appearance or preserved specimens that have lost color. Color plates with grouped male abdominal segments are also presented. Appendices include a list of damselflies that may eventually be found in the state, details on conservation status, a bibliography and resource list, a glossary and indexes to common and scientific names.

This is an excellent guide to a lesser known group of colorful insects. More than half the U.S. damselfly species occur in Texas, many of which range through the Great Plains. While it belongs in all entomological libraries, odonatophiles east of the Rocky Mountains will find it especially useful. **Forrest L. Mitchell**, *Texas AgriLife Research, Texas A&M System, Stephenville.*

Grass: In Search of Human Habitat. By Joe C. Truett. Foreword by Harry W. Greene. Berkeley: University of California Press, 2010. xvii + 217 pp. Illustrations, notes, references, index. $40.00 cloth.

Grass: In Search of Human Habitat meanders over a lot of landscape, aiming to link grassland ecosystems and human well being. Truett's approach is narrative and personal, recounting his childhood in rural East Texas, training in wildlife biology and range management at Texas A&M, and career experiences in grassland management, including his current position as a biologist with the Turner Endangered Species Fund.

From the book's opening image of atomic bomb testing on the New Mexico Plains, the book has a decidedly southwestern feel. Most of his examples and case studies are from drier portions of the Great Plains, particularly those in west Texas and eastern New Mexico. Truett draws on all of these experiences to sketch a picture of current attitudes and key problems in grassland conservation.

What are these key problems? They turn out to be a complex mix of a history of science-based range management that may succeed in maximizing short-term gains in livestock production but generally fails to consider conservation of native specie; and an increasingly difficult economic climate for ranchers and other grassland denizens.

In addressing the first issue, Truett reviews the classic academic works on grassland ecology and range management—for example, Frederick Clements's successional theory and Howard Odum's ideas on energy flow. Chapter notes are included but are brief and not linked to specific passages in the body of the chapter. Overall, Truett gives an engaging summary of the basic ideas in grassland ecology as well as the high points of current debates about how to best manage grasslands.

Much of the book is devoted to discussing the heavy human dependence on grasslands and whether this relationship can be maintained in company with grassland conservation. Can humans continue to use grasslands for food, fiber, and newer uses like biofuels and carbon banking while still sustaining the ecosystem? Many of us in academic ecology struggle with resolving perceived conflicts between conservation and human grassland use. In many cases, a "win-win" scenario exists in which, for example, the proper use of livestock grazing is perfectly compatible with a healthy grassland ecosystem. In other cases, such as conserving prairie dog populations, tensions have to be negotiated. Truett discusses some promising strategies that benefit both conservation and landowner concerns, such as conservation easements, conservation grants, and ecotourism.

Grasslands comprise the western "wide open spaces" that figure prominently in the country's imagination. Not many of us, even ardent conservationists, are eager to see the iconic ranching and cowboy culture disappear. Truett, however, points out that making a living in these remote areas is not going to get any easier, especially with the dwindling supply and increased cost of fossil fuels. Maintaining miles of fence line, for example, involves huge outlays in transportation costs. A clear-eyed view of expenses versus profit in ranching does not paint a rosy picture for continued economic viability. In fact, Truett makes the point that most existing ranch operations have significant subsidies, often in the form of a wife's job in town.

A particularly strong and effective message in this book is the economic difficulty encountered by people trying to make a living off grasslands in the Great Plains and Southwest. Truett renders this dilemma with an empathetic eye as a person with both a personal and professional history in grasslands. He sees answers in viewing the land differently, more for its conservation and ecotourism value than for its domestic livestock-producing potential. In this expanded vision, he ultimately presents a hopeful future for the continued viability of grasslands and their inhabitants. **Mary Ann Vinton**, *Department of Biology, Creighton University.*

Food Justice. By Robert Gottlieb and Anupama Joshi. Cambridge, MA: MIT Press, 2010. vii + 290 pp. Photographs, notes, index. $27.95 cloth.

It is a story about food we have heard before—big is bad; small, local, and organic is better; and if you can link small, local, and organic to students, that is best of all. Part of the problem is that the usual suspects—Wal-Mart, McDonalds, PepsiCo, etc.—have so many more resources than the usual cast of small-is-good heroes eking out a living from the earth and hard work: organic

farmers, migrant workers, CSA founders and operators, and similar supporters. Gottlieb and Joshi provide some hope by pointing to a few small victories among the heroes, but it is a fight with ever-moving targets.

There are a number of issues and cases discussed in the pages of *Food Justice* that would interest *Great Plains Research* readers. The authors point to the Dust Bowl as a key event for getting people to start thinking about food justice. The northern Great Plains—the Corn Belt—is likely to see major social changes if the move towards local foods is successful. The 2006 race for Iowa's secretary of agriculture is discussed as a victory for food justice activists. Running on a platform of "health farms," "healthy families," and a "healthy Iowa," Denise O'Brien won the primary election. She lost the general election by two percentage points to Bill Northey, a "conventional farmer." Her success is stated as an example of how important healthy food is for the voting public.

The book also inadvertently points to the difficulties with the "small-and-local-is-beautiful" approach. Gottlieb smiles at us from the book's dust jacket, strategically positioned in front of a stack of books, some of which are most likely printed on paper produced from pulp with connections to deforestation efforts in the Amazon rainforest and polluted waters, and written by authors not local to Los Angeles. Promoting local efforts must be all-encompassing—local art, local media, local business—or larger concerns with social justice will continue to be undermined. Thomas Jefferson is mentioned as a yeoman farmer. Jefferson was a great wordsmith, and an individual with a lot of property for his time, as well as a slave owner. On page 231, the authors argue that the only thing to lose by seeking change in the food arena is "an unjust food system." There are, however, much larger stakes at play. If the food justice movement fails because a majority of low-income consumers see the members of the movement as privileged—a problem the authors point to—this could be a major setback for other social justice movements. Failure also opens the door for the Wal-Marts and Tescos of the world to gain even more control over our food. The spirit of the sentiment is much appreciated and understood to mean that success would lead to losing "an unjust food system," but if food justice groups do become a food justice movement, it must be precise in choosing targets and strategies. **Toby A. Ten Eyck**, *Department of Sociology, Michigan State University.*

Arch Lake Woman: Physical Anthropology and Geoarchaeology. By Douglas W. Owsley, Margaret A. Jodry, Thomas W. Stafford, Jr., C. Vance Haynes, Jr., and Dennis J. Stanford. College Station: Texas A&M University Press, published for the Center for the Study of the First Americans, 2010. xiv + 93 pp. Color plates, maps, photographs, illustrations, tables, reference list, index. $30.00 cloth.

Approximately 10,000 radiocarbon years before present, the body of a 17- to 19-year-old female, probably associated with the Plainview Culture, was buried on the south side of Arch Lake, located near the present-day border of New Mexico and Texas. The young woman was interred in an extended supine position with a necklace of talc beads low on her neck, a bag containing red pigment and a unifacial stone tool on her left hip, and a bone tool placed on her chest. Her grave remained relatively undisturbed until 1967 when it was exposed, discovered, and carefully excavated by archaeologists. The Arch Lake Woman's skeleton is among the oldest found in North America and therefore of significant interest to archaeologists and physical anthropologists. While known at the time to be a fascinating archaeological find, the Arch Lake Woman remains have not been extensively studied.

In 2000, Douglas Owsley and a team of Paleoamerican experts undertook an extensive reinvestigation of the skeleton, radiocarbon dates, burial geology, and artifact assemblage. The skeletal remains investigation included the development of a biological profile, new radiocarbon dating, stable isotope analysis, and comparison of the Arch Lake Woman's skeletal features to those of other early Americans, Native Americans, Africans, and Europeans. The investigation also included geoarchaeological analysis of the burial location, microprobe analysis of the red pigment in the burial fill, and comparison of Early American mortuary practices.

In *Arch Lake Woman*, Owsley and his colleagues successfully demonstrate the wealth of information that can be gleaned from ancient skeletons such as Arch Lake Woman. What stands out in the analyses is that, like other early Americans, the Arch Lake Woman is morphologically different from modern Native Americans. Furthermore, while similar in much of her morphology and lifestyle to other early Americans, the young woman from Arch Lake is distinct in two ways: she was buried in an extended supine position, and she had a relatively short and wide cranial vault relative to the other Paleoamericans. Early Americans are more commonly found in a flexed position and are characterized by long and narrow cranial vaults.

Arch Lake Woman is a concise, technical book that provides a wealth of information about this early American skeleton from the southwestern Great Plains. It should be read by anyone who does research on Paleoamericans or Great Plains prehistory. Besides their analyses and interpretations, Owsley and his colleagues provide raw cranial, postcranial, and dental measure-

ments as well as detailed descriptions of the burial artifacts. For nonspecialist readers with a recreational curiosity about the earliest occupants of the Great Plains, this book is worth examining. Because its target audience is professionals, however, it may require some scientific background to be fully comprehended. **Daniel J. Wescott**, *Department of Biological Sciences, Florida International University.*

Holy Ground, Healing Water: Cultural Landscapes at Waconda Lake, Kansas. By Donald J. Blakeslee. College Station: Texas A&M University Press, 2010. x + 252 pp. Maps, photographs, illustrations, tables, appendix, notes, glossary, bibliography, index. $45.00 cloth, $22.00 paper.

In *Holy Ground, Healing Water* readers are treated to a historical journey through the changing cultural landscapes of the Waconda Lake area, northcentral Kansas. This region provides the setting for discussion of unique and representative Native American and Euro-American cultural developments in the Great Plains. Don Blakeslee, anthropologist with Wichita State University, briefly reviews roughly 13,000 years of Native traditions, based on archaeological investigations in the region, then discusses the Pawnee Trail, early European and Euro-American expeditions, complex Native-Native and Native-Euro-American interactions during the 19th century, sacred and secular perceptions and uses of Waconda Spring, and Lincoln Park, a local example of the many late-19th- to early-20th-century recreational and educational parks that once dotted the nation. Blakeslee has not only uncovered significant themes that defined Waconda, but places them in the context of broader cultural and historical issues.

Among many contributions is Blakeslee's expertise regarding the Pawnee Trail and sacred geography of the historic Pawnee people. A central thread of the first half of the book is the ancient Pawnee Trail, which ran between the Platte and Arkansas Rivers of Nebraska and Kansas. It was not only a route of Native travel and interaction in prehistory, but later a pathway associated with international intrigue as Spanish, French, and Euro-Americans entered the Plains. This humanly constructed feature played a dynamic role in the development of the region's varied cultural landscapes, as well as in the history of multiple groups and nations—Native, Spanish, French, and American.

Many readers will find Blakeslee's generalized review of Native American cosmology and specific discussion of this region's sacred geography fascinating. Prehistoric Native construction of a sacred landscape is interpreted from the Sage site intaglio identified during archaeological survey in Mitchell County. Combined with distinctive natural features that took on special meaning for Pawnees and others, we are provided with insight into Native ideologies. Discussion of the role of Waconda Spring in Pawnee cosmology (chapter 5) helps readers understand the dynamic nature of cultural landscapes, especially when the vastly different Euro-American perspectives and uses of this natural spring are subsequently analyzed (chapter 7). Especially interesting are comments on the various stories or myths developed by Euro-Americans as they defined their own place in this region, a related theme in discussions of the "Post Rock Landscape" (chapter 6).

This book is written for both general readers and specialists interested in archaeology, anthropology, geography, and Native, Euroamerican, environmental, and social history. For the most part, its style is appropriate for nonspecialists, including useful maps, other illustrations, and a glossary. Professionals will find the endnotes and references essential for evaluation and further research. Whether readers are attracted to this book by its focus on the Waconda region or the Great Plains as a whole, they will gain new insight, both specific and broad, into a variety of stimulating subjects related to changing cultural traditions in the Great Plains. **Lauren W. Ritterbush**, *Department of Sociology, Anthropology, and Social Work, Kansas State University.*

Light from Ancient Campfires: Archaeological Evidence for Native Lifeways on the Northern Plains. By Trevor R. Peck. Edmonton, AB: Athabasca University Press, 2011. xvi + 508 pp. Illustrations, photographs, maps, tables, references, index. C$44.95 paper.

Despite the relatively long legacy of professional archaeological research in the northern Great Plains, few comprehensive syntheses of the region's 13,000-year human history have been produced in recent years. This is particularly the case for the Canadian side of the region, which has tended to be overlooked in most scholarly summaries of Great Plains prehistory. The shadowy nature of the Canadian prairies to the wider community of Plains archaeologists is not due to a lack of archaeological research in the region—Alberta, alone, has over 35,000 registered sites—but instead reflects the poor dissemination of CRM (Culture Resource Management) reports and other "grey" literature, where the bulk of archaeological information resides. By drawing extensively upon these unpublished sources, this book aims to provide a comprehensive synthesis and revision of the prehistoric record of, principally, southern Alberta.

Organized chronologically, beginning with "Pre-Clovis" (>11,050 BP) and the Early Prehistoric period and ending with the transition to the historic period (~200 BP), all of the book's chapters follow the same

pattern: first, a brief overview of an archaeological phase or complex (e.g., "McKean complex"), followed by a detailed summary of the key sites in Alberta, and ending with a broader discussion of each phase/complex in terms of technology, subsistence, similarity to sites/cultures elsewhere in the Plains, and so on. This is undertaken for no less than 29 phases/complexes spanning the entire breadth of the prehistoric period. Although some archaeological cultures (e.g., Country Hills complex) included in Peck's synthesis are only recognized in southern Alberta, most will be familiar to archaeologists working in other areas of the Northern Plains. Thus, the relevance of this book extends beyond its somewhat limited geographical scope. Excellent photos, tables, maps, and other illustrations occur throughout the text and greatly enhance the volume's overall usefulness.

With his focus on detailed description of the physical evidence, inclusion of large amounts of raw data, and generous use of unpublished sources, Peck brings to light a rich and diverse source of information on Plains prehistory that would otherwise have remained unknown outside of the Alberta archaeological community. This is a book that is long overdue, one that deserves to be regarded as a key source on the cultural history of the northern Great Plains. **Matthew Boyd**, *Department of Anthropology, Lakehead University, Thunder Bay, Ontario.*

Wives and Husbands: Gender and Age in Southern Arapaho History. By Loretta Fowler. Norman: University of Oklahoma Press, 2010. xii + 382 pp. Maps, photographs, illustrations, notes, bibliography, index. $39.95 cloth.

Wives and Husbands will likely become a classic of ethnographically informed historical anthropology. From the moment distinguished anthropologist Loretta Fowler's work opens with its account of Little Raven and Walking Backward—a brother and sister born in the early nineteenth century who lived to see great changes—to its final pages, which offer at least ten "new lines of research" that scholars might do well to follow to correct errors regarding everything from women's status under change to the "reidentification process" undergone by educated Arapahos returning to their communities, a wide variety of readers will find themselves engaged in a book impossible to put down because of the quality of its writing and its deft instruction at many levels.

Fowler's very last line sums up in modest fashion her central message: "These Southern Arapaho stories offer a window onto the way history makes gender and gender makes history." It is not, however, the rich stories themselves of five different, time-staggered cohorts that add new dimensions to Plains history, but rather the way that Fowler has masterfully woven these stories into three major historical eras shaped by influential individuals working within a complex gender system undergoing constant transformation.

The central survival strategy for these Southern Arapaho persons, whose portraits Fowler draws with beautiful detail and historical accuracy, is that of "partnering." Rather than elaborate strict rules of genealogical succession, Fowler describes the flexible, yet tradition-informed ways that brother-sister and husband-wife (often plural) partnerships formed the economic, social, political, and moral backbone to Southern Arapaho adjustments from prereservation (1805–1869) to reservation (1870–1901) and modernized neoreservation eras (1902–1936). By focusing on the age-based differences in access to wealth, ceremonial power, and resources outside of Arapaho communities, Fowler contributes significantly to a mature feminist theory and historiography that cannot exclude age, rank, origin stories, familial differences, and personalities in its considerations of women's and men's relative power. Men's and women's cooperation and creativity in bison hunting, quillwork production, agriculture, freighting, stock raising, trading, reacting in conciliatory and skeptical ways to American civilizing practices, adjusting to death from warfare and disease, and in Ghost Dance and peyote religious practices have influenced Southern Arapaho modern existence and a continued ethos of gender complementarity.

Finally, Fowler's discussion of the connections between the Southern Arapahos and other Great Plains peoples such as Southern Cheyennes, Northern Arapahos and Cheyennes, Utes, and Kiowas make this work a necessary read for all students of American history, American Indian history, and the wages of cultural encounters. **Kathleen Fine-Dare**, *Department of Anthropology, Fort Lewis College, Durango, Colorado.*

Red Power Rising: The National Indian Youth Council and the Origins of Native Activism. By Bradley G. Shreve. Foreword by Shirley Hill Witt. Norman: University of Oklahoma Press, 2011. xviii + 275 pp. Photographs, illustrations, notes, bibliography, index. $34.95 cloth.

While many histories of the "Red Power" movement trace its origins to the founding of the American Indian Movement in Minneapolis during 1968 and the occupation of Alcatraz Island in San Francisco Bay a year later, Bradley G. Shreve offers a compelling case that youth activism began during the 1950s, most notably in the Southwest. The Kiva Club (University of New Mexico), the Tribe of Many Feathers (Brigham Young University), and the Sequoyah Club of Oklahoma, among others, joined into the Regional Indian Youth Council in 1959 and the National Indian Youth Council in 1961. In con-

trast to AIM, which emerged from urban areas, NIYC was mainly rural and reservation-based.

Members of the NIYC made fishing rights in Washington State their first major policy thrust in 1964; activism was aimed at sovereignty, treaty rights, cultural preservation, and self-determination, all of which have shaped Indigenous development since. The NIYC was the first to use the phrase "Red Power." One of NIYC's major leaders was Clyde Warrior, a full-blood Ponca who had been raised traditionally by his maternal grandparents. Warrior was a "towering intellect," a fiery orator, and a "mesmerizing" fancy dancer who also consumed "legendary amounts of tequila [and] whiskey before passing out." He died of liver failure at age 28 in 1968.

Shreve, Chair of the Division of Social and Behavioral Sciences at Diné College in Tsaile, Arizona, has a talent for biographical detail and the telling quote, as with Warrior, on his full-blood heritage: "The sewage of Europe does not flow through my veins." Shreve also has a keen eye for factional differences in strategy and tactics that played havoc with the NIYC. The racism the book describes can get quite raw. At one point around 1963, Shirley Hill Witt was driving a car with several NIYC colleagues in Michigan when it was rammed by another car on a highway. The injured Indians were picked up by an ambulance that had to go into Wisconsin because no hospitals along the route in Michigan would admit American Indians.

Many notable leaders emerged from the NIYC in addition to Warrior: Hank Adams; Shirley Hill Witt; Herbert Blatchford; Mel Thom; and Gerald Wilkinson, who led the organization from 1969 until his sudden death during1989. In her foreword, Witt notes that the NIYC's ideas of gender equity, drawn from Native traditions, were well in advance of their time, even among other activist youth groups, such as the Student Nonviolent Coordinating Committee (SNCC). Viola Hatch, who served on NIYC's board for nearly 40 years, contended that "Women were the backbone [of NIYC], and the men knew it."

Shreve writes that he does not wish to replace existing histories, but to complement them. In doing so, he has provided an essential historical record of an organization that has survived much travail into the present. **Bruce E. Johansen**, *School of Communication, University of Nebraska at Omaha.*

Generous Man – *Ahxs-i-tapina*: Essays in Memory of Colin Taylor, Plains Indian Ethnologist. Edited by Arni Brownstone and Hugh Dempsey. Wyk, Germany: Tatanka Press, 2008. 216 pp. Illustrations, photographs, notes bibliography, appendicies. $50.00 paper.

This volume celebrates Colin Taylor's contributions to North American ethnology through the presentation of 14 research articles that reflect the diversity and vigor of Taylor's scholarship. Taylor spent his entire life in the Sussex region of southeastern England and the majority of his career teaching at the University of Hastings. His interest in Native Americans began with a boyhood fascination that matured into a disciplined and enduring passion for research and scholarly discourse. Arni Brownstone and Hugh Dempsey, two respected scholars and close friends and colleagues of Taylor, edited the volume. The three of them, along with John C. Ewers, Christian Feest, Bill Holm, and several others comprised an important group of academics, museum professionals, and advocational anthropologists who shared a research focus on the Northern Plains and in the 1980s and '90s collectively produced a significant body of research and publications in ethnology and material culture studies. This group also participated in various conferences and gatherings at which they shared their research with a broader audience, particularly at the annual Plains Indian Seminar at the Buffalo Bill Historical Center in Cody, Wyoming. This combination of personality, scholarship, institutional reputation, and geographic location contributed to the ascendancy of the Plains Indian Seminar to one of the premier venues for Native American material culture scholarship.

The volume's papers address a broad range of subjects and themes examined from diverse perspectives and orientations, ranging from highly formal analyses of stylistic distributions to more reflexive examinations of culture contact and exchange. The combined scholarship is exceptional and generally incorporates an unusually high level of Native documentation (largely drawings) and oral tradition in the examination of topics commonly addressed in more formalistic and static manners. Taken collectively the bibliographies for the individual articles provide an exhaustive guide to scholarly resources on the ethnology and material culture of Northern Plains Indians.

Readers unaware of Taylor and his contributions to Plains ethnography and ethnology would have benefited from an expanded biographical sketch and a complete listing of his publications. It would also have been useful to have had some biographical information for the contributors to better contextualize the diversity of perspective and experience represented in the volume. These minor criticisms aside, this title provides an important resource that will be of great interest and value to a broad readership of both academic and popular audiences. It will be of particular interest to students of Native American material culture and its social and ceremonial contexts. **Daniel C. Swan**, *Department of Ethnology, Sam Noble Museum, University of Oklahoma.*

First Nations Education Policy in Canada: Progress or Gridlock? By Jerry Paquette and Gérald Fallon. University of Toronto Press, 2010. xxii + 420 pp. Illustrations, tables, charts, notes, reference list, index. $85.00 cloth, $39.95 paper.

It is a daunting challenge to identify, define, and make sense of First Nations education in Canada. Much of our understanding of current First Nations education is determined by mainstream media. First Nation citizens are continuously reported to be in a deficit compared to their dominant Canadian counterparts. When we take a deeper look into First Nations education, however, we find a great diversity of both successes and challenges, based largely on the fact that there are 614 First Nation communities in Canada. Policies regarding First Nations education have blanketed all regions of Canada from the Maritimes to the Woodlands, Great Plains, and the Northwest Coast. It is the interpretation of policy that drives the procedures and practices that differ from region to region. Each First Nation community has a unique experience with education as each bureaucracy interprets policy and implements programs.

Although it tends to be an elusive topic, Paquette and Fallon provide an excellent primer on First Nations educational policy, while offering as well important conceptual thoughts and concrete understandings on how First Nations have been positioned within the social and cultural context of Canada. The text provides a basic history of First Nations education in contrast to public education in Canada. The diverse paradigms used in framing First Nations education aid us in understanding the diversity of education in First Nation communities.

Past and present policy directed at First Nations education is so surreal it is hard to believe it is actually a part of Canadian history. Right from the beginning, as First Nations people were seen as being less than human or always in a state of dependency, their communities have never been asked for their input or given the opportunity to address their own educational needs. Paquette and Fallon provide insight into how the basis of education policy has been initiated through the mechanism of Indian and Northern Affairs Canada (INAC).

Readers will find this book an excellent resource for fathoming First Nations education. I would particularly recommend it for Aboriginal education courses. Policy can become stagnant, which is the case in Canada through the Indian Act. Improving education policy for First Nations must recognize basic human rights and the right to self-determination. **Mark Aquash**, *Department of Education Studies, University of British Columbia.*

Integrating Aboriginal Perspectives into the School Curriculum: Purposes, Possibilities, and Challenges. By Yatta Kanu. University of Toronto Press, 2011. xiii + 244 pp. Tables, discussion questions, references/recommended reading, index. $60.00 cloth, $24.95 paper.

This is an excellent book about an issue of importance for the future of cities in the Canadian prairies and Great Plains. It examines the difficult task of integrating Aboriginal cultural knowledge into school curricula. In the first chapter Yatta Kanu explains why this matters. In subsequent chapters she draws upon field research over the period 2003–2007 with 84 Aboriginal students and 18 teachers in six low-income, inner-city schools in a Canadian prairie city with a large Aboriginal population. She brings together the results of an integrated series of research studies, each building on the one before, and the existing academic literature, and she draws upon the voices of Aboriginal students and their teachers.

The research is conducted in a respectful and collaborative fashion, and makes good use of comparisons between classrooms in which attempts were made to integrate Aboriginal curriculum content and instructional and assessment methods, and otherwise similar classrooms in which this was not the case. The book is a fine example of how to conduct qualitative educational research—a model in this respect, in my view.

Kanu's findings are consistent with the well-established cultural discontinuity theory. More than that, however, she not only is able, by the use of her research methodology, to show the difficulties and the virtues of integrating Aboriginal cultural content and perspectives and instructional and assessment methods into the school curriculum; she also shows the limits of this cultural approach. Challenges abound: the preparation of teachers; the availability of resources; administrators' lukewarm support; and especially the problems associated with the socioeconomic conditions of so many Aboriginal students—i.e., poverty and related conditions—and their well-known, adverse impact on educational outcomes.

The author provides many insights into the kinds of classroom strategies that can improve educational outcomes for low-income, Aboriginal students—strategies that are sensitive to and respectful of cultural differences. But at the same time she argues, as so many others before her have done, that socioeconomic variables—poverty and related conditions—are likely to impede and may outweigh any such innovations.

This book is essential reading for those interested in education as a vehicle for social change in conditions of racialized poverty. **Jim Silver**, *Director of Urban and Inner-City Studies, University of Winnipeg.*

Gentle People: A Case Study of Rockport Colony Hutterites. By Joanita Kant. Brookings, SD: Prairie View Press, 2011. i + 120 pp. Photographs, tables, maps, charts, index. $16.00 paper.

Joanita Kant's *Gentle People* is an excellent case study of South Dakota's Rockport Hutterite Colony. The book includes in-depth description and analysis of the lifestyle of Rockport Colony residents and covers people of all ages and interests. There are numerous helpful photographs, both contemporary and historical.

Members of the Rockport Colony belong to a religious society that has practiced "community of goods" for nearly five centuries. The book not only introduces the reader to the deep-seated beliefs and practices of members, but also provides important sociological analysis supported by helpful figures and maps, including population pyramids, floor plans, and colony branching charts.

The Hutterites have indeed created an important alternative and communitarian society, which citizens of the modern world might learn much from, especially in terms of economy of scale and conflict management. Kant gives us a good picture of how different life is in a small community where residents are tied to each other by social, economic, and religious bonds.

Her book, however, also contains an abundance of factual errors, which greater attention to secondary sources might have forestalled. On page 17, for example, we are told that the unnamed Hutterite village where communal life was resurrected in Ukraine in the 1850s was located about 200 miles "northwest" of Odessa. Hutterthal was in fact located primarily *east* and a bit north of Odessa. On the same page, Darius Walter is listed as the leader of the Scheromet Hutterite village, when in fact Michael Waldner (Walter's competitor) was the leader of that group. Kant suggests that there were three Hutterite villages in south Ukraine at the time of immigration to the United States; there were in fact five.

Kant claims that only in "rare cases" (p. 10) do Hutterites pursue post-secondary education; since the mid-1990s, however, over 100 Schmiedeleut (Group One) Hutterites have graduated with bachelor's degrees from Brandon University (Manitoba). Kant says (on p. 18) that after settling in Dakota Territory, the non-communal Hutterian Prairieleut were "no longer members of the Hutterite faith." This is not the view of the Prairieleut, and their well-known leader Paul Tschetter (mentioned twice for other reasons in the book), who formed the same kind of Hutterite churches in which they had worshiped in Ukraine. In one of these congregations (Neu Hutterthal) the traditional sermons were the only homilies read into the 1940s, an issue I discuss in detail in *The Prairie People: Forgotten Anabaptists* (1999).

Other problems stem from an absence of footnotes, making the origin of some information impossible to track. For example, Kant suggests that the Hutterites influenced the Mennonites to settle in Ukraine in the late 18th century, though no source for this notion is provided.

Kant also de-emphasizes the significant diversity among Hutterite colonies, even within the same Leut, or what Kant calls "denomination." She does not mention that the 15,000-strong Schmiedeleut group divided in 1992, and that each group (Groups One and Two) has gone its separate way, institutionalizing differences significantly and quickly. These groups have not been unified since 1992. Hutterites cannot be neatly characterized as a single entity.

It is perplexing, moreover, that there are so many important academic works on the Hutterites missing in the reference section of Kant's book, including my own (the most recent: *The Hutterites in North America*, 2010), Austrian historian Astrid von Schlachta's *Die Hutterer zwischen Tirol und Amerika* (*The Hutterites: Between Tirol and America*, 2006), ex-Hutterite Robert Rhodes's *Nightwatch* (2009), historian Leonard Gross's *The Golden Years of the Hutterites* (1980), and Alvin Esau's *The Courts and the Colonies* (2004), along with studies undertaken by Karl Peter (*The Dynamics of Hutterite Society*, 1987) and Donald Kraybill and Carl Bowman (*On the Backroad to Heaven*, 2001).

Despite all this, Kant's case study is valuable, providing important insights into the Rockport colony's social environment, economic activities, governance, and general worldview. The reader gets a good sense of what transpires when colonies divide as well as the dynamics of extended family relationships, education, daily life, and the sense of place. The history of the Rockport Colony is also carefully positioned within the South Dakota context. If some of the historical commentary as well as Kant's attempt to compare Rockport to the larger Hutterite world had been omitted, thereby keeping the focus on the Rockport Colony and its place in the history of the Dakota Territory and the state of South Dakota, the work could have been much improved. **Rod Janzen**, *Department of History, Fresno Pacific University*.

Remaking the Heartland: Middle America since the 1950s. By Robert Wuthnow. Princeton, NJ: Princeton University Press, 2011. xiii + 358 pp. Tables, appendix, notes, bibliography, index. $35.00 cloth.

Shrinking farm numbers, population losses, and empty storefronts on Main Street have come to be seen as symptoms of an inevitable slide to oblivion for many Heartland communities. Empirical evidence of such decline is easily found, making the trend a favorite

topic for journalists. In *Remaking the Heartland*, Robert Wuthnow offers a very different interpretation of the same trends. His central argument is that Middle America (defined as eight states including most of the Great Plains) has been characterized by adaptation to changing social and economic realities in a way that has made the region a "more vibrant contributor to the national economy" today than it was a half-century ago.

Wuthnow does not deny the difficulties brought on by depopulation. But, rather than dwelling on nostalgia for the past or fretting over the future, he chooses to concentrate on the tenacity that has allowed many Heartland communities to survive and even prosper in the face of regional downsizing. To bolster his case, he calls upon a complex "multimethod" analysis using personal interviews; archival statistical data about individuals, communities, and counties; and local histories, events, and publications. The result is an interesting and scholarly mix of historical and sociological research.

Wuthnow does not attribute decline in the Heartland to any single cause or condition. In his analysis agriculture, drought, depression, transportation, technology, entrepreneurship, markets, wars, politics, public policy, and the aspirations of individuals and communities combine to weave a tapestry of change. Nothing is simple and linear. In fact, the author effectively debunks several simple explanations of decline through his analysis of archival data.

Although *Remaking the Heartland* emphasizes the period "since the 1950s," Wuthnow calls upon historical records from the late 19th through the early 21st centuries to tell the stories of numerous people and places. This results in a narrative that jumps back and forth through time and requires attentive reading in order to arrive at a summary conclusion that the author himself never exactly provides.

The appendix includes a series of 23 tables that are referenced but not discussed in the body of the book. Drawn from archival data, these tables include both simple descriptive profiles and multivariate models. For students of Middle American history these data provide a wealth of information, allowing readers to draw their own conclusions regarding the forces that have shaped the region. **Randolph L. Cantrell**, *University of Nebraska Rural Initiative, University of Nebraska–Lincoln.*

Manitoba Politics and Government: Issues, Institutions, Traditions. Edited by Paul G. Thomas and Curtis Brown. Winnipeg: University of Manitoba Press, 2010. 452 pp. Illustrations, tables, charts, notes, appendices, index. $29.95 paper.

This collection of 20 essays stems from a conference held at St. Johns College, University of Manitoba, in the fall of 2008, convened specifically to address what its organizers (now the book's editors) saw as the most glaring gaps in the coverage of "various aspects of Manitoba society, politics, government and contemporary policy issues." As with all such projects—especially when contributors come from several different fields—the contents are a bit uneven. Indeed, readers may feel somewhat whipsawed as they move from the smooth prose and deft touch of western Canada's leading historian, Gerry Friesen (who provides the first substantive chapter), to the more clipped tones of the political scientists, economists, senior policy advisers, and government mandarins who provide the vast majority of the volume's essays. Still, despite the inherent problems of such a collection, the editors have done a solid job of both grouping the essays into four more-or-less coherent sections and providing some much-needed connective tissue between the papers in their introduction.

Unfortunately, the central theme that Thomas and Brown (and many of the authors) seem to agree upon is summed up in the title of their introduction, "Manitoba in the Middle," a play upon Manitoba's position in the geographic center of Canada and a description of its centrist and, dare one say it, "Consensus Model" political culture. I say unfortunate as this makes Manitoba and its politics sound far less exciting, interesting, and *important* than has been the case since the province's founding in 1870. And, to be frank, I cringed just a bit when I read one contributor's concluding comments indicating that, in terms of political culture, "Manitoba's 'mediocre' image is well-earned, if undervalued. . . ." Ah, to be mediocre—it makes one so proud to hail from Manitoba. (Oops, hide the pride, that would be immodest and hence "un-Manitoban"!)

There were also a few times when reading some of the essays that I thought perhaps I had been transported back in time to the heyday of consensus historiography—a smidgin of Richard Hofstadter here, a sprinkling of Louis Hartz there, and, as a Canadian corrective, a pinch of Gad Horowitz over there. Judiciously leavened by the writings of political scientists who are more current, and proofed by the comments of well-placed political insiders, the overall sense of the book is that Manitobans have in fact inhabited a peaceable kingdom—dedicated to a collective quest for peace, order, and good government—for much of the past 141 years. Now, please understand, these essays, particularly those by Nelson Wiseman, Chris Adams (who challenges this model), and virtually all of the essays in part 3, "Government Institutions and Processes," which provide much valuable inside information on the recent functioning of Manitoba's government, are quite useful and make important contributions to the literature (and primary source base) on Manitoba politics. But it wasn't

until part 4, "Manitoba's Economy and Society," that a less celebratory tone came to predominate, particularly in Jim Silver's powerful essay "Segregated City: A Century of Poverty in Winnipeg," and in Joan Grace's trenchant critique of the current New Democratic Party government's so-called "Manitoba Advantage" as it does—and does not—apply to women.

On the whole, however, while this reviewer obviously has issues with the collection's overall tone, there is a wealth of information contained in this volume that will make it essential reading for any serious student of Manitoba politics for many years to come. Moreover, some of the pieces are so well written that they will even appeal to a broader nonacademic audience—Jean Friesen's piece on being a Member of the Legislative Assembly and Frances Russell's essay on the evolution of political reporting spring to mind in this regard. And, although this work will be most useful to those who teach and study Manitoba affairs, it will also have considerable utility for those whose teaching and research interests include both Canadian and northern Great Plains history, politics, and society. **Jim Mochoruk**, *Department of History, University of North Dakota.*

Hard Grass: Life on the Crazy Woman Bison Ranch. By Mary Zeiss Stange. Albuquerque: University of New Mexico Press, 2010. xv + 304 pp. Photographs, resources. $27.95 cloth.

Ranch wives have traditionally worked "off the place" to bring in needed income, and Mary Zeiss Stange may be their ultimate symbol. A professor of women's studies and religion at Skidmore College in Saratoga Springs, New York, she commutes home to the Crazy Woman Bison Ranch in the sagebrushy southeastern corner of Montana.

Since publishers discovered the West, readers have savored memoirs about difficult lives, and a series of personal essays about a New Jersey woman who raises bison might have sold like buffalo burgers in a tourist joint. Nowhere else, she opines, does the world turn upside down as quickly as on a ranch; characteristically, she doesn't take the easy route of writing entertaining personal reminiscences.

Twenty years ago, Stange and her husband traded a modest New Jersey house for seven square miles of overgrazed prairie and set out to right the wrongs done to a place that had been mismanaged ecologically as well as environmentally. The restoration begins disastrously with llamas before it proceeds to success with bison. Her narration includes her own experiences, but most of her essays are serious, in-depth studies of the broader topics that constitute life in the great grasslands spreading across the interior of the country. She begins with prehistory, analyzing the evolution of both plants and animals in the region, before moving on to the often brutal human history. She covers every imaginable subject, from the Buffalo Commons to carnivores and the problems of being a "locavore" in the sagebrush Plains. She looks at the history of the Cheyenne Natives of the region and the current interest in coalbed methane. She contemplates cows, emotional distance, gender stereotypes, mirages, hunting, privacy, weather, and the Montana Dream. Her observations and opinions are solidly buttressed with research, and she lists her primary sources.

Stange's writing is pithy and precise. Wildlife, she says, "tends to specialize in evanescence." She reminds the reader often that she is an outsider, but shows how thoroughly she has absorbed the lessons of the land and its people in her Axioms of Ranch Life, which might be posted in any western ranch kitchen. Throughout the book she comments on and illustrates painful truths about the western character: Your neighbors will help you fight fire, but they might shoot your puppy.

Wanta buy a little ranch in the West? Before you read those real estate brochures, read this book. **Linda M. Hasselstrom**, *Hermosa, South Dakota.*

Sex, Murder, and the Unwritten Law: Courting Judicial Mayhem, Texas Style. By Bill Neal. Foreword by Gordon Morris Bakken. Lubbock: Texas Tech University Press, 2009. xvi + 280 pp. Map, photographs, illustrations, notes, bibliography, index. $29.95 cloth.

"If, as has often been contended, truth is the first casualty of traditional warfare, then logic, it appears, is the first casualty of sexual warfare." And with that thematic statement in hand, author Bill Neal is off to the proverbial races with an often delightful, sometimes troubling, and generally entertaining legal discourse on the so-called "unwritten law": that a cuckolded husband or a woman wronged has the God-given right to avenge or be avenged, even to redress by murder. With a curiously dispassionate, or at least overly serious, foreword by Cal State–Fullerton professor Gordon Morris Bakken, Neal's tales of adultery, murder, and boundlessly ridiculous "not guilty" verdicts cross several decades from the 1880s over a North Texas path of tornadic sex-and-revenge events.

Looking back through centuries of legal cases and precedents from which this unwritten law evolved, Neal considers six cases that more or less represent that evolution as it stood along the Red River at the turn into the 20th century and beyond. In each, the tragic event itself is played out against the trial that followed, replete with the actual testimony and strategies that eventually produced a stunning but somehow not surprising verdict

exonerating the victim of the adulterous conduct from the charge of murder. In the epilogues for each tale, the author follows the primary figures into their respective futures, offering an occasional perspective on the impact of the judgment rendered.

One of the book's many fascinating contributions is the 1906 address to the American Bar Association by Baton Rouge Judge Thomas J. Kernon, who included, in his attempt to reduce the unwritten law into an oversimplified list, this spectacularly shocking but typical "Law III: Any man who seduces an innocent girl may, without a hearing, be shot or stabbed to death by her, or any relative of hers; and, if deemed necessary by the slayer, such shooting or stabbing may be done in the back, or while laying in wait." As Neal then asserts, "clever pioneer defense lawyers often stretched the boundaries of Judge Kernon's code to accommodate a variety of factual situations."

Neal considers the six sensational cases in his study of the unwritten law as it played itself out in Texas courtrooms by describing each through eyewitness and newspaper accounts, trial testimony, jury verdicts and findings, and outside opinion. The first is the story of the Texarkana shooting of an adulterous preacher by a 63-year-old Confederate veteran for the soiling of his unfaithful wife. During the trial proceedings, both sides leaned heavily on biblical invectives, though none more astounding than the defendant's description of his victim as a "knavish, psalm-singing hypocrite" and "base-born libertine." In the end, the defendant was found guilty only of assault and fined $50. The second tale is that of a wronged young woman, pregnant by a faithless man who had promised to marry her—a particularly vile ploy to enjoy an innocent girl's treasures—and her recourse by shooting him to death as he sat in a Gainesville courtroom. Two of her wayward pistol shots killed innocent bystanders, but in the end Miss Verna was found not guilty of all three deaths: apparently the crime of seduction of the innocent trumps blood shed even in the environs of the court of justice itself.

In the third story, when Miss Winnie Morris of Quanah, Texas, is corrupted by her boss in 1915, her family joins in on the revenge, three of them shooting miscreant Garland Radford into a pulp while Winnie's mother shouts for a hatchet to finish the familial affair: all were subsequently exonerated by an understanding jury. The fourth story, a Valentine's Day, 1925, murder by the father of the wronged girl, is unfortunately lost in a much-too-long back story of the oil boom of the 1920s. The last two tales are connected through the Ft. Worth oil-rich families of the Wagners and Davises, concluding with perhaps the most sensational Texas trial of the 1970s and the preposterous not guilty rendering for the celebrated Cullen Davis.

Bill Neal, author of *Getting Away with Murder on the Texas Frontier* (2009) and his newest, *Vengeance is Mine: The Scandalous Love Triangle that Triggered the Boyce-Sneed Feud* (2011), again entertains his readers with a lively writing style, an eye for the appealing tale, and a penetrating if sometimes disturbing perspective on the legal system a century ago as it wandered an often bizarre path across the Old South, Texas, and the Great Plains. **Paul N. Spellman**, *Division of Social and Behavioral Science, Wharton County Junior College, Richmond, Texas.*

NEWS AND NOTES

CONFERENCES

November 14, 2011

The 2011 McGovern Conference will be at the Sherman Center, Dakota Wesleyan University, Mitchell, SD. The theme is "The Plains Political Tradition: South Dakota's Political Culture." Senator George McGovern will speak on his new book, *The Plains Political Tradition: Essays on South Dakota Political Culture* (SDSHS Press, 2011). Website: mcgoverncenter.com/conference/index.htm.

November 16–20, 2011

The 110th Annual Meeting of the American Anthropological Association will be held in Montreal, QC, Canada. The theme is "Traces, Tidemarks and Legacies." Website: www.aaanet.org/meetings/. Sarah Green is the Executive Program Chair. E-mail: 2011aaaprogramchair@gmail.com

November 13–16, 2011

The 59th Annual Meeting of the Entomological Society of America will be held in Reno, Nevada, where we'll celebrate the theme, "Identify... Clarify... Speak Out!" Website: www.entsoc.org/am/index.htm.

January 29–February 3, 2012

The 65th Annual Meeting of the Society for Range Management will be held in Spokane, WA. The theme is "Lessons from the Past—Strategies for the Future." Website: www.rangelands.org/spokane2012/.

February 24–28, 2012

The 2012 Annual Meeting of the Association of American Geographers will be held in New York. Website: www.aag.org/cs/annual_conference.

March 1–3, 2012

The 55th Annual Missouri Valley History Conference will be at Embassy Suites Dowtown/Old Market, Omaha, NE. The theme is "The Tides of War: Navies, Privateers & Pirates, aggression on the seas from antiquity to the present." Contact Dr. Jeanne Reames, MVHC Program Chair by e-mail: mvhc.coordinator@gmail.com; website is www.unomaha.edu/mvhc/index.php.

March 7–9, 2012

The 46th Annual Meeting of the South-Central Section of the Geological Society of America will be in Alpine, TX. Abstract deadline is December 6, 2011. Website: www.geosociety.org/Sections/sc/2012mtg/.

March 28–30, 2011

The Center for Great Plains Studies, University of Nebraska–Lincoln, presents its 38th Interdisciplinary Symposium in collaboration with Homestead National Monument of America, National Park Service. "1862–2012: The Making of the Great Plains" will be held at the University of Nebraska–Lincoln.

In 1862, Congress passed four landmark pieces of legislation: the Homestead Act, the Morrill Act, the Pacific Railroad Act, and the act to establish the U.S. Department of Agriculture; it was also the year of the fateful Dakota Conflict. These acts and events fundamentally shaped the Great Plains as well as the nation. This symposium will examine their consequences for the society, culture, and commerce of the Great Plains.

The conference is free and open to the public. See pages 144 and 202 for more information. Contact the Center by e-mail: cgps@unl.edu; website: www.unl.edu/plains.

March 30–31, 2012

The 144th Annual Meeting of the Kansas Academy of Science will be held at at Wichita State University. Website: www.kansasacademyscience.org/.

April 20, 2012

The Annual Meeting of the Nebraska Academy of Sciences and the **Nebraska Junior Academy of Sciences State Science Meeting** will be held at Nebraska Wesleyan University in Lincoln, Nebraska. Website: www.neacadsci.org.

May 9–11, 2012

The 64th Annual Meeting of the Rocky Mountain Section of the Geological Society of America will be in Albuquerque, NM. Website: http://www.geosociety.org/Sections/rm/2012mtg/.

CALL FOR PAPERS

October 28, 2011

The 55th Annual Missouri Valley History Conference is issuing a call for papers. The theme is "The Tides of War: Navies, Privateers & Pirates, aggression on the seas from antiquity to the present." Contact Dr. Jeanne Reames, MVHC Program Chair by e-mail: mvhc.coordinator@gmail.com; website is www.unomaha.edu/mvhc/index.php.

January 2, 2012

The South Dakota State Historical Society (SDSHS) Press invites chapter proposals for a book, *The Politcal Culture of South Dakota*, to be edited by Jon K. Lauck, John E. Miller, and Donald C. Simmons, Jr., and published by the SDSHS Press in 2014. Interested parties should consult the forthcoming The Plains Political Tradition: Essays on South Dakota Political Culture (SDSHS Press, 2011), which will serve as a model for the future volume and an building block for future research. For more information, contact Martyn Beeny, Associate Editor, SDSHS Press, 900 Governors Drive, Pierre, SD 57501; website: http://faculty.isi.org/announcements/index/view/id/258; e-mail: Martyn.beeny@state.sd.us.

February 15, 2012

The 75th Annual Meeting of the Rural Sociological Society will be held July 25–29, 2012, in Chicago at the Palmer House Hilton. By this time pretty much everybody knows that 2012 is the 75th anniversary of the founding of the Rural Sociological Society and that our meetings will be held in the same hotel where the RSS was launched in 1937.

What you may not realize is that 2012 is also the 150th anniversary of the founding of the U.S. Department of Agriculture, the federal agency that has primary responsibility for the quality of life in rural America. This confluence should encourage us to use the annual meetings as a time of reflection not only of the path traveled but the road ahead. What policies – public and otherwise – have contributed to the patchwork of uneven prosperity we find at home and abroad and how can we do better? For more information, see the website: www.ruralsociology.org.

ANNUAL INDEX

INSTRUCTIONS TO AUTHORS

SUBMISSIONS

- All manuscripts must be concise: no more than 5,000 words excluding abstract and reference sections.
- Tables and figures (including maps) must be carefully composed to achieve the author's goal of clarity of presentation.
- There is no limit for either figures or tables accompanying the manuscript. Authors must, however, be judicious in their use of figures and tables.
- All submissions must be double-spaced, and include abstract, key words, text, and references, and printed on 8.5 by 11-inch white paper with 1-inch margins. Use Times New Roman font.
- Informational footnotes are not accepted.
- Authors must prepare a separate title page with their name(s) and affiliation(s), and any acknowledgments, which will not be sent to reviewers. The title of the paper must be repeated directly above the abstract.
- Authors must submit three copies of their manuscripts and a CD-R of all figures and tables.
- If the manuscript is accepted for publication, author(s) will be asked to send the final document as an e-mail attachment or on a CD-R in Word or Rich Text Format/.rtf file.

REVIEW PROCESS. ALL MANUSCRIPTS ARE GIVEN DOUBLE-BLIND REVIEW. Authors must prepare a separate title page with their name(s) and affiliation(s), and any acknowledgments, which will not be sent to reviewers. The title of the paper must be repeated directly above the abstract. Authors should avoid self-identification in the text. When at least two external reviewers with expertise in the topic have submitted their evaluations, the manuscript is reviewed by the Editor who makes the final decision to publish.

Send your submissions to
Editor
Robert F. Diffendal, Jr.
Great Plains Research
University of Nebraska–Lincoln
P.O. Box 880246
Lincoln, NE 68588-0246

Phone: (402) 472-6970
E-mail: gpr@unl.edu

Article Style. Authors should write simply and in the first person, communicate with a broad interdisciplinary audience in jargon-free language, and avoid sexist, racist, or otherwise biased language or intent.

Title. Article titles should not exceed 10 words (or 82 characters) and should not have subtitles.

(1) **Text Headings** are left-justified, all caps, and bold: INTRODUCTION, METHODS, RESULTS, DISCUSSION, CONCLUSIONS, ACKNOWLEDGMENTS, REFERENCES. (2) **Text Subheadings** are left-justified, title caps, and bold. (3) **Text Lower Subheadings** are left-justified, title caps, bold, no tab, and lead into the paragraph.

Abstract. A short abstract of fewer than 200 words should precede the main text. The abstract should identify the problem addressed in the paper, indicate the methodology, and summarize the results. Authors should prepare an abstract that will be interesting to and understood by nonspecialists in the field. Five to eight **key words** should accompany the abstract.

Illustrations. All illustrations including maps should be referenced parenthetically by arabic numbers in the text. For example, "Rainfall increases with elevation (Fig. 1)." Captions for figures should be sent as a separate file and not included or embedded into the figure itself. All illustrations should be sized for 1-column width (3.25") or 2-column width (6.625"), be no more than 9.0" in height, and be sent as separate files as "grayscale" **tiff** or **eps** graphic files at 350 dpi, and "line" illustrations should be 1200 dpi. High quality **pdf** files are acceptable.

DO NOT send figures embedded into your article, as Word figures, or as PowerPoint® graphics. Send illustrations/figures as separate files on a CD-R. Use a sans serif font such as Arial.

Maps. A bar scale in kilometers and a north arrow must be included on all maps. Enlarged details of maps should be to scale. All geographic places mentioned in the text should be shown on a map. Use a sans serif font such as Arial.

Measurements. All measurements should be given in **SI units** (expanded metric system).

Tables. Tables should be presented on separate sheets apart from the text and printed as quality images. They should be formatted to fit the standard text area of the journal [1-column width (3.25") or 2-column width (6.625") and no more than 9.0" in height], since they may be treated as camera-ready illustrations at the time of publication. Send tables separately as Word files with article file on CD-R. Use Times New Roman font.

Reference Style. *Great Plains Research* uses *The Chicago Manual of Style*, 16th edition, as its reference guide. The journal uses author-date citations in chronological order in the text [for example: (Smith et al. 1990; Templer 1992; Jones in press)] and a complete reference section that gives author, year, title, source, and page references for journal or newspaper articles. **Include page numbers for quotations** [for example: (Templer 1992, 45)].

- For a journal article:
  Murkin, H.R. 1998. Freshwater functions and values of prairie wetlands. *Great Plains Research* 8:3–15.
- For a book:
  Blouet, B.W., and F.C. Luebke, eds. 1979. *The Great Plains: Environment and Culture*. University of Nebraska Press, Lincoln, NE.
- For an article in a book or conference volume:
  Wedel, W.R. 1994. Coronado and Quivira. In *Spain and the Plains*, ed. R.H. Vigil, F.W. Kaye, and J.R. Wunder, 45–66. University Press of Colorado, Niwot, CO.

For complete guidelines, please see our web page: **www.unl.edu/plains**

inside this issue

GREAT PLAINS RESEARCH

VOLUME 21, NUMBER 2 FALL 2011

NATURAL SCIENCES

SOCIAL SCIENCES

University of Nebraska Lincoln

ISSN 1052-5165