Habitat Use And Diet Analysis Of Breeding Common Barn-Owls in Western Nebraska

Joseph A. Gubanyi M.S.
University of Nebraska - Lincoln

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HABITAT USE AND DIET ANALYSIS
OF BREEDING COMMON
BARN-OWLS IN WESTERN
NEBRASKA

Joseph A. Gubanyi, M.S.

1989
HABITAT USE AND DIET ANALYSIS OF BREEDING
COMMON BARN-OWLS IN WESTERN NEBRASKA

by

Joseph A. Gubanyi

A THESIS

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Under the Supervision of Professor Ronald M. Case

Lincoln, Nebraska

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HABITAT USE AND DIET ANALYSIS OF BREEDING COMMON BARN-OWLS IN WESTERN NEBRASKA

Joseph A. Gubanyi, M.S.
University of Nebraska, 1989

Advisor: Ronald M. Case

I studied barn owl (Tyto alba) breeding biology in western Nebraska 1984-1986. I had greatest success capturing males (56% success) at night using trap doors at nest sites and females (91% success) using hoop nets at nest sites during the day. Barn owls removed 16 of 23 tail-mounted radios. Eight birds were radiotracked for 7-14.5 hours. The mean foraging range was 198 ha (32-299 ha, n = 8) with < 1% overlap among birds from adjacent nest sites. Field-tested telemetry error was high (mean displacements of radiolocations for 2 birds were 208 and 241 m). I found no relationship between percent cover in foraging habitat and reproductive success. I identified 10,140 prey items from 15 nest sites and found both annual and seasonal variation in barn owl diets. Microtus ochrogaster occurred most frequently (32.7%) and increased in the diet from 17.6 to 27.2 to 43.5% 1984-1986. M. ochrogaster and Perognathus hispidus annual frequencies were both negatively correlated with Reithrodontomys megalotus and Peromyscus maniculatus frequencies. Prey delivery rates averaged 1.7 to 5.1 prey per hour at 4 nest sites. Males delivered 77% of the prey. Probability of a given prey species delivered to the nest was independent of the previous species delivered to the nest. Analysis of prey size and search time did not support single prey loader foraging theory. Reproductive success of barn owls appears to be influenced by nest site quality, foraging ability of parents, and diet.
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HABITAT USE AND DIET ANALYSIS OF BREEDING COMMON BARN-OWLS IN WESTERN NEBRASKA

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I studied barn owl (Tyto alba) breeding biology in western Nebraska 1984-1986. I had greatest success capturing males (56% success) at night using trap doors at nest sites and females (91% success) using hoop nets at nest sites during the day. Barn owls removed 16 of 23 tail-mounted radios. Eight birds were radiotracked for 7-14.5 hours. The mean foraging range was 198 ha (32-299 ha, \(n = 8\)) with < 1% overlap among birds from adjacent nest sites. Field-tested telemetry error was high (mean displacements of radiolocations for 2 birds were 208 and 241 m). I found no relationship between percent cover in foraging habitat and reproductive success. I identified 10,140 prey items from 15 nest sites and found both annual and seasonal variation in barn owl diets. Microtus ochrogaster occurred most frequently (32.7%) and increased in the diet from 17.6 to 27.2 to 43.5% 1984-1986. M. ochrogaster and Perognathus hispidus annual frequencies were both negatively correlated with Reithrodontomys megalotus and Peromyscus maniculatus frequencies. Prey delivery rates averaged 1.7 to 5.1 prey per hour at 4 nest sites. Males delivered 77% of the prey. Probability of a given prey species delivered to the nest was independent of the previous species delivered to the nest. Analysis of prey size and search time did not support single prey loader foraging theory. Reproductive success of barn owls appears to be influenced by nest site quality, foraging ability of parents, and diet.
Introduction

Barn owls are exceptional hunters having among the best auditory and visual senses in the animal kingdom (Dice 1945, Konishi 1973, Knudsen 1981). They are able to catch more prey than needed to feed themselves and their young, and therefore stockpile prey. Barn owls are known for high reproductive potential, are capable of reaching their first reproduction in less than a year, breed in all months of the year, and double-brood when sufficient food is available.

Barn owl populations should be secure with their foraging skill and reproductive potential, but that is not the case throughout much of their range in North America. Barn owls have been on the Audubon Blue List because of declining populations throughout much of their range (Tate 1981). They have been listed as an endangered species in 6 midwestern states and are a candidate for endangered status in a seventh state (Laycock 1985). Much of the barn owl decline has been attributed to changing land use patterns which have eliminated grasslands and meadows, the barn owl’s principal foraging habitat (Colvin 1986). Barn owls in Nebraska have suffered a population decline in the eastern part of the state. This spurred the Nebraska Game and Parks Commission to monitor barn owl populations and start a barn owl captive breeding program. Barn owl populations in western Nebraska have not experienced population declines typical of much of the Midwest.

No extensive study of barn owls has been undertaken in Nebraska. A detailed analysis of the barn owl and its habitat in western Nebraska may provide information for developing a management plan to prevent further barn owl decline in Nebraska.
Research Objectives

1. To quantify barn owl foraging habitat and non-foraging habitat.

2. To determine a discriminant function that will distinguish barn owl foraging habitat from non-foraging habitat.

3. To determine barn owl foraging range in the study area.

4. To measure the density of prey species in barn owl foraging habitat.

5. To determine barn owl diet.

6. To measure barn owl productivity.

7. To determine barn owl foraging habitat preferences.

8. To determine the relationship between barn owl productivity and type of prey eaten.

9. To determine the relationship between barn owl productivity and distance traveled to foraging sites.

10. To determine the relationship between barn owl productivity and area of the foraging site.
Barn owls are easily identified by their heart-shaped face and white to creamy-colored plumage. They are medium to large-sized owls standing roughly 400-500 mm tall and weighing 400-500 g (Karalus and Eckert 1974). Males tend to have less spotting and buff coloring on the breast and underside than females (Colvin 1984). Females weigh 115 g more and are 40 mm taller than males on the average (Karalus and Eckert 1974).

Barn owls are found on every continent except Antarctica (Mikkola 1983). They become less common in the more northerly parts of their range, principally ranging in a belt around the world between latitudes 40 north and 40 south. They are found throughout the United States and extend into Canada both along the Pacific Coast and in the Great Lakes region (Tyler and Phillips 1978). Johnsgard (1980) lists the barn owl as uncommon throughout Nebraska.

In North America barn owls are considered strictly nocturnal (Tyler and Phillips 1978) although in Europe they are frequently seen foraging before dusk (Mikkola 1983). Barn owl enemies are limited to humans and a few large raptors, most notably the great horned owl, Bubo virginianus, (Tyler and Phillips 1978). Barn owls are birds of open country (Tyler and Phillips 1978). In the eastern U.S. they forage over wet meadows and salt marshes while roosting in adjacent woodlands or humanmade structures (Colvin 1984). In the West much of the open country where barn owls occur is drier with less vegetation than in the east. Typical barn owl habitat in the West consists of grasses intermingled with shrubs. In the East barn owls typically nest in humanmade structures but also use tree cavities (Colvin 1984), while in the West barn owls most frequently nest in natural cavities found in cliffs and
cutbanks (Marti et al. 1979). Barn owls readily use artificial nest boxes, often with greater reproductive success than natural cavities found in the same area (Marti et al. 1979, Colvin 1984). On occasion, barn owls live and breed in small colonies with adjacent nests as close as 5 m (Smith et al. 1974, Martin 1986). Barn owls in western Nebraska are found in agricultural areas where rangeland is prevalent (Wingfield 1980, 1983b, 1985). They have been found nesting in artificial nest boxes and natural cavities in cut banks.

Stewart (1952) reported 1.5 years average life expectancy for barn owls. He stated that one barn owl was found 11.5 years after it was banded in the nest. Karalus and Eckert (1974) stated that a number of barn owls lived beyond 15 years in captivity. Barn owls at age 3 have a greater life expectancy than barn owls under age 1 (Honer 1963). Thus, low life expectancy for barn owls reported by Stewart is really indicative of high juvenile mortality for the species.


Although barn owls breed in every month (Ames 1967, Reese 1972, Colvin 1984), they are most frequently found nesting April through July (Colvin 1986) and on occasion have double broods (Morejohn 1955, Reese 1972, Colvin 1984) and are polygynous (Colvin 1984). Stewart (1952) reported one barn owl nesting 10 months after it was banded as a nestling.

Mikkola (1983) reported that mean clutch sizes from Europe ranged from 5.1 to 8.1 with one extreme in which 18 eggs were laid, all hatching. In a 6-year study in the Chesapeake Bay area, Reese (1972) reported means of 2.7 to 4.8 young fledged per successful nest attempt. However, a significant number of nest attempts which were initiated had no young fledge, and when these nests were included, the mean number of fledged young was 1.7 to 2.4. Smith et al. (1972), studying a colony of barn owls in Utah, reported 1.3 young
fledged per nest. Human interference may have contributed to the low
number. Wingfield (1980, 1981, 1983a, 1983b, 1985), reported 3.3 to 4.9 young
fledged per nest over a 5-year period in western Nebraska.

Colvin (1984) found a high correlation \( (r = 0.947) \) between number of
barn owls fledged per nest and amount of rainfall recorded. Wilson et al.
(1986) found similar results in central Mali in Africa. They found number and
size of clutches were greater when there was an observed eruption of rodents.
Otteni et al. (1972) were able to show a high correlation \( (r = 0.913) \) between
biomass of mammals in the diet and number of young reaching fledging. Fast
and Ambrose (1976) found when a barn owl was given a choice between
artificially created grassland and artificially created woodland, it more
frequently foraged in grassland. Lovari and Fundi (1976) related diet of barn
owls to frequency of vegetative cover types within a 2 km radius from the nest
site. Honer (1963) noted that barn owls in the Netherlands foraged in
untended, overgrown fields which were characterized by variation in
topography and alternation of vegetation types. Colvin (1984) was able to
determine that owls spent more time in grassland areas than would be expected
by chance alone. Colvin (1985), studying barn owls in Ohio, found that a 30-
year decline in barn owl populations was strongly correlated with a reduction
in grass-associated agriculture. Colvin stated the critical element in barn owl
habitat was suitable foraging habitat, namely, vole-containing grasslands and
meadows. Ault (1971) showed that there was a strong relationship between
certain habitat variables and barn owl reproduction. Ault concluded that barn
owls cue on these parameters (ie. - barn owls will choose the habitat with the
greatest kilometers of road available) in selecting breeding habitat.
Habitat quantification has been done successfully with a number of other species. Wiens (1969) developed a method which used physiognomic characteristics of grasslands in discriminant function analysis to identify essential habitat components for grassland birds. Whitmore (1981) used Wien's technique to successfully distinguish between non-habitat and habitat of grasshopper sparrows (*Ammadramus savannarum*) in grasslands. Discriminant function analysis was used successfully to classify different components of spruce grouse (*Dendragapus canadensis*) habitat (Ratti et al. 1984), to separate used and unused wetland habitats of breeding marbled godwits (*Limosa fedoa*) (Ryan et al. 1984), and to separate scaled quail (*Calipepla squamata*) night roosting habitat from non-roosting habitat (Stormer 1984). The net result of these studies is that wildlife managers are able to predict the kinds of habitat that particular species will use and thus manage accordingly. There are some problems with this methodology. There is a lack of standardization in data collecting and analysis (Anderson 1979), causing relationships between wildlife and habitat to be obscured when compared in the literature. Nevertheless, these methodologies if properly used can provide detailed and precise information about a species' habitat.

Much has been learned about behavioral patterns and ecological requirements for certain species through radiotracking. Radio transmitters have been made small and light enough to fit passerines (Bray and Corner 1972, Martin and Bider 1978). Radiotelemetry has been used for determination of home range, habitat use, movement patterns, territoriality, social behavior, and survival rates (Dunstan 1972, Nicholls and Fuller 1987). Nicholls and Warner (1972), in a classic study, used a semi-automatic, permanently mounted radio receiver and antenna to monitor barred owl (*Strix varia*) movements on
a continuous 24-hour basis. This system enabled the collection of millions of radiolocations. Computer analysis of these data points gave a detailed description of barred owl habitat use. Since then, considerable radiotelemetry research has been done with improvements in transmitter attachments, power sources, techniques of monitoring radioed animals, and knowledge of the effects of transmitters on animals (Nicholls and Fuller 1987).

Harnesses have been used to attach radios to game birds (Brander 1968) and barred owls (Nicholls and Warner 1972). Baekken et al. (1987) used backpacks to attach radios to northern hawk owls (*Surnia ulula*), and Martin and Bider (1978) sewed radios to the skin on the backs of blackbirds. Colvin (1984) and Kenward (1978) used tail-mounted radios on raptors. Tail-mounted radios drop when birds molt their tail feathers and thus are not permanently attached. Cochran (1980) felt that radio transmitters should not weigh more than 5% of body weight. Some investigators have used radios weighing as much as 8% of body weight (Cochran 1980). Caccamise and Hedin (1985) stated that determining radio weights purely by percent body weight will overburden larger birds. They proposed an alternative method for determining radio load weight based on aerodynamics of the bird. Tail-mounted radios create additional load problems because of their positioning away from the bird's center of gravity. Kenward (1978) believed tail-mounted radios for raptors should weigh less than 4% of body weight while Nicholls and Fuller (1987) stated that tail-mounted radios for owls should weigh no more than 2% of body weight.

A number of methods have been proposed for calculating home range of animals from radiolocations. Two general approaches are used, the grid cell approach and the outline approach (Kenward 1987). The grid cell approach
divides a map of the habitat into a grid and radiolocations are placed into grid
cells. The number of radiolocations per grid cell is tabulated allowing for
relative frequency of habitat use to be calculated. Nicholls and Warner (1972)
used this technique successfully in their work with barred owls. The outline
approach involves drawing a perimeter around the outermost data points and
determining the area of the resulting polygon. (Hayward et al. 1987) The
minimum convex polygon method is a popular form of the outline approach.
The smallest possible convex polygon is drawn around all data points and then
the area of that polygon is determined. The minimum convex polygon method
is dependent on the number of tracking days (Baekken et al. 1987), and it
assumes a uniform utilization distribution that is it makes no attempt to
distinguish areas of high activity from areas of low activity. It is also sensitive
to movements in the periphery of home range (Samuel and Garton 1985). Any
range analysis study needs to have sufficient data points. Laundre and Keller
(1984) evaluated a number of home-range studies of coyotes based on
radiolocations and concluded that most studies based their home-range
calculations on data sets that were too small. They believed that 4 to 5 24-hour
samples of sequential radiolocations would be sufficient for home range
calculations. Baekken et al. (1987) felt that a minimum of 10 radiolocations per
day for 10 days would have been needed to calculate an asymptotic home range
for boreal owls (Aegolius funereus).

Methods

Study Area

Since 1980 the Nebraska Game and Parks Commission has monitored
barn owl nesting in western and central Nebraska. They located known nest
sites, installed artificial nest structures, and recorded nest site use and reproductive success. By 1984, 94 nest sites were documented in 17 counties in western and central Nebraska (Wingfield 1985). A small area of concentrated barn owl use was located in Lincoln County, Nebraska (Figure 1). The area, approximately 19 X 11 km, is bordered on the north by the North Platte River. The flood plain is a broad, flat area characterized by dense, seasonally wet meadows including Phalaris sp., Bromus sp., Agrostis sp., Leguminosae sp., Equisetum sp., and Cyperaceae sp. The southern part of the study area rises in elevation changing into Sandhills prairie, characterized by sandy soil and drier, sparser vegetation. Corn and wheat are the two principal crops in the intensively farmed study area. Dominant breeding season grasses are Bromus tectorum and Stipa comata. Wooded areas, primarily windbreaks and woodlots around residences, make up less than 5% of the total area around nest sites.

**Locating Nests**

In spring of 1980 the Nebraska Game and Parks Commission initiated a management program for barn owls in Nebraska (Wingfield 1980). The program involved a media campaign to locate existing barn owl nests. Artificial nest boxes and barrels were placed in areas where barn owls were known to have nested. Through this program 15 barn owl nests were identified in the study area described above (13 artificial nest structures and 2 natural cavities). An additional 3 sites were found in the study area by checking natural cavities along the Sutherland Canal and in cut banks along roads.

**Capturing Owls**

Four methods were used to capture owls.
Hoop net - We hid under a tarp beneath the nest box before the male's first arrival. When the owl entered the nest box, we placed the hoop net over the entrance before the owl could escape. We then removed the owl by hand from the nest cavity or net. We also used the hoop net to capture females roosting with nestlings during the day. After approaching the nest site quietly, the entrance to the cavity was covered with the net before the female had a chance to escape. The owl was then removed as described above.

Trap door - We placed a hinged door at the opening of the nestbox. When the owl entered the nest box, the door was closed by pulling a monofilament line. For natural cavities in cut banks, we used a sliding trap door with frame. The sliding door was held open by a monofilament line and released after the owl entered the cavity. In both cases the apparatus was set in an open position for several days to allow the owl to adjust to the apparatus. We used a wire hook to snag the foot of owls in deep cavities.

Bal-chatri - We made a circular bal-chatri trap (McClure 1984) 25 cm in diameter and 7 cm high. The trap contained a mouse as bait and was anchored to the ground where it was visible from a regular perch used by the owl we were trying to capture. The top of the trap had numerous loops of monofilament line designed to ensnare the owl's feet when it landed on the baited trap. We also used a carpet filled with monofilament loops tacked to the top of the nest box where adult owls landed before entering the nest box with food.

Mist nets - We placed mist nets in the flight corridor used by adult barn owls when bringing food back to the nest.
Banding, Measuring, and Sexing of Barn Owls

Captured owls were placed in a zippered pillow case and weighed with a 1 kg spring Pesola scale (Colvin 1984). Sex of the barn owl was determined by a combination of factors including weight (males weigh 15-20% less than females), amount of spotting and white on the breast, and behavior (males generally roost away from the nest in the day and bring food to young at night while females often roost with young during the day and spend little or no time foraging for young at night) (Colvin 1984). All birds were banded with U.S. Fish and Wildlife Service, No. 6 lock-on leg bands.

Radiotelemetry

All radio transmitters were purchased from Wildlife Materials, Carbondale, Illinois. Two-stage radio transmitters, with an activity circuit, in the 150-151 MHz range were used. Radio transmitters weighed 9.7 g which ranged from 1.6 to 2.3% of the study birds' body weights. Radios had a line of sight range of 5 km and theoretical lifespan of 2.5 months. Radio transmitters were designed to be tail-mounted. Several procedures were used to attach transmitters. Tail clips were fashioned after an Olin Bray design (Bray and Corner 1972) used with blackbirds (a revised clip design was obtained via personal communication with Ron Johnson, University of Nebraska, Lincoln) which secured the radio to the middle two rectrices. Radios also were sewed to the middle two rectrices (Kenward 1978). A falconry technique, using a piece of surgical tubing slid up the shaft of the middle rectrix and then secured both to the feather shaft and to the radio with a plastic wire cinch, was used (obtained via personal communication with Bob Linderholm, Cambridge, Nebraska). Finally, radios were fastened to the middle two rectrices using hot melt glue (Colvin 1984). Receivers used for tracking were model LA-12 (from
AVM Instrument Co., Champaign, Illinois). Two vehicles were equipped with roof-mounted, rotating dual yagi antennas and CB radios. After synchronizing watches, the two parties with radio receivers moved to prescribed locations and using a null-peak system, made radiolocations at regular intervals (every 5 minutes) while a third party monitored nest activity. The purpose of the nest observer was to help coordinate radiolocations with foraging activity. Radiolocations were later plotted on U.S. Geological Survey 7.5 minute topographic maps. By recording the times when owls brought prey to the nest, we assumed that the radiolocations made just prior to that were in foraging habitat. Barn owl foraging range was determined using the minimum convex polygon method. A planimeter was used to estimate the area of the polygon created by the outline of the radiolocations.

Habitat Quantification

Barn owl foraging habitat was determined from plotted radiolocations on cover maps. Non-foraging habitat was identified as unused areas that were no farther than foraging areas from nest sites. The following habitat parameters were measured:

Litter depth - a metal rod (5 mm diameter) was placed vertically into the litter and depth was measured to the nearest mm. Measurements were taken every 2 m along randomly placed 100-m transects in a given habitat.

Effective height - Dr. Jim Stubbendieck (University of Nebraska, Lincoln) suggested I use a device which measured effective height by the ability of the vegetation to hold up a lightweight disk (Santillan et al. 1979). Specifically, a plastic lid from a 5-gallon bucket was fitted with a small metal sleeve in the center enabling it to slide down a metal tubing 1.5 m long and 1.6 cm in diameter. The tubing was marked in 1 cm increments. The disc was 29.5
cm in diameter and weighed 165 g. The measure was taken by placing the tubing perpendicular to the ground and dropping the disc down the tube from the 1.5 m mark. The height above the ground that the disk was supported by the vegetation was recorded from the tube.

Robel index - a vegetation board divided in 10 cm increments as described by Robel et al. (1970) was placed vertically in the vegetation. Viewing the vegetation board from a distance of 4 m and height of 1 m, the number of increments obscured by the vegetation was determined and recorded.

Percent grasses and percent forbs - a 929 cm² metal frame (1 ft²) was placed every 2 m along a randomly placed 100-m transect and percent occurrences of grasses and forbs for the length of the transect were recorded. Ten 100-m transects were placed for a given habitat.

Percent woody plants - this was done in the same manner as the grasses and forbs except that a 1 m² frame was used.

These habitat variables were used to differentiate barn owl foraging habitat from non-foraging habitat.

Cover Mapping

Distances for all radiolocations to the nest site were calculated. Because the most distant radiolocations had the greatest potential error due to weaker signals and the acute angle of intercept, we omitted the 5% most distant radiolocations for each bird. The mean of the remaining most distant radiolocations was 1.3 km. Cover categories included grassland, wheat, row crops (principally corn), conservation tillage corn, fallow, and woodlots. We used aerial photographs and slides from the U.S. Agriculture Soil Conservation Service (ASCS) office in Lincoln County to determine percent cover within a
1.3 km radius around each nest site. Cover categories were later reduced to crop (wheat, corn, potato, and sorghum), field (pasture, hay field, and grassland), fallow, and woodlots. We determined areas with a planimeter.

**Nesting and Barn Owl Productivity**

Barn owls have a tendency to abandon the nest if disturbed during incubation or for the first two weeks after hatching (Colvin 1984), therefore, no attempt was made to determine clutch size. Reproductive success was measured as the number of birds successfully fledged per nest. This count was obtained when young were banded during the fifth to seventh week after hatching. To ensure that number of birds banded equaled number of birds fledged, the nest site was checked for remains and/or bands of any birds that might have died after banding and prior to fledging. Additional observations were recorded when banding and telemetry revealed information about nest site fidelity, polygyny, and double clutches.

**Diet**

Pellets were prepared for examination by two methods: (1) pellets were soaked in warm water for several minutes and then teased apart to separate bones and other remains used to identify prey; and (2) pellets were soaked in an 8% NaOH solution for a minimum of 6 hours (Bull and Akenson 1985), after which bones and other fragments were separated. Bones and fragments saved included skulls, jaws, bird synsacrum and sternums, insect exoskeletons, and any unusual or unexplained materials. The skeletal remains were compared to the research collection at the Nebraska State Museum (University of Nebraska Lincoln) and to the research collection at Concordia Teachers College, Seward, Nebraska. Vertebrate prey were identified principally by skulls. However, two non-cranial bones were diagnostic for two species and also were used in
identification. Humeri of *Scalopus aquaticus* (eastern mole) were diagnostic by shape and the auditory bullae of *Dipodomys ordii* (Ord's kangaroo rat) were also diagnostic by size and shape. Care was taken not to count the same individual twice. Thus, auditory bullae of *D. ordii* and humeri of *S. aquaticus* were used to count individuals only in the event that matching skulls were not found.

**Small Mammal Trapping**

Small mammals within barn owl foraging habitat were sampled using Sherman live traps (25.5 × 7.5 × 7.5 cm). Randomly placed grids (40 to 100 traps per grid) were placed at 10 m intervals in a habitat. Rodents were trapped for 5 nights and then the grid was relocated. Traps were baited at dusk with an oatmeal-peanut butter mix and checked the following morning and left closed during the day. Captured animals were marked with ear tags. Trap location, species identification and ear tag number were recorded for each captured animal.
Figure 1. Map showing nest sites in Lincoln County, Nebraska

- Nesting attempted in 1985 and 1986
- Nest attempted in 1985 only
- Nesting attempted in 1986 only
- No nest attempt in 1985 or 1986
- Active Nest site found in 1986
Figure 1. Map showing nest sites in Lincoln County, Nebraska

- Nesting attempted in 1985 and 1986
- Nest attempted in 1985 only
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- Active Nest site found in 1986
A RADIOTELEMETRY STUDY OF BARN OWLS
IN WESTERN NEBRASKA

Abstract

We radio-tracked barn owls, *Tyto alba*, in western Nebraska in 1985-86. Hoop nets were most effective in capturing daytime, roosting females, and trap doors were most effective in capturing males at night. Barn owls prematurely removed 16 of 23 (70%) tail-mounted radios. The mean foraging range was 198 ha (32-299 ha, n = 8) with little overlap between birds from adjacent nest sites. Field-tested error resulted in average displacements of 208 and 241 m for 2 birds tested. We feel barn owl sensitivity to nest disturbances in the early stages of nesting and to tail-mounted radio transmitters along with difficulty in capturing barn owls and in obtaining accurate radiolocations make telemetry studies of nesting barn owls a challenging proposition.

Introduction

The barn owl, *Tyto alba*, is listed as endangered in 6 midwestern states and is a candidate for endangered status in a seventh (Laycock 1985). Much of the barn owl decline has been attributed to changing land use patterns which have reduced the barn owl's principal foraging habitat, grasslands and meadows (Colvin 1986). Barn owls prey chiefly on rodents (Errington 1932, Fitch 1947, Pearson and Pearson 1947, Wallace 1948, Boyd and Shriner 1954, Maser et al. 1980, Fielder 1982). The Nebraska Game and Parks Commission
started a barn owl captive breeding program in 1979 to restore barn owls in eastern Nebraska. Barn owls in western Nebraska have not experienced population declines noted in much of the Midwest. There are no extensive studies of barn owls in Nebraska. We studied barn owl nest success and foraging habitat in western Nebraska. Ultimately, we were trying to identify good barn owl habitat. In this paper we present the results of a 2-year radiotelemetry study on barn owl habitat in western Nebraska.

**Methods**

The study area, approximately 19 X 11 km, is located in Lincoln County, Nebraska. The northern border of the study area is roughly outlined by the North Platte River. The flood plain is a broad, flat area characterized by dense, seasonally wet meadows including Phalaris sp., Bromus sp., Agrostis sp., Leguminosae. Equisetum sp., Cyperaceae. The southern part of the study area rises in elevation changing into Sandhills prairie characterized by sandy soil and drier, sparser vegetation. Corn and wheat are the two principal crops in this intensively farmed area. During the owl's breeding season, the dominant grasses are Bromus tectorum and Stipa comata. Wooded areas, primarily windbreaks and woodlots around residences, make up less than 5% of the total area around nest sites.

In spring of 1980 the Nebraska Game and Parks Commission initiated a management program for barn owls in Nebraska (Wingfield 1980). Barn owl nests were located through a media campaign, and artificial nest boxes were placed in areas where barn owls were known to be present during the breeding season. We selected 15 known nest sites in the study area and looked
for additional sites by checking natural cavities along the Sutherland Canal and in cut banks along roads.

Four methods were used to capture owls.

Hoop net - We hid under a tarp beneath the nest box before the male's first arrival. When the owl entered the nest box, we placed the hoop net over the entrance before the owl could escape. We then removed the owl by hand from the nest cavity or net. We also used the hoop net to capture females roosting with nestlings during the day. After approaching the nest site quietly, the entrance to the cavity was covered with the net before the female had a chance to escape. The owl was then removed as described above.

Trap door - We placed a hinged door at the opening of the nestbox. When the owl entered the nest box, the door was closed by pulling a monofilament line. For natural cavities in cut banks, we used a sliding trap door with frame. The sliding door was held open by a monofilament line and released after the owl entered the cavity. In both cases the apparatus was set in an open position for several days to allow the owl to adjust to the apparatus. We used a wire hook to snag the foot of owls in deep cavities.

Bal-chatri - We made a circular bal-chatri trap (McClure 1984) 25 cm in diameter and 7 cm high. The trap contained a mouse as bait and was anchored to the ground where it was visible from a regular perch used by the owl we were trying to capture. The top of the trap had numerous loops of monofilament line designed to ensnare the owl's feet when it landed on the baited trap. We also used a carpet filled with monofilament loops tacked to the top of the nest box where adult owls landed before entering the nest box with food.
Mist nets - We placed mist nets in the flight corridor used by adult barn owls when bringing food back to the nest.

Captured owls were placed in a zippered pillow case and weighed with a 1 kg spring Pesola scale. Sex of barn owls was determined by a combination of factors including weight, amount of spotting and white on breast, and behavior (males generally roosted away from the nest in the day and fed young at night while females often roosted with young during the day and spent little or no time feeding young at night) (Colvin 1984). All birds were banded with U.S. Fish and Wildlife Service, No. 6 lock-on leg bands.

Tail-mounted, two-stage radio transmitters with a life of 2.5 months and weighing 9.7 g were purchased from Wildlife Materials, Carbondale, Illinois. Radios had a field-tested line of sight range of 5 km. Four methods were used to attach the transmitters:

1) a tail clip designed from a model used with blackbirds (Bray and Corner 1972) clamped the radio to the middle two rectrices;
2) radios were sewed to the middle two rectrices (Kenward 1978);
3) after positioning a piece of surgical tubing on the proximal end of the middle rectrix, the radio was secured to the surgical tubing with a plastic wire cinch (personal communication, Bob Linderholm, Cambridge, Nebraska);
4) radios were fastened to the middle two rectrices using hot melt glue (Colvin 1984).

We used two vehicles, equipped with roof-mounted, rotating dual yagi antennas, null-peak systems, model LA-12 radio receivers (from AVM Instrument Co., Champaign, Illinois) and CB radios. Radio transmitters were field-tested for ideal line-of-sight error which was 1°. After synchronizing watches, we recorded radiolocations at regular intervals from prescribed
locations, while a field assistant monitored nest activity. Radiolocations were later plotted on U.S. Geological Survey 7.5 minute topographic maps. We determined barn owl foraging range by the minimum convex polygon method and the area of the polygon with a planimeter.

Distances for all radiolocations to the nest site were calculated. Because the most distant radiolocations had the greatest potential error due to weaker signals and the acute angle of intercept, we omitted the 5% most distant radiolocations for each bird. The mean of the remaining most distant radiolocations was 1.3 km. Cover categories included grassland, wheat, row crops (principally corn), conservation tillage corn, fallow, and woodlots. We used aerial photographs and slides from the U.S. Agricultural Soil Conservation Service (ASCS) office in Lincoln County to determine percent cover within a 1.3 km radius around each nest site. Cover categories were later reduced to crop (wheat, corn, potato, and sorghum), field (pasture, hay field, and grassland), fallow, and woodlots.

**Results**

We captured and attached radios to 9 barn owls in 1985 and 10 barn owls in 1986. We were successful in 22 of 45 capture attempts using 4 methods (Table 1). We were successful in 10 of 11 attempts capturing females during the daytime at the nest site with a hoop net. Several times females made no attempt to escape and were captured inside the nest cavity. We were successful in only 2 of 10 attempts using the hoop net method to capture males bringing food to young. Either birds were too quick in entering and exiting the nest cavity, or they became wary of our presence and would not enter at all. The most effective way of capturing males at night was using a trap door. We were successful in 10 of 18 capture attempts. Five of the unsuccessful attempts were
due to experimenter error (i.e. trap door stuck open, missed cue, etc.). The remaining 3 unsuccessful attempts occurred when the nestlings were older (> 5 weeks) and adults fed young at the entrance to the cavity. We were not successful with the bal-chatri trap and mist net in 4 and 2 attempts, respectively.

Four methods were used to attach radio transmitters to barn owls (Tables 2 and 3). In 5 attempts with the clip we were able to obtain radiolocations for only 1 bird on 1 night before radios were dropped. One radio was dropped 2 days after being attached. In most cases birds were able to slide the clip off the feather shafts. We sewed 4 radios to the middle two rectrices. Three of these birds dropped their radios within 3 weeks. In one case the bird separated the radio from one rectrix and then pulled out the other rectrix with the radio still attached. In another case the bird separated the radio from both rectrices. One radio was never found and one bird still had the radio attached at the end of the research season. We attached 4 radios using the surgical tubing method. No radio was known to be on a bird after 2 weeks. Three recovered radios were still attached to the original rectrix which the bird had removed. Of 10 radios fastened using the hot melt glue method. 5 radios were dropped within 1 week. Of these 5 birds, one separated the radio from both rectrices and 4 removed one or both of the attached rectrices.

We obtained 346 (62%) radiolocations in 561 attempts from 8 different birds during the 2-year study (Table 4). We were unable to plot 21% of the attempts due to radio signals disappearing. Radio signals disappeared when birds were beyond the range of the receiver or when birds were in a cavity or near obstacles. The remaining 17% were not plotted due to improbable or impossible radiolocations when the owl's position resulted in nearly parallel
compass bearings. The mean number of plotted radiolocations was 43 (22-111) for 8 birds. The mean foraging range was 198 ha (32-299 ha, Table 4).

We were able to calculate telemetry error for 2 of 8 birds. The telemetry team determined some radiolocations unaware that the nest monitor had visual contact with birds at nest sites. Average displacements from the actual locations were 241 m (96-361 m) for 8 radiolocations and 208 m (0-578 m) for 17 radiolocations. Average compass bearing errors were 10° (0-18°) and 13° (0-44°), respectively. At the first site the radiolocations on July 27 tended to err to the east whereas on July 28 they tended to err to the west (Figure 2). This nest site was a cavity in an east-facing bank, which apparently caused reflection of radio signals.

We determined foraging ranges and day roosts for 5 birds from 3 neighboring nest sites (Figure 3). We observed less than 1% foraging habitat overlap by birds from adjacent nest sites. Smith et al. (1974) observed 100% range overlap by pairs of barn owls in Utah. Colvin (1984) reported extensive range overlap in areas of high density nesting in New Jersey.

Habitat available within 1.3 km of 14 nest sites averaged 63.4% (47.0% to 81.9%) cropland and 34.0% (16.5% to 49.0%) grassland, yet 60.5% of our radiolocations within 1.3 km of nest sites were in grasslands. Colvin (1984) found that barn owls used grasslands more than would be expected by chance alone.

We categorized 14 nest sites from 1985 into three groups based on reproductive success. Group 1 consisted of 4 nest sites where young were successfully fledged. Group 2 consisted of 4 nest sites where nesting was attempted but no young were successfully fledged. Group 3 consisted of 6 nest sites where nesting was not attempted in 1985. Discriminant function analysis
was used to classify the nest sites based on percent ground cover data. The discriminant function successfully classified 75% of the nest sites for group 1 and 50% for group 2 and 3. We concluded that percent cover was not helpful in predicting reproductive success using discriminant function analysis. Backward elimination multiple regression failed to show a significant relationship between percent cover and number of birds fledged per nest ($p = 0.3279$).

**Discussion**

We spent an inordinate amount of time capturing barn owls. This was due to owls removing radios and their wariness once they had experienced a capture attempt. We were most successful capturing females roosting with young during daytime. We captured only 1 male using this daytime method. Since we were interested in determining habitat use by males, it was necessary to attempt night captures of males. Hiding under a tarp and using a hoop net was effective only if it was a novel experience for the owls. We were unable to capture owls by this method on repeat attempts. Konishi (1973) found that barn owls were able to quickly learn experimental schemes. We found barn owls learned to avoid variations in the hoop net capture method. The most effective means of capture at night was the trap door approach. Failed attempts at this method were due to experimenter error rather than the basic design. The trap door assembly did not inhibit activity of barn owls even on repeat capture attempts although owls were more wary of human presence on these repeat capture attempts. Colvin and Hegdal (1986) made 293 captures of barn owls in New Jersey (46% day time, 54% night time). For day captures they recommended using hoop nets or covering the entrance to the cavity with a block of wood on a pole. They recommended trap doors on nest boxes for
night captures. They were successful using noose carpets on frequently used perches at nest sites where trap doors could not be used. Martin (1986) had unfavorable results using bal-chatri traps due to owls' ability to free themselves from the slip-knot nooses. Martin had the most success using a Swedish goshawk trap which lured the owl into a baited 3 ft³ box. A hinged trap door was triggered by an infrared sensor when the owl entered the trap. Martin noted that barn owls became trap shy after repeated trap attempts.

We chose tail-mounted radio transmitters (Kenward 1978) rather than harness mounted radio transmitters (Nicholls and Warner 1968) chiefly because the chances of recapturing barn owls after the nesting season were minimal, and a tail-mounted radio would allow the barn owl to drop the radio during its next tail molt. Our radio transmitters weighed 1.6 - 2.3% of body weights of barn owls we captured which is within recommendations for tail-mounted radio transmitters (Caccamise and Hedin 1985, Nicholls and Fuller 1987). Although we observed no restrictions in barn owl movement or foraging ability (one radio-tagged barn owl returned 30 prey items to the nest in 4 hours), the barn owls were apparently bothered by the tail-mounted radios. We found 16 of 23 radios (70%) were removed prematurely by barn owls. Colvin (1984) had 9 of 16 tail-mounted radios (56%) removed and two more radios destroyed by barn owls in New Jersey. Other raptors appear to be less sensitive to tail-mounted radio transmitters. Kestrels (Falco sparverius) and goshawks (Accipiter gentilis) accepted tail-mounted radio transmitters without incident (Kenward 1978). Ural owls (Strix uralensis) prematurely removed only 1 of 19 tail-mounted radios (Scherzinger 1987). In our study 13 birds removed radios within 3 weeks (6 birds within 1 week). Because of
premature radio dropping, we were unable to monitor individual barn owl movements for more than 3 weeks.

Cochran (1980) stated in ideal telemetry situations using a null system at frequencies above 100 MHz with 3-element yagi antennas spaced 1 to 2 wavelengths apart, accuracy can be to 1 degree for strong signals. MacDonald and Amlaner (1980) stated in addition to system error radio signals are affected by topography, buildings, metal fences, telephone lines, and vegetation. When we field-tested our system in an ideal line-of-sight situation, the system error was 1 degree. Error calculated from field data was > 10° which resulted in significant displacement of radiolocations from actual locations making some of the foraging range and percent habitat use results tenuous at best. This did not present a problem when we were identifying barn owl day roosts. Owls were stationary during the day, and we were able to take multiple radiolocations for the same position. During the night owls were highly mobile, and multiple radiolocations for the same position were not possible and we were forced to rely on radiolocations with large errors. The highly mobile nature of barn owls make obtaining accurate radiolocations a difficult proposition.

The foraging ranges we reported are less than the "core" ranges Colvin (1984) reported. Colvin's "core" ranges ranged from 204 to 1414 ha (11 to 81 radiolocations per owl). Our foraging ranges ranged from 32 to 299 ha (22 to 111 radiolocations per owl). Several reasons contribute to this difference. Because we were interested in the foraging range and not overall range, we did not use day roost locations in our calculations (which would have increased ranges in 4 of 8 cases). We deleted the 5% most distant radiolocations, and for 5 of 8 birds we made radiolocations 3 or 4 consecutive nights for a major portion
of the night rather than making fewer locations per night over an extended period of time.

In contrast to Colvin (1984) and Smith et al. (1974), we found little range overlap among birds from adjacent nest sites (Figure 3). Birds from the same nest site had considerable overlap and on occasion we detected birds from one nest site using a particular habitat at the same time. In 4 nights of monitoring one nest site (a total of 16 hours), only twice did a neighboring bird fly past the nest site area although two neighboring nest sites were within 300 m of the monitored nest site. On both occasions adults from the nest site being monitored were not present. Unfortunately, we were unable to capture birds from the 2 adjacent nest sites, which may have allowed us to determine greater overlap of ranges from neighboring nest sites. Our data suggest that neighboring barn owls have few interactions.

Our data show that radiolocations on a given night were clustered (Figure 4). This is consistent with foraging theory which states a predator tends to return to a patch where it has recently experienced success (Zach and Falls 1976). A predator may not return to the same patch where it was successful the previous night even though it may continue to return to a successful patch during the same night. Our data suggest that barn owls use only part of their foraging range on a given night. Baekken et al. (1987) recommended, based on asymptotic cumulative home ranges, 10 days of radiotracking to determine home ranges in hawk owls (Surnia ulula). We were unable to radiotrack barn owls long enough to determine asymptotic cumulative home ranges.

Using percent cover measurements, we were unable to separate successful barn owl nest sites from unsuccessful nest sites or used barn owl
sites from unused barn owl nest sites for a particular year, nor were we able to show a relationship between cover and number of fledglings. Ault (1971) was able to show a strong correlation between number fledged and 3 habitat parameters in the nest site vicinity (km of road, habitat diversity, and hectares of grain). Colvin (1985), using Christmas count data, showed a strong correlation ($r = 0.7324$, $p = 0.016$) between grass-associated agriculture and barn owl populations, attributing barn owl population declines in Ohio to a decrease in grass-associated agriculture. A variety of factors unrelated to habitat parameters influence reproductive success including age of adults, nest site quality, predators, and human interference. Our nest sites were located in areas frequently visited by landowners, experimenters and others. Several nest abandonments in our study area were likely induced by human disturbance.

While available grassland foraging habitat has been reported as important to barn owls (Colvin 1985; Marti 1986), nest site requirements also influence barn owl presence and reproductive success (Marti et al. 1979) and should be included in attempts to evaluate barn owl habitat preferences.

We feel several factors make telemetry studies of barn owls a challenging proposition. Barn owls are difficult to capture (especially in recapture attempts) quickly becoming wary of experimenters and trapping schemes. We found barn owls extremely sensitivity to tail-mounted radio transmitters. We would not recommend harness-mounted radio transmitters because barn owls use nest cavities less as the season progresses and would be more difficult to capture in order to remove radios. Their highly mobile nature when foraging makes obtaining accurate radiolocations difficult. Barn owls are prone to nest abandonment if the nest is disturbed during incubation.
or within 2 weeks of hatching (Colvin and Hegdal 1986). Nest monitoring and diet analysis offer alternatives for gathering natural history data on barn owls (Gubanyi 1989).
Table 1. Different capture attempts employed and their success rates.

<table>
<thead>
<tr>
<th>Method</th>
<th>Number of Attempts</th>
<th>Number of Successes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoop net, day</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Hoop net, night</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Trap door</td>
<td>18</td>
<td>10</td>
</tr>
<tr>
<td>Bal-chatri ( + variations)</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Mist net</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>45</strong></td>
<td><strong>22</strong></td>
</tr>
</tbody>
</table>
Table 2. Radiotelemetry dates, methods of attachment, and outcome for radiotelemetry in 1985.

### 1985

<table>
<thead>
<tr>
<th>Nest Site</th>
<th>Period Tracked</th>
<th>Total Nights</th>
<th>Total Hours</th>
<th>Attachment Method</th>
<th>Date of Attachment</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>9, female</td>
<td>4 June</td>
<td>1</td>
<td>1.0</td>
<td>clip</td>
<td>June 2</td>
<td>radio found at nest site June 16</td>
</tr>
<tr>
<td>10, unknown</td>
<td>28 June-12 July</td>
<td>8</td>
<td>13.0</td>
<td>sewing</td>
<td>June 23</td>
<td>radio still attached as of July 12</td>
</tr>
<tr>
<td>1, female</td>
<td>24 Jun-10 July</td>
<td>5</td>
<td>12.0</td>
<td>sewing</td>
<td>June 20</td>
<td>radio not on bird July 10; found in building adjacent to nest site, July 15</td>
</tr>
<tr>
<td>2, female</td>
<td>28 Jun-12 July</td>
<td>8</td>
<td>13.0</td>
<td>sewing</td>
<td>June 23</td>
<td>radio not on bird July 10; found in building adjacent to nest site, July 15</td>
</tr>
<tr>
<td>2, male</td>
<td>28 Jun-12 July</td>
<td>8</td>
<td>13.0</td>
<td>sewing</td>
<td>June 23</td>
<td>radio still attached as of July 12</td>
</tr>
<tr>
<td>5, female</td>
<td>28 Jun-12 July</td>
<td>8</td>
<td>13.0</td>
<td>sewing</td>
<td>June 23</td>
<td>radio not on bird July 10; found in building adjacent to nest site, July 15</td>
</tr>
<tr>
<td>5, male</td>
<td>28 Jun-12 July</td>
<td>8</td>
<td>13.0</td>
<td>sewing</td>
<td>June 23</td>
<td>radio still attached as of July 12</td>
</tr>
<tr>
<td>8, male</td>
<td>24 Jun-10 July</td>
<td>5</td>
<td>12.0</td>
<td>sewing</td>
<td>June 20</td>
<td>radio not on bird July 10; found in building adjacent to nest site, July 15</td>
</tr>
<tr>
<td>1, female</td>
<td>24 Jun-10 July</td>
<td>5</td>
<td>12.0</td>
<td>sewing</td>
<td>June 20</td>
<td>radio not on bird July 10; found in building adjacent to nest site, July 15</td>
</tr>
</tbody>
</table>

bird and radio never located
radio found at nest site June 16
neither radio nor bird located after May 22
radio found at nest site June 16
radio found at nest site June 16
radio found in barn 300 m. from nest site July 9
radio not on bird July 9; radio never found
radio still attached as of July 12
radio not on bird July 10; found in building adjacent to nest site, July 15
Table 3. Radiotelemetry dates, methods of attachment, and outcome for radiotelemetry in 1986.

<table>
<thead>
<tr>
<th>Nest Site</th>
<th>Period Tracked</th>
<th>Total Nights</th>
<th>Total Hours</th>
<th>Attachment Method</th>
<th>Date of Attachment</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>7, female</td>
<td></td>
<td>0</td>
<td>0</td>
<td>ST</td>
<td>June 10</td>
<td>radio found near nest site June 26</td>
</tr>
<tr>
<td>7, male</td>
<td></td>
<td>0</td>
<td>0</td>
<td>ST</td>
<td>June 11</td>
<td>radio found 1.6 km at Leach nest site roost June 26</td>
</tr>
<tr>
<td>1, male</td>
<td></td>
<td>0</td>
<td>0</td>
<td>ST</td>
<td>June 11</td>
<td>bird recaptured without radio June 22; radio never found;</td>
</tr>
<tr>
<td>1, male</td>
<td>26 Jun-3 July</td>
<td>2</td>
<td>7.5</td>
<td>HMG*</td>
<td>June 22</td>
<td>radio not on bird July 8; found July 9; radio dropped while being monitored July 16</td>
</tr>
<tr>
<td></td>
<td>15 July</td>
<td>1</td>
<td>7.0</td>
<td>HMG</td>
<td>July 14</td>
<td>radio still on July 6; unknown after</td>
</tr>
<tr>
<td>5, female</td>
<td></td>
<td>0</td>
<td>0</td>
<td>ST</td>
<td>June 26</td>
<td>radio not on bird June 24; radio never found; unable to recapture bird</td>
</tr>
<tr>
<td>5, male</td>
<td></td>
<td>0</td>
<td>0</td>
<td>HMG</td>
<td>June 18</td>
<td>radio found July 9, 2.0 km from nest</td>
</tr>
<tr>
<td>4, male</td>
<td>5-8 July</td>
<td>3</td>
<td>7.0</td>
<td>HMG</td>
<td>July 5</td>
<td>radio found July 25, 0.3 km from nest</td>
</tr>
<tr>
<td>17, male</td>
<td>27-29 July</td>
<td>3</td>
<td>12.0</td>
<td>HMG</td>
<td>July 24</td>
<td>radio off bird Sept 4; never found</td>
</tr>
<tr>
<td>16, female 1</td>
<td></td>
<td>0</td>
<td>0</td>
<td>HMG</td>
<td>July 24</td>
<td>radio off bird July 30</td>
</tr>
<tr>
<td>16, female 1</td>
<td>2-5 August</td>
<td>4</td>
<td>14.5</td>
<td>HMG</td>
<td>July 31</td>
<td>unknown after August 5</td>
</tr>
<tr>
<td>16, female 2</td>
<td></td>
<td>4</td>
<td>14.5</td>
<td>HMG</td>
<td>July 25</td>
<td>bird remains with radio found on Sept 4; possible great horned owl predation</td>
</tr>
<tr>
<td>16, male</td>
<td>2-5 August</td>
<td>4</td>
<td>12.0</td>
<td>HMG</td>
<td>August 2</td>
<td>unknown</td>
</tr>
</tbody>
</table>

* HMG = Hot Melt Glue Method
  ST = Surgical Tubing Method
Table 4. Radiotelemetry attempts and outcomes for two owls in 1985 and six owls in 1986.

<table>
<thead>
<tr>
<th>Site(Year)</th>
<th>Number of Attempts</th>
<th>Number Successful Attempts</th>
<th>Number Lost Signals</th>
<th>Number Impossible Coordinates</th>
<th>Range (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8, male (85)</td>
<td>49</td>
<td>38</td>
<td>7</td>
<td>4</td>
<td>149</td>
</tr>
<tr>
<td>5, male (85)</td>
<td>42</td>
<td>22</td>
<td>12</td>
<td>8</td>
<td>299</td>
</tr>
<tr>
<td>17, male (86)</td>
<td>137</td>
<td>111</td>
<td>18</td>
<td>8</td>
<td>295</td>
</tr>
<tr>
<td>4, male (86)</td>
<td>95</td>
<td>33</td>
<td>31</td>
<td>31</td>
<td>255</td>
</tr>
<tr>
<td>1, male (86)</td>
<td>89</td>
<td>40</td>
<td>31</td>
<td>18</td>
<td>217</td>
</tr>
<tr>
<td>16, female 1 (86)</td>
<td>55</td>
<td>42</td>
<td>9</td>
<td>4</td>
<td>32</td>
</tr>
<tr>
<td>16, female 2 (86)</td>
<td>48</td>
<td>24</td>
<td>5</td>
<td>19</td>
<td>194</td>
</tr>
<tr>
<td>16, male (86)</td>
<td>46</td>
<td>36</td>
<td>7</td>
<td>3</td>
<td>140</td>
</tr>
<tr>
<td>Total</td>
<td>561</td>
<td>346</td>
<td>120</td>
<td>95</td>
<td></td>
</tr>
</tbody>
</table>
Figure 2. Map showing telemetry error at site 16. The telemetry team radiolocated the bird unaware that it was at the nest site.

* July 27 radiolocation errors
○ July 28 radiolocation errors
■ Nest site
Figure 3. Map of foraging ranges for 5 birds from 3 neighboring sites.

Site 1 - a single male was radiolocated from this site
Site 4 - a single male was radiolocated from this site
Site 17 - 2 females and 1 male shared the same nest site

* Nest sites of radiolocated birds
◊ Day roosts of radiolocated birds
* Nest sites of birds not radiolocated
Figure 4. Radiolocations made 3 consecutive nights for male at site 16.

- July 27 radiolocations
- July 28 radiolocations
- July 29 radiolocations
- Nest site

1 mile
Literature Cited


ANALYSIS OF BREEDING BARN OWL DIET AND NESTING SUCCESS IN WESTERN NEBRASKA

Abstract

Barn owl (Tyto alba) diet and productivity were analyzed in Lincoln County, Nebraska 1984-1986. Nest attempts were made at 21 of 28 nest sites checked in 1985 and 1986. Total count of prey was 10,140 prey items. Microtus ochrogaster comprised 32.7% of total diet and showed a marked increase in frequency from 1985 to 1986. Barn owl productivity increased from 1985 to 1986 with more nests initiated, higher percent successful nests, and higher mean number fledged per nest attempt. Frequency of prey in the diet was significantly different than proportions of prey captured by trapping. M. ochrogaster was overrepresented and Peromyscus maniculatus underrepresented in the diet. M. ochrogaster and Perognathus hispidus frequencies in the diet were negatively correlated both to Reithrodontomys megalotus and to P. maniculatus but were not correlated with each other, nor were the latter two correlated with each other. R. megalotus decreased and P. hispidus increased in the diet through the season. A number of factors appear to influence barn owl productivity including diet, quality of nest site, and foraging ability of parent birds.

Introduction

Examination of barn owl diets has broad application to understanding their basic ecology. Studies have included descriptions of prey (Marti 1973, Yaksic, F. and J. Yanez 1979, Maser et al. 1980), interspecific comparisons of
diet (Baumgartner and Baumgartner 1944, Marti 1974, Rudolf 1978, Gustafson 1983), bioenergetics analysis (Hamilton and Neill 1981, Colvin 1984, Feldhamer 1985), analysis of diet over time (Baumgartner and Baumgartner 1944, Marti 1974, Bull and Akenson 1985, Campbell et al. 1987), and effect of diet on reproductive success (Otteni et al. 1972, Colvin 1984). Jones (1949) examined 222 pellets from 3 localities in western Nebraska and found that Microtus sp., Peromyscus sp., and Reithrodontomys sp. occurred in the greatest percentage of pellets. Rickart (1972) collected 55 barn owl pellets from western Nebraska during the summer and found that 58% of pellets contained Microtus sp. Epperson (1976) collected 104 pellets and additional pellet debris from central Nebraska in the fall and found Microtus sp. and Peromyscus sp. were 37.8% and 27.4% of the total number, respectively. We examined pellets from barn owl nest sites in western Nebraska from 1984 to 1986 to determine the relationship between diet and reproductive success.

**Study Area**

Since 1980 the Nebraska Game and Parks Commission has monitored barn owl nesting in western and central Nebraska. They located known nest sites, installed artificial nest structures, and recorded nest site use and reproductive success. By 1984, 94 nest sites were documented in 17 counties in western and central Nebraska (Wingfield 1985). A small area of concentrated barn owl use was located in Lincoln County, Nebraska. The area, approximately 19 X 11 km, is bordered on the north by the North Platte River. The flood plain is a broad, flat area characterized by dense, seasonally wet meadows that contain Phalaris sp., Bromus sp., Agrostis sp., Leguminosae sp., Equisetum sp., and Cyperaceae sp. The southern part of the study area rises in
elevation changing into Sandhills prairie, characterized by sandy soil and drier, sparser vegetation. Corn and wheat are the two principal crops in the intensively farmed study area. Dominant breeding-season grasses are *Bromus tectorum* and *Stipa comata*. Wooded areas, primarily windbreaks and woodlots around residences, make up less than 5% of the total area within 1.3 km of nest sites.

**Methods**

During the breeding seasons of 1984-1986, we collected pellets from nest sites within the study area. Pellets were either soaked in warm water for several minutes and then teased apart to separate bones and other remains or soaked in an 8% NaOH solution for a minimum of 6 hours and rinsed to separate bones from fur and other remains (Bull and Akenson 1985). Prey were identified by skulls, dentition, bird synsacrams and sternums, and insect exoskeletons. In the absence of skulls, humeri of *Scalopus aquaticus* and auditory bullae of *Dipodomys ordii* were used to identify respective species. Scientific collections at the Nebraska State Museum in Lincoln, Nebraska, and Concordia Teachers College, Seward, Nebraska, were used as reference materials.

From 18 June to 13 July 1985, small mammals within barn owl foraging habitat were sampled using Sherman live traps (25.5 X 7.5 X 7.5 cm). Traps were placed at 10 m intervals in randomly placed grids (40 to 100 traps per grid). Habitats included cut and uncut wild hay fields, Sandhills prairie, conservation tillage corn field, roadside ditch, pasture, and a grassland wildlife habitat. Rodents were trapped for 5 nights and then the grid was relocated. Traps were baited with an oatmeal-peanut butter mix at dusk and checked the
following morning and left closed during the day. Captured animals were
marked with ear tags. Trap location, species identification and ear tag number
were recorded for each captured animal.

Number of birds fledged per nest was obtained when young were
banded, 5 to 7 weeks after hatching. To ensure that number of birds banded
equaled number of birds fledged, the nest site was checked for bird remains
and bands of any birds which might have died after banding and prior to
fledging.

Results

Pellets and debris were collected from 6, 9, and 11 nest sites in 1984,
1985, 1986, respectively. A total of 3688 pellets was collected along with pellet
debris in and below nest cavities. From these pellets and debris, 10,140 prey
items were identified. Seventeen mammal species (Table 5), comprised 99.3%
of all prey, and rodents 95.3% of all prey. Four species, Microtus ochrogaster
(32.7%), Reithrodontomys megalotus (18.0%), Perognathus hispidus (16.0%),
and Peromyscus maniculatus (12.1%) accounted for 79% of the total. Mus
musculus, Rattus norvegicus, and combined bird species each made up less
than 1% of prey items in the diet. We found two species, reported as very rare
in other studies, Mustela nivalis (Phillips 1951, Colvin and McLean 1986) and
Sylvilagus sp. (Foster 1927, Marti 1973, Hamilton and Neill 1981) also in
extremely small numbers (< 0.1%) in our study.

In 4300 trap nights, we captured 357 individuals including 9 species
(Table 6). Insufficient data were collected to obtain population estimates for
individual species at a number of sites. Total rodent population estimates
ranged from 6/ha for Sandhills prairie to 159/ha for the roadside ditch. P.
**maniculatus** was the most frequently captured animal accounting for 48.2% (172) of all individuals. Two species, *P. hispidus*, and *Microtus* sp., occurred more frequently in the diet than expected from trapping and *P. maniculatus* occurred less frequently in the diet than expected from trapping (chi square = 4430, *P* < 0.001).

Annual frequency of *M. ochrogaster* in the diet increased from 17.6 to 27.2 to 43.5% during the 3-year period. Annual frequency of *R. megalotus* decreased from 22.7 to 20.1 to 14.1% (Figure 5). *M. ochrogaster* had a strong negative correlation with *R. megalotus* (*r* = -0.80) and a weak negative correlation with *P. maniculatus* (*r* = -0.47). *P. hispidus* had a weak negative correlation with *P. maniculatus* (*r* = -0.47), and *R. megalotus* had a weak positive correlation (*r* = 0.50) with *P. maniculatus* (Table 7).

Enough pellets were collected at 9 sites to analyze seasonal diet patterns. *M. ochrogaster* and *P. maniculatus* showed no pattern while *R. megalotus* decreased in the diet seasonally at all 9 sites (Spearman's *r*, *P* < 0.10 at 7 sites), and *P. hispidus* increased seasonally at all nine sites (Spearman's *r*, *P* < 0.10 at 8 sites) (Figure 6). Sixty-four percent of *Geomys bursarius* were collected in July. All *G. bursarius* were juveniles.

Thirteen barn owl nest sites were checked for nesting activity in 1985 and 15 in 1986. With the exception of one new site in 1985 and two new sites in 1986, all sites checked had a known prior history of barn owl nesting. Nest attempts were made at 69% (9) of the sites in 1985 and at 80% (12) in 1986. Fifty-six percent (5) of nest attempts were successful in 1985, and 75% (9) in 1986 (Table 3). Mean number fledged per successful nest attempt in 1986 (5.8) was significantly greater than in 1985 (4.2) (Mann-Whitney U-test, *P* < 0.02). We did not find a significant relationship between *M. ochrogaster* frequency
in the diet and number fledged (Spearman's $r = 0.26$, $P = 0.13$). Breeding success at natural cavities was compared to breeding success at artificial nest sites. All natural cavities (5 locations, 7 nest attempts) were holes in cut banks along canals, lakes, and roads. Artificial nest sites included 5 nest boxes in barns, 3 nest boxes attached to the outside of grain bins and one 55-gallon barrel placed in a canal bank. Fourteen nest attempts were made in 9 artificial nest structures. Mean number fledged per artificial nest site (4.1, $n = 9$) was not significantly greater ($t = 0.787$, $P = 0.2232$) than mean number fledged per natural cavity (3.0, $n = 5$).

Twenty-one birds fledged within the study area in 1985 compared to 57 in 1986. This increase represents both a greater number of successful nests and a greater number fledged per nest attempt. In 1986 one nest site had two successive, successful nest attempts (6 and 5 fledged). We assumed both nest attempts were from the same adults. No second clutches occurred at any nest site in 1985. In 1986 there were two cases of polygyny. In one case, the nests were 1.6 km apart and 6 and 5 young fledged. In the other case, two females shared a 55-gallon barrel in a canal bank. Ten eggs were counted when the site was first checked. Five young fledged from the combined nest effort.

Discussion

Mammals constituted 99.3% of barn owl diet in western Nebraska. This corroborates studies of Errington (1932), Fitch (1947), Pearson and Pearson (1947), Boyd and Shriner (1954), Maser et al. (1980), and Fielder (1982) although infrequently birds have comprised a significant proportion of barn owl diet (Bonnot 1928, Carpenter and Fall 1967, Otteni et al. 1972, Buden 1974). *Microtus ochrogaster* was the most frequent prey in the diet (33.0%).
Microtus spp. have been well-documented as principal prey species in barn owl diets (Hall 1927, Wallace 1948, Phillips 1951, Reed 1957, Clark and Wise 1974, Dawe et al. 1978, Colvin 1984, Bull and Akenson 1985, Schwarz and Bleich 1985). Non-microtines reported as principal prey in the diet include cotton rat, Sigmodon hispidus, (Baumgartner and Baumgartner 1944, Raun 1960, Hamilton and Neill 1981), heteromyid spp. (Alcorn 1942, Hawbecker 1945, Fitch 1947, Ault 1971, Fielder 1982, Gustafson 1983), and woodrat, Neotoma fuscipes (Cunningham 1960). The high number of species in barn owl diets does not appear to be unusual. Twenty or more species have been reported in barn owl diets (Buden 1974, Colvin and McLean 1986, and Campbell et al. 1987). All 17 mammal species we found were reported in earlier barn owl diet studies. Given the broad range of prey species, barn owls in North America have been reported as opportunistic foragers (Ticehurst 1935, Hawbecker 1945, Boyd and Shriner 1954, Raun 1960, Carpenter and Fall 1967, Smith et al. 1972, Buden 1974, Jaksic et al. 1982, Feldhamer 1985).

Trapping data suggest barn owls may not be opportunistic. Barn owls apparently took different proportions of prey than were present, as indicated by trapping. We noted M. ochrogaster more frequently in diet than in trapping and Peromyscus less frequently in diet than in trapping (Table 6). This same pattern was found in New Jersey (Colvin 1984) and Pennsylvania (Pearson and Pearson 1947). Fulk (1976) was unable to account for low incidence of Peromyscus in barn owl diet in California. Marti (1986) stated that barn owls concentrated foraging in vole habitat, and Errington (1932) felt that barn owls in California would not survive without Microtus spp. in their diet. Fast and Ambrose (1976) found that a barn owl took significantly more Microtus than Peromyscus when provided in equal proportions. Derting and
Cranford (1989) found that barn owls took less time to capture *Microtus pennsylvanicus* than *Peromyscus* spp. and took *M. pennsylvanicus* more frequently when given a choice between *Peromyscus* spp. and *M. pennsylvanicus*. Colvin (1986) concluded barn owls selected for *Microtus* or *Microtus*-sized species.

*M. ochrogaster* frequency in the diet was negatively correlated both with *R. megalotus* \(r = -0.80, P = 0.0001\) and *P. maniculatus* \(r = -0.47, P = 0.0237\) but showed no correlation with *P. hispidus* \(r = 0.06\) during the 3-year study. *P. hispidus* was negatively correlated with *R. megalotus* \(r = -0.47\) and to *Peromyscus* \(r = -0.31\). These inverse relationships might be explained by the size of the prey. Jones et al. (1983) report *M. ochrogaster* and *P. hispidus* averaged 60.1 and 47.8 g, respectively whereas *R. megalotus* and *P. maniculatus* averaged 13.3 and 21.1 g, respectively. Colvin (1984) believed that barn owls foraged for an ideal-sized prey in the size range of *M. pennsylvanicus* (41 g). In studies where microtines were not the principal prey species, the principal prey was often of a comparable size (Hawbecker 1945, Ault 1971, Gustafson 1983). Thus, barn owls in our study area may have foraged for the larger *M. ochrogaster* and *P. hispidus* and then switched to the smaller *R. megalotus* and *P. maniculatus* in years when the other two species were less abundant.

*M. ochrogaster* is well known for its population fluctuations (Krebs et al. 1967, Gards and Howard 1981) with reported densities as high as 361/ha (Aumann 1976), while *P. hispidus* maintain stable, low-density populations (Jones et al. 1983). Only one trapping site in 1985 provided enough captures of *P. hispidus* to make a population density estimate (8/ha). These two prey species appear to differ in their availability to the barn owl, *P. hispidus*...
tending to have lower, less fluctuating densities and *M. ochrogaster* capable of higher densities characterized by population fluctuations. Therefore, *M. ochrogaster* could affect productivity and population densities of its major predators more so than *P. hispidus*. This is apparently what happened in our study. The frequency of *M. ochrogaster* in the diet went from 27.2% in 1985 to 43.5% in 1986. This could reflect a *M. ochrogaster* population increase in the barn owl’s foraging habitat (small mammal trapping was done only in 1985).

In 1986 barn owls in the study area had more nest attempts, a higher percentage of successful nest attempts, and a higher mean number fledged per nest attempt (Table 8) than in 1985. Colvin (1984) found a high correlation \( r = 0.947 \) between rainfall and barn owl productivity and he related increased rainfall to increased *M. pennsylvanicus* population density. Ault (1971) found a high correlation \( r = 0.98 \) between frequencies of three species of rodent, *Sigmodon hispidus*, *Neotoma cinerea*, and *P. maniculatus*, in the diet and number fledged per nest. Otteni et al. (1972) found a high correlation \( 0.913 \) between frequency of mammals in the diet and number of owls fledged per nest. They concluded that although barn owls were able to switch to a large blackbird population after a hurricane-caused population crash of small mammals, they were not able to fledge as many young. It is possible an increased population density of *M. ochrogaster* resulted in an increased prey base for barn owls and, therefore, increased frequency of *M. ochrogaster* in the diet and an improved reproductive effort in 1986.

Nest site quality may also influence reproductive success. We found the mean number fledged per nest attempt was 4.1 birds for artificial nest sites compared to 3.0 birds for natural cavities. Colvin (1984) found 0.6 more young
fledged per artificial nest than natural cavities and stated artificial nest sites were less susceptible to predation and damage by weather.

Prey delivery rates ranged from 1.7 to 5.1 prey/hr at 4 nest sites in 1985 and 1986 (Gubanyi 1989). At one nest site with 8 young where 2.2 prey/hr were delivered, one dead, emaciated young was found and two more young disappeared. No nestlings were lost at nest sites with higher prey delivery rates. Other factors that likely influenced reproductive success in the study area are predation, human disturbances, and agricultural practices.

We observed seasonal variation at nest sites where sufficient data were collected. The frequency of juvenile *G. bursarius* in the diet went up in late spring and early summer, coinciding with the above-ground dispersal of young. Evans and Emlen (1947) in California and Marti (1974) in Colorado found increased *Thomomys* frequency in the diet corresponding to increased *Thomomys* above-ground activity. Colvin and McLean (1986) in Ohio found a seasonal increase in mole frequency in the diet corresponding to above ground dispersal of young. All 4 principal prey species showed seasonal variation in the diet. *M. ochrogaster* and *P. maniculatus* varied but with no regular pattern. However, *R. megalotus* consistently decreased in frequency through the nesting season and *P. hispidus* increased through the nesting season. Campbell et al. (1987) found a high correlation ($r = 0.97$) between *Microtus* frequency in the diet and abundance in habitat. Fitch (1947) and Dawe et al. (1978) attributed seasonal variation in barn owl diets to rodent behavior (e.g. - hibernation, dispersal of young). Evans and Emlen (1947) and Wallace (1948) felt that seasonal variation in diet was related to relative abundance of prey species. Marti (1974) listed seasonal vegetation changes, prey behavior changes, and reproductive patterns of prey as possible causes.
for seasonal changes in the diet of barn owls. When *R. megalotus* frequencies were regressed with *P. hispidus* frequencies for 9 sites only 1 of 9 regressions had a significant correlation (*P* < 0.05) suggesting that seasonal variation of *R. megalotus* and *P. hispidus* frequency in the diet were independent of each other. It appears that *R. megalotus* did not serve as a buffer species.

It appears that barn owls adjust their diet according to the availability of species. There is also evidence that barn owl productivity may be influenced by *Microtus* population fluctuations. Whether barn owl productivity increases only because *Microtus* populations increase or because of a general increase in the prey base caused by a *Microtus* population increase remains to be demonstrated.
Table 5. Number and percent of prey items in barn owl pellets collected from nest sites in Lincoln County, Nebraska during summers of 1984 - 1986.

<table>
<thead>
<tr>
<th>Prey Species</th>
<th>1984 No. (%)</th>
<th>1985 No. (%)</th>
<th>1986 No. (%)</th>
<th>Total No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Microtus ochrogaster</em></td>
<td>224 (17.6)</td>
<td>1257 (27.2)</td>
<td>1807 (43.5)</td>
<td>3349 (33.0)</td>
</tr>
<tr>
<td><em>Reithrodontomys megalotus</em></td>
<td>289 (22.7)</td>
<td>932 (20.1)</td>
<td>588 (14.1)</td>
<td>1810 (17.9)</td>
</tr>
<tr>
<td><em>Perognathus hispidus</em></td>
<td>223 (17.5)</td>
<td>908 (19.6)</td>
<td>482 (11.6)</td>
<td>1630 (16.1)</td>
</tr>
<tr>
<td><em>Peromyscus maniculatus</em></td>
<td>145 (11.4)</td>
<td>516 (11.1)</td>
<td>553 (13.3)</td>
<td>1214 (12.0)</td>
</tr>
<tr>
<td><em>Microtus pennsylvanicus</em></td>
<td>122 (9.6)</td>
<td>194 (4.2)</td>
<td>346 (8.3)</td>
<td>665 (6.6)</td>
</tr>
<tr>
<td><em>Perognathus flavescens</em></td>
<td>98 (7.7)</td>
<td>454 (9.8)</td>
<td>97 (2.3)</td>
<td>649 (6.4)</td>
</tr>
<tr>
<td><em>Blarina hylophaga</em></td>
<td>60 (4.7)</td>
<td>112 (2.4)</td>
<td>76 (1.8)</td>
<td>248 (2.5)</td>
</tr>
<tr>
<td><em>Onychomys leucogaster</em></td>
<td>12 (0.9)</td>
<td>60 (1.3)</td>
<td>42 (1.0)</td>
<td>115 (1.1)</td>
</tr>
<tr>
<td><em>Geomys bursarius</em></td>
<td>31 (2.4)</td>
<td>36 (0.8)</td>
<td>32 (0.8)</td>
<td>99 (1.0)</td>
</tr>
<tr>
<td><em>Cryptotis parva</em></td>
<td>7 (0.6)</td>
<td>31 (0.7)</td>
<td>46 (1.1)</td>
<td>84 (0.8)</td>
</tr>
<tr>
<td><em>Dipodomys ordii</em></td>
<td>6 (0.5)</td>
<td>43 (0.9)</td>
<td>17 (0.4)</td>
<td>67 (0.7)</td>
</tr>
<tr>
<td><em>Mus musculus</em></td>
<td>8 (0.6)</td>
<td>24 (0.5)</td>
<td>20 (0.5)</td>
<td>52 (0.5)</td>
</tr>
<tr>
<td><em>Sorex cinereus</em></td>
<td>9 (0.7)</td>
<td>18 (0.4)</td>
<td>17 (0.4)</td>
<td>44 (0.4)</td>
</tr>
<tr>
<td><em>Scalopus aquaticus</em></td>
<td>10 (0.8)</td>
<td>6 (0.1)</td>
<td>10 (0.2)</td>
<td>26 (0.3)</td>
</tr>
<tr>
<td><em>Rattus norvegicus</em></td>
<td>2 (0.2)</td>
<td>5 (0.1)</td>
<td>1 (0.02)</td>
<td>8 (0.1)</td>
</tr>
<tr>
<td><em>Mustela nivalis</em></td>
<td>3 (0.2)</td>
<td>0 (0.0)</td>
<td>1 (0.02)</td>
<td>4 (0.04)</td>
</tr>
<tr>
<td><em>Sylvilagus sp.</em></td>
<td>2 (0.2)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>2 (0.02)</td>
</tr>
<tr>
<td>bird species</td>
<td>21 (1.7)</td>
<td>32 (0.7)</td>
<td>21 (0.5)</td>
<td>74 (0.7)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1272</td>
<td>4628</td>
<td>4156</td>
<td>10140</td>
</tr>
</tbody>
</table>
Table 6. Number of prey captured in 4300 trap nights of small mammal trapping in Lincoln County, Nebraska, 18 June to 13 July 1985.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number</th>
<th>Percent</th>
<th>Percent in Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microtus sp</td>
<td>66</td>
<td>18.5</td>
<td>31.4</td>
</tr>
<tr>
<td>Peromyscus maniculatus</td>
<td>172</td>
<td>48.2</td>
<td>11.1</td>
</tr>
<tr>
<td>Reithrodontomys megalotus</td>
<td>74</td>
<td>20.7</td>
<td>20.1</td>
</tr>
<tr>
<td>Perognathus hispidus</td>
<td>20</td>
<td>5.6</td>
<td>19.6</td>
</tr>
<tr>
<td>Perognathus flavescens</td>
<td>9</td>
<td>2.5</td>
<td>9.8</td>
</tr>
<tr>
<td>Dipodomys ordii</td>
<td>1</td>
<td>0.3</td>
<td>0.9</td>
</tr>
<tr>
<td>Onychomys leucogaster</td>
<td>7</td>
<td>2.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Mus musculus</td>
<td>2</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Blarina hylophaga</td>
<td>6</td>
<td>1.7</td>
<td>2.4</td>
</tr>
</tbody>
</table>
Table 7. Correlations from simple linear regression among four main prey species from 23 nest sites 1984 -1986.

<table>
<thead>
<tr>
<th></th>
<th>M. ochrogaster</th>
<th>R. megalotus</th>
<th>P. maniculatus</th>
<th>P. hispidus</th>
</tr>
</thead>
<tbody>
<tr>
<td>M. ochrogaster</td>
<td>1.00</td>
<td>-0.80*</td>
<td>-0.47*</td>
<td>0.06</td>
</tr>
<tr>
<td>R. megalotus</td>
<td>1.00</td>
<td>0.50*</td>
<td>-0.31</td>
<td></td>
</tr>
<tr>
<td>P. maniculatus</td>
<td></td>
<td></td>
<td>1.00</td>
<td>-0.47*</td>
</tr>
<tr>
<td>P. hispidus</td>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
</tbody>
</table>

* Significant at $P < 0.05$

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<thead>
<tr>
<th></th>
<th>1985</th>
<th>1986</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nest Sites Checked</td>
<td>13</td>
<td>15</td>
<td>28</td>
</tr>
<tr>
<td>Nest Attempts</td>
<td>9</td>
<td>12</td>
<td>21</td>
</tr>
<tr>
<td>Successful Nests</td>
<td>5</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean no. fledged per nest attempt</td>
<td>2.3</td>
<td>4.7</td>
<td>4.3</td>
</tr>
<tr>
<td>Mean no. fledged per successful nest</td>
<td>4.2</td>
<td>5.8</td>
<td>5.1</td>
</tr>
</tbody>
</table>
Figure 5. Annual changes in barn owl diet for the most frequently occurring prey species from 1984 to 1986 in Lincoln County, Nebraska.
Figure 6. Seasonal changes in hem ovdiel showing decrease in Helithrodonomye and increase in Perognathus hispidus through the season.


FORAGING BEHAVIOR IN BARN OWLS AS DETERMINED BY NEST MONITORING

Abstract

Nesting barn owls, Tyto alba, were studied in western Nebraska May-September, 1985-86. Monitoring an illuminated nest allowed us to determine prey delivery rate, sequence of prey species delivered, and time sequence of prey delivered to nest. Prey delivery rates averaged from 1.7 to 5.1 prey per h for 4 nest sites. Males delivered 77% of all prey. Our data did not support the hypothesis that single-prey loaders are more likely to take larger prey as search time increases. The probability of any given prey species delivered to the nest was independent of the previous species delivered to the nest. Our data suggest that the number of fledglings can be influenced by foraging efficiency of parents. We found nest monitoring an effective means for gathering barn owl natural history data and recommend its use with other nocturnal species.

Introduction

It is difficult to collect behavioral data of free-ranging nocturnal species. Walker (1943) illuminated an elf owl (Micrathene whitneyi) nest and was able to determine type of prey brought back to the nest, how and where owls foraged, and intra- and interspecific associations of elf owls. Hayward (1987) attached betalights to backpack-mounted radio transmitters on boreal owls (Aegolius funereus) to study foraging behavior. Braun Hill and Clayton (1985) discussed a variety of nocturnal observation equipment including image intensifiers, image converters, and active markers (light-emitting...
tags). Marti (1989) observed food-sharing and feeding behavior in nestling barn owls. As part of a breeding habitat study of barn owls (*Tyto alba*) in Lincoln County, Nebraska, we monitored barn owl nests during the spring and summers of 1985 and 1986. In this paper we report male and female parental foraging investment, searching time for prey, and sequence of prey brought back to the nest.

**Methods**

Observers were 15-50 m from the nest. A 200,000 candle power spotlight was set in a fixed position illuminating the nest site area. A heavy duty marine battery had enough charge to maintain light for our longest monitoring period (7 h). We recharged the battery on days following nest monitoring. A 15-45 X spotting scope was used to identify prey brought back to the nest.

One or more of the adult owls at each nest site were outfitted with radio transmitters. This aided in identification of owls and in knowing the location of owls at all times but was not essential to the nest monitoring. Generally, monitoring stations were set up at dusk, 0.5 - 1.0 h before the adults first appeared at the nest site. When we set up after dark, we did so when the adults were not in the vicinity of the nest area. Owls seemed unaffected by our presence and continued to deliver prey to the nest while the nest was monitored. The nest monitor recorded which adult arrived, time adult arrived, time adult entered nest cavity, whether adult had prey and identification of prey, if possible, and when adult owl left the nest site area.
Results/Discussion

Four nest sites were monitored, one in 1985 and three in 1986. We observed nests for a total of 46.0 hours on 17 different nights. Mean prey return rates ranged from 1.7 to 5.2 prey per h for the four nest sites observed (Table 9). The highest rate for a single observation period was 7.5 prey per h at nest site 1 during a 4-h period (Table 10). The lowest prey delivery rate was 0.8 prey per h at nest site 5. The prey delivery rate tended to decline on subsequent observation periods. In a barn owl study in Utah, Smith et al. (1974) reported that adults delivered 1.8 prey per h over a 5-h period to 2 young in the nest aged 10.5 and 10.8 weeks. Colvin (1984) recorded the number of visits per h by a pair of adults to a nest with three 5-8 weeks old young. During two different monitoring periods, the female visited the nest 0.30 times per h and the male visited the nest 1.54 times per h. The male showed a consistent pattern of flying between the nest site and grass habitats. Bussmann (1937, cited in Smith et al., 1974) reported an average 11.3 feedings per night over a number of 5.5-h hunting periods (2.1 nest visits per h).

There were 4 young in the nest. Our observations showed very few visits were made to the nest without prey. In 12.8 h of observation over four different nights at nest site 1, the male made 65 deliveries of prey to the nest, never visiting the nest without prey during our observation. Assuming visits to the nest were, in fact, prey deliveries, the above data are useful in comparison. The 1.7 prey per h delivered to the nest at nest site 5 in 1985 is comparable to Colvin's 1.54 male visits to the nest. Both sites fledged 3 young. Our data showed an increased rate of prey delivery for nest sites with a greater number of young (Table 9).
We used our findings and published data to see if there was a relationship between the number of nestlings and prey delivery rate. We found a significant linear regression ($r = 0.80$, $P = 0.0319$). The same data had a significant 2nd order polynomial regression ($r = 0.91$, $P = 0.0286$, Figure 7). The ability to successfully fledge young appears to be influenced both by prey delivery rate and egg production. In 1986, the lowest prey delivery rate (2.2 prey per h) was at nest site 17. Eight young were known to have hatched from 10 eggs. However, 4 weeks after hatching only 5 nestlings remained. One owlet, emaciated and smaller than its surviving siblings, was found dead in the nest cavity. It was assumed that the young were dying as a result of starvation or fratricide, phenomena well-known in raptors (Hawbecker 1945, Ingram 1959, Baudvin 1979, cited in Welty, 1982). It appears the number of fledglings was limited by the inability of the parents to supply sufficient food to the developing young. This may be a phenomenon with younger, less experienced and efficient foragers or in years when available prey is limited. At nest site 1, where the prey delivery rate was 5.1 prey per h, all 6 known nestlings fledged. In 1986 we found evidence of stockpiling, a phenomenon reported in barn owls (Wallace 1948, Reese 1972, Smith et al. 1974, Tyler and Phillips 1978). Stockpiling is evidence that in certain situations barn owls are able to provide more food than needed by nestlings. We also fostered out 2 orphaned barn owl nestlings (their nest collapsed) to a pair of owls already raising 4 nestlings. All six nestlings fledged. It appears when prey numbers are sufficient or abundant, efficient foragers would be able to fledge more young if they produced more eggs.

Our data also indicate considerable differences in foraging ability of the three adults at nest site 17 compared to the single male at nest site 1. A single
adult male was able to deliver prey at more than 2X the combined rate of the three adults at nest site 17. The two sites were less than 2 km apart and the foraging habitat of each was essentially the same. One possible explanation for this disparity is age of the breeding adults. Several factors support this. Nest site 1 was active the year before whereas nest site 17 was not. Nest site 17 was the last known nest initiated in the study area, a full month later than nest site 1. Younger, less experienced birds would be less efficient foragers.

Bühler (1964, cited in Farner and King, 1971) suggested that barn owls initiate nesting when they are stimulated by a surplus of available prey. Approximately 300 m from nest site 17 a pair of barn owls, which had nested at the same site the year before, also initiated nesting a full month before adults at nest site 17, successfully fledging 7 young (this nest site was not monitored).

Another possible explanation for variable prey delivery rates may be prey populations. The lowest prey delivery rate in our study was at nest site 5 in 1985. An analysis of diet in 1985 and 1986 revealed that there was a marked increase in *Microtus ochrogaster* in the diet from 1985 to 1986 (Gubanyi 1989). There was also a marked improvement in barn owl productivity in 1986 with more nests initiated, more young fledged per nest, and two examples of polygyny compared to none in 1985 (Gubanyi 1989). Others have suggested that barn owls have a preference for microtines or microtine-sized prey in their diet (Colvin 1984, Marti 1986, Fast and Ambrose 1976). If microtine populations were in fact down in 1985, then there may not have been a suitable alternative prey for the barn owl, thus influencing lower prey delivery rate in 1985. Unfortunately, there are no prey delivery data and diet data from the same site over the 2-year period to support this idea. Further analysis of prey delivery rates in relation to prey abundance and prey
frequency in the diet may give additional data on foraging strategies of barn owls.

Percent of prey delivered to the nest by males ranged from 4% to 100% (Table 9). With the exception of one site, the major portion of prey (> 70%) was delivered by the male. At nest site 1 the female was observed in the nest site vicinity only once during our monitoring (4 nights, 12.8 h observation) and delivered no prey to young. Smith et al. (1974) reported that both male and female adult barn owls in Utah participated in foraging for young which were near fledging, but they did not report male and female frequency of foraging investment. Colvin (1984) found that male barn owls in New Jersey did the majority of foraging for young, and that female foraging for young showed a sharp decline, in some cases ceasing, when young were greater than 4 weeks old. In 1986 the highest prey delivery rate was at the site with the highest male investment, and the lowest prey delivery rate was at the nest site with the lowest male investment. Colvin (1984) stated that smaller size in male barn owls is adaptive for greater foraging efficiency and larger females are adapted for greater egg production. Colvin felt that females selected mates based on their foraging ability which was assessed during courtship when the male would offer prey to the female. If females are able to assess the male's foraging ability, then it is conceivable that they will leave all of the foraging to the male when he is efficient (as at nest site 1 in our data) or will help out if the male is unable to meet the high energy needs of the growing nestlings (as at nest site 17 in our data). Further investigation may determine the precise roles of males and females in foraging for young in barn owls.

Colvin (1984) reported that in New Jersey the majority of feeding was done 1-2 h after sunset and 1-2.5 h before sunrise with little foraging by adult
owls noted during the middle of the night. Smith et al. (1974) noted that prey deliveries to the nest became sporadic after 0145. On 26 June, we monitored nest site 1 from 1000 to 0200, recording prey species and time spans between prey deliveries (Table 11). We used the Runs Test to test sequence of time spans between prey deliveries for randomness ($H_0$: Distribution of times is random). We failed to reject $H_0$ ($p = 0.1251$), thus supporting the hypothesis that prey delivery rate did not decrease during the observation period.

McNair (1979) proposed that a predator's rate of encounter with a given prey may depend on the previous encounter. This encounter-to-encounter dependence might happen if particular prey species were clumped. If this were the case, then it would be advantageous for a predator to return to a particular patch after a successful prey encounter. Thus the probability would be greater for encountering the same prey species on a subsequent search and less for encountering alternate prey species. An effective way to evaluate this hypothesis is with a first-order Markov Process (Martin and Bateson 1986). A first-order Markov Process determines the frequencies of a follow-up event after an initial event. Using a contingency table and chi-square test, frequencies can be compared to expected frequencies given that events are independent. Because we were able to identify the prey brought back to the nest at nest site 1 (Table 11), we submitted the prey sequence to a Markov Analysis and chi-square test. The chi-square test was not significant (chi-square value = 24.36, $p = 0.227$). We, therefore, concluded that prey delivered to the nest was independent of the previous encounter and did not support McNair's hypothesis.

Central Place Foraging Theory predicts that in a single-prey loader (a forager that delivers only one prey item at a time to the nest) the minimum
acceptable prey size will increase with travel time from the nest (Lessells and Stephens 1983, Stephens and Krebs 1986). We assumed that time spans between prey deliveries (Table 11) represented time spent pursuing prey. Of 6 prey species that were delivered to nest site 1 on 26 June (Table 11), 3 were categorized as small (mean weight ≤ 20 g), and these species included *Peromyscus* sp., *Reithrodontomys* sp., and *Blarina hylophaga*. The remaining 3 species, *Microtus* sp., *Perognathus hispidus*, and *Dipodomys ordii*, were categorized as large (mean weight ≥ 40 g). Weights of prey species for this region were obtained from Jones et al. (1983). Predicting that mean travel time for small prey would be less than mean travel time for large prey, we conducted a t-test on the data. Mean travel times for small and large prey were 8.3 min and 8.2 min, respectively. The t-test was not significant (t = 0.064, p = 0.9494). We concluded that our data did not support this tenet of Central Place Foraging Theory.

Direct observation of a nest with a systematic means of recording data can be a useful means in determining foraging behavior in nocturnal species. It is inexpensive and over a period of time considerable data can be collected. We were able to collect data on male and female investment in reproduction, relate foraging behavior to fledging success, and test 2 hypotheses of foraging theory with our data. Nest monitoring has a much broader application as a means of gathering data for nocturnal species than currently reported.

Colvin (1984) advises barn owls not be disturbed during incubation or within 2 weeks of hatching because barn owls are highly prone to nest abandonment during this time. Therefore, we recommend that nest monitoring during this stage of nesting be done only with good cause and extreme caution.
Table 9. Nest monitoring data from 4 barn owl nest sites observed during the breeding seasons of 1985 and 1986 in Lincoln Co., Nebraska.

<table>
<thead>
<tr>
<th>Nest Site</th>
<th>Total Hrs(days) Observed</th>
<th>No. (Age) of Nestlings*</th>
<th>Prey/hr Delivered By Male</th>
<th>Prey/hr Delivered By Female</th>
<th>Total Prey Delivered Per Hour</th>
<th>Total Prey Delivered Per Nestling</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>12.7 (5)</td>
<td>3 (4-7)</td>
<td>1.6</td>
<td>0.1</td>
<td>1.7</td>
<td>0.57</td>
</tr>
<tr>
<td>1</td>
<td>12.8 (4)</td>
<td>6 (5-8)</td>
<td>5.1</td>
<td>0.0</td>
<td>5.1</td>
<td>0.85</td>
</tr>
<tr>
<td>17</td>
<td>10.7 (4)</td>
<td>5 (3-5)</td>
<td>0.1</td>
<td>2.1</td>
<td>2.2</td>
<td>0.44</td>
</tr>
<tr>
<td>16</td>
<td>9.8 (3)</td>
<td>6 (7-8)</td>
<td>2.3</td>
<td>0.9</td>
<td>3.3</td>
<td>0.55</td>
</tr>
</tbody>
</table>

* Number of nestlings also equals number of fledglings. Age of nestlings is in weeks.
Table 10. Prey delivery rates for single monitoring periods by nest site.

<table>
<thead>
<tr>
<th>Observation Period</th>
<th>Nest Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>2.6</td>
</tr>
<tr>
<td>2</td>
<td>0.8</td>
</tr>
<tr>
<td>3</td>
<td>3.0</td>
</tr>
<tr>
<td>4</td>
<td>2.3</td>
</tr>
<tr>
<td>5</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1.7</strong></td>
</tr>
</tbody>
</table>

* Human interference may have influenced prey delivery rate.
Table 11. Time of prey deliveries and identification of prey delivered by a male barn owl as determined by monitoring a nest on 26 June 1986.

<table>
<thead>
<tr>
<th>Time</th>
<th>Prey</th>
<th>Elapsed Time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1001</td>
<td>unknown</td>
<td>--</td>
</tr>
<tr>
<td>1012</td>
<td>unknown</td>
<td>11.6</td>
</tr>
<tr>
<td>1023</td>
<td>Microtus sp.</td>
<td>10.6</td>
</tr>
<tr>
<td>1028</td>
<td>Microtus sp.</td>
<td>4.3</td>
</tr>
<tr>
<td>1041</td>
<td>Microtus sp.</td>
<td>14.0</td>
</tr>
<tr>
<td>1057</td>
<td>Perognathus hispidus</td>
<td>15.8</td>
</tr>
<tr>
<td>1104</td>
<td>Peromyscus sp.</td>
<td>6.8</td>
</tr>
<tr>
<td>1114</td>
<td>Microtus sp.</td>
<td>9.6</td>
</tr>
<tr>
<td>1120</td>
<td>unknown</td>
<td>5.8</td>
</tr>
<tr>
<td>1124</td>
<td>Microtus sp.</td>
<td>4.0</td>
</tr>
<tr>
<td>1129</td>
<td>unknown</td>
<td>5.1</td>
</tr>
<tr>
<td>1135</td>
<td>Reithrodontomys sp.</td>
<td>6.1</td>
</tr>
<tr>
<td>1140</td>
<td>Perognathus hispidus</td>
<td>5.6</td>
</tr>
<tr>
<td>1149</td>
<td>Microtus sp.</td>
<td>8.9</td>
</tr>
<tr>
<td>1159</td>
<td>Dipodomys ordii</td>
<td>9.6</td>
</tr>
<tr>
<td>1205</td>
<td>Perognathus hispidus</td>
<td>6.1</td>
</tr>
<tr>
<td>1209</td>
<td>Reithrodontomys sp.</td>
<td>4.3</td>
</tr>
<tr>
<td>1213</td>
<td>Microtus sp.</td>
<td>4.0</td>
</tr>
<tr>
<td>1236</td>
<td>Peromyscus sp.</td>
<td>22.8</td>
</tr>
<tr>
<td>1244</td>
<td>Peromyscus sp.</td>
<td>8.1</td>
</tr>
<tr>
<td>1248</td>
<td>Peromyscus sp.</td>
<td>3.5</td>
</tr>
<tr>
<td>1253</td>
<td>Microtus sp.</td>
<td>5.6</td>
</tr>
<tr>
<td>0102</td>
<td>Perognathus hispidus</td>
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</tr>
<tr>
<td>0110</td>
<td>Microtus sp.</td>
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</tr>
<tr>
<td>0123</td>
<td>Peromyscus sp.</td>
<td>13.1</td>
</tr>
<tr>
<td>0138</td>
<td>Microtus sp.</td>
<td>8.3</td>
</tr>
<tr>
<td>0147</td>
<td>Dipodomys ordii</td>
<td>15.0</td>
</tr>
<tr>
<td>0151</td>
<td>Blarina hlyophaga</td>
<td>8.9</td>
</tr>
<tr>
<td>0159</td>
<td>unknown</td>
<td>4.4</td>
</tr>
<tr>
<td>0201</td>
<td>Perognathus hispidus</td>
<td>1.3</td>
</tr>
</tbody>
</table>
Figure 7. Relationship of number of nestlings to prey delivery rates. The graph shows a linear regression \((r = 0.80)\) and a 3rd order polynomial regression \((r = 0.90)\). Numbered data points are from literature. All other data points are from the Nebraska study.

\[
y = 0.66x - 0.21
\]

\[
y = -0.05 + 2.04x - 0.75x^2 + 0.09x^3
\]

1. Smith et al. (1974)
Literature Cited


Gubanyi, J. 1989. Habitat use and diet analysis of barn owls in western Nebraska. M. S. Thesis, University of Nebraska, Lincoln, Nebraska


Conclusion

The original purpose of this project was to identify barn owl habitat. I intended to identify barn owl foraging areas and compare them to non-foraging areas by measuring a number of habitat parameters. Telemetry error was too great to determine which habitat patch an owl was using, therefore, I was unable to use habitat measures to distinguish foraging habitat from non-foraging habitat.

Colvin (1985) found that barn owl densities in Ohio were strongly correlated with areas in grass. I suggest that barn owls in western Nebraska are also linked with areas in grass. The mean percent grassland habitat available to barn owls within their foraging areas was 34%. In spite of nesting on or near farmsteads where commensal rodents (*Mus musculus* and *Rattus norvegicus*) are expected to be common, barn owls took < 1% commensal rodents as prey. Barn owls preyed on field rodents almost exclusively.

*M. ochrogaster* may be an important component to barn owl breeding biology in western Nebraska. When *M. ochrogaster* was greater in the diet, barn owl productivity increased. Whether this increased productivity is related specifically to *M. ochrogaster* abundance or to a general increase in the prey base caused by *M. ochrogaster*, can not be determined from my data. Further study of prey abundance and prey frequency in the diet along with barn owl productivity would show whether barn owl productivity is influenced specifically by *Microtus* sp. or generally by fluctuations in the prey base.

Nest monitoring offers an alternative means for analyzing foraging behavior in barn owls. Prey delivery rates can be measured and related to age
of foragers and reproductive success. Foraging patterns can be determined and analyzed, and foraging theory hypotheses can be tested.

In conclusion, barn owl status in Nebraska is apparently dependent on suitable grassland foraging habitat and availability of nest cavities. The absence of either would be limiting to barn owls. The best management program for barn owls in Nebraska should be to provide artificial nest sites (if nest cavities are presently lacking) in areas where suitable foraging habitat is available. In 1985 the mean percent of grass habitat available within 1.3 km of successful nest sites was 39%. Only one of 5 successful attempts had less than 20% grass habitat (19%). In 1986 when there were indications the prey base had increased, the mean percent available grass habitat at successful nest sites decreased to 29%. This indicates that marginal habitats (those habitats with limited grass habitat foraging areas) could become more suitable in years when prey availability is high. I recommend that suitable foraging habitat for barn owls in Nebraska be defined as 20% or more of cover within 1.3 km of nests be grass habitat. This should allow for successful barn owl production in years of high and low prey availability.
Acknowledgements

I am especially grateful to Dr. Ron Case, my advisor, for his patient support and advice throughout the project. I would also like to thank Greg Wingfield, Nebraska Game and Parks Commission, for getting me started and giving continued support throughout the project. Special thanks go to a number of people who offered advice and/or materials which proved invaluable to my research. These include Ross Lock, Dr. Ron Johnson, Dr. Paul Johnsgard, and Carl Langefeldt. Helpful suggestions were made on the manuscript by Jenny Roebke and Russell Mosemann. Statistical consultations were provided and much appreciated by Dr. Anne Parkhurst, Dr. Kent Eskridge, and Alex D. Polymenopoulos. Field and lab assistance was received and much appreciated from Dave Reiner, Chris Gordon, Elizabeth Vos, Mark Donaldson, Paul Pearson, Steve Dybdal, Becky Bren, and Giles Schildt. Matt Beisel illustrated the trap design. Many thanks go to the people in Hershey, Nebraska, who helped me locate barn owl nest sites and showed an interest in the project and concern for the conservation of barn owls.

I gratefully acknowledge the financial support received for this project from the Nebraska Game and Parks Commission, University of Nebraska Research Council, and National Wildlife Federation.
Literature Cited


_______. 1981. Barn owl breeding pair distribution. Unpublished manuscript received from Nebraska Game and Parks Commission.


Appendix A

Number of prey captured in 4300 trap nights of small mammal trapping at 8 trap sites in Lincoln County, Nebraska, 18 June to 13 July 1985.

<table>
<thead>
<tr>
<th>Species</th>
<th>Trap 1</th>
<th>Trap 2</th>
<th>Trap 3</th>
<th>Trap 4</th>
<th>Site 5</th>
<th>Site 6</th>
<th>Site 7</th>
<th>Site 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microtus sp</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td>1</td>
<td>42</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Peromyscus maniculatus</td>
<td>11</td>
<td>2</td>
<td>9</td>
<td>15</td>
<td>56</td>
<td>12</td>
<td>57</td>
<td>10</td>
</tr>
<tr>
<td>Reithrodontomys megalotus</td>
<td>8</td>
<td>-</td>
<td>7</td>
<td>17</td>
<td>8</td>
<td>33</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Perognathus hispidus</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Perognathus flavescens</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dipodomys ordii</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Onychomys leucogaster</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Mus musculus</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Blarina hylophaga</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Trap Site Descriptions**
1 - wild hay field; seasonally wet and subjected to cutting.
2 - Sandhills prairie; subjected to grazing.
3 - Sandhills prairie; subjected to minimal grazing.
4 - middle grass prairie; not subjected to grazing
5 - middle grass prairie along canal; not subjected to grazing
6 - prairie habitat set aside for wildlife; no grazing
7 - conservation tillage corn stubble; no grazing
8 - middle grass prairie; not subjected to grazing
Appendix B

Vegetation measures from rodent trap grids collected 18 June to 13 July 1985 in Lincoln County, Nebraska.

<table>
<thead>
<tr>
<th>Site</th>
<th>Effective Ht</th>
<th>Litter Depth</th>
<th>Robel Index</th>
<th>% Grass</th>
<th>% Forbs</th>
<th>% Woody</th>
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<td>SD (s)</td>
<td>n</td>
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<td>2.8 1.0</td>
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</table>

**Trap Site Descriptions**

1 - wild hay field; seasonally wet and subjected to cutting; a was cut prior to data collecting; b and c were not
2 - Sandhills prairie; subjected to grazing; a, b, and c represent 3 samples
3 - Sandhills prairie; subjected to minimal grazing.
4 - middle grass prairie; not subjected to grazing
5 - middle grass prairie along canal; not subjected to grazing
6 - prairie habitat set aside for wildlife; no grazing
8 - middle grass prairie; not subjected to grazing
Weights of adult barn owls captured in Lincoln County, Nebraska, 11 June to 2 August 1986.

<table>
<thead>
<tr>
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<th>Date</th>
<th>Sex</th>
<th>Weight (g)</th>
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<tbody>
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<td>male</td>
<td>489</td>
</tr>
<tr>
<td>7</td>
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<td>male</td>
<td>450</td>
</tr>
<tr>
<td>5</td>
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<td>4</td>
<td>5 July</td>
<td>male</td>
<td>447</td>
</tr>
<tr>
<td>16</td>
<td>25 July</td>
<td>male</td>
<td>405</td>
</tr>
<tr>
<td>17</td>
<td>2 August</td>
<td>male*</td>
<td>485</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>16 June</td>
<td>female</td>
<td>595</td>
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<tr>
<td>17</td>
<td>24 July</td>
<td>female*</td>
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<td>24 July</td>
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<td>545</td>
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</table>

* Two females and one male reared a single clutch which was believed to have offspring from both females.
Appendix D

Hectares of cover within 1.3 km of 14 common barn-owl nest sites in Lincoln County, Nebraska in 1985.

<table>
<thead>
<tr>
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<td>160</td>
<td>39</td>
<td>262</td>
<td>78</td>
<td>8</td>
</tr>
</tbody>
</table>

* Nest category classification
1 - successful nest attempt
2 - failed nest attempt
3 - nesting not attempted in 1985

** includes 212 ha riparian woods
Appendix E

Map showing ground cover within 1.3 km of nest site 5 in Lincoln County, Nebraska in 1985.

- Grass habitat
- Row crops, principally corn
- Wheat
- Summer fallow
- Other (woods, farmsteads, etc.)
* Nest site 5
Appendix F

Illustration of sliding trap door assembly used to capture owls in natural cavities.

Monofilament line

2" X 2"

Stake

Sliding trap door

Nest cavity

1 ft
4 ft