INVESTIGATION INTO THE DECLINE OF POPULATIONS OF THE LESSER PRAIRIE-CHICKEN (*Tympanuchus pallidicinctus*) ON LANDS ADMINISTERED BY THE BUREAU OF LAND MANAGEMENT, CARLSBAD FIELD OFFICE, NEW MEXICO

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Bureau of Land Management, Carlsbad Field Office

620 E. Greene Street, Carlsbad, New Mexico 88220

John L. Hunt and Troy L. Best

Department of Biological Sciences, 331 Funchess Hall,

Auburn University, AL 36849-5414

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EXECUTIVE SUMMARY

Populations of lesser prairie-chickens (*Tympanuchus pallidicinctus*) have declined sharply across the geographic range of the species, including southeastern New Mexico. Suggested causes include drought, conversion of habitat to agricultural use, improper grazing management, chemical control of shinnery oak, hunting, and disturbance and fragmentation of habitat caused by petroleum development. The Bureau of Land Management, which administers public lands that include habitat of lesser prairie-chickens, is required to manage for the conservation of the species and to ensure that their actions do not contribute to the further need to list the species as threatened or endangered. As a partial response to this requirement, the Bureau of Land Management authorized and provided support for the study documented herein.

Lesser prairie-chickens use a breeding system in which males display at leks for females. A lek is an area where males set up and defend territories on which they perform elaborate mating displays. Most activity, including nesting and brood-rearing, takes place near the lek. For this reason, the lek is the focal point of much research on lesser prairie-chickens. This study compared several components of habitat at active and abandoned leks within the Carlsbad Field Office. These components were then analyzed with factor analysis to determine which contributed most to decline in populations. Formerly occupied areas in the Carlsbad Field Office were surveyed for breeding leks. Management recommendations based on the findings are included.

Several vegetative characters of active and abandoned leks of lesser prairie-chickens were measured using the line-point sampling method. Vegetative cover and composition of active leks and associated control points were significantly different from

those of abandoned leks and control points in all 3 years of the study. Active leks and control points had significantly more *Andropogon* and less *Sporobolus* than did abandoned leks and control points. Abandoned leks were more likely to be near *Prosopis* >60 cm in height than were active leks. Vegetative structure as measured by the Robel method was not significantly different for active and abandoned leks. Results are symptomatic of overgrazing, which is detrimental to populations of lesser prairie-chickens.

Several aspects of petroleum development were measured at active and abandoned leks, including number of active and inactive oil wells within 1.6 km, presence or absence of power lines, and length of road within 1.6 km. Abandoned leks had more active wells, more total wells, and greater length of road than active leks, and were more likely than active leks to be near power lines. Effects on lesser prairie-chickens may include increased mortality due to collision with power lines, increased disturbance due to increased presence of humans, destruction of habitat due to installation of roads and drill pads, and fragmentation of habitat. Petroleum development at intensive levels probably is not compatible with populations of lesser prairie-chickens.

Ambient sound levels were measured at 33 active leks, 39 abandoned leks, and 60 control points. Sound levels at leks and control points were not significantly different. Sound levels were about 4 decibels greater at abandoned leks than at active leks. This difference, while statistically significant, is probably not great enough to explain abandonment of leks. Instead, difference in noise levels is symptomatic of high levels of petroleum development, which contributes to abandonment through increased destruction and fragmentation of habitat and greater amounts of human-caused disturbance.

In April 2002 and 2003, surveys were conducted in the Carlsbad Field Office to determine whether active breeding leks existed there. Ten routes were established and surveyed three times each year. At 0.8-km intervals on each route, observers listened for calls of lesser prairie-chickens for 3-5 minutes, for a total of 2,256 observations. One active lek was detected in both years. Except for this lek, near Eunice, no breeding population of lesser prairie-chickens exists on public lands in Eddy or southern Lea counties.

Factor analysis of characters associated with active and abandoned leks was conducted to determine which potential causes are associated with decline in populations. Two factors accounted for 50.1% of variation within the dataset. The first factor, which loaded heavily for variables associated with petroleum development accounted for 31.5% of variation. The second factor, which loaded heavily for variables associated with overgrazing, accounted for 18.6% of variation. Discriminant-function analysis of these factors indicated that petroleum development was more important than overgrazing in explaining the difference between active and abandoned leks.

Based on these findings, the following recommendations are made:

1. Emphasis on research and management should be shifted away from locations where breeding populations once existed to areas where they now exist and to areas relatively low in petroleum development. Annual population surveys should be made in these areas.
2. New petroleum development should not be allowed in areas occupied by lesser prairie-chickens, including the Sand Ranch administered by the Roswell

Field Office, Lesser Prairie-Chicken Areas administered by the state, and areas in northern Lea County administered by the Carlsbad Field Office.

3. Overgrazing should be eliminated in areas occupied by lesser prairie-chickens.
4. Large areas with little or no petroleum development and reduced levels of grazing should be developed for reestablishment of populations. Lesser prairie-chickens may return naturally, but could be reintroduced once the areas are established.
5. Off-road vehicles should not be allowed in areas used by lesser prairie-chickens.
6. Power lines should not be allowed in habitat used by lesser prairie-chickens. Unused power lines should be removed.
7. Cooperative agreements should be pursued with owners of private lands where lesser prairie-chickens may occur.
8. Future research should include continued surveys of suitable habitat, study of feasibility of reintroduction, investigation into possible interaction between fragmentation of habitat and grazing, and study of effects of artificial waterers on lesser prairie-chickens and other wildlife.

CHAPTER 1

BIOLOGY OF THE LESSER PRAIRIE-CHICKEN (*Tympanuchus pallidicinctus*) WITH EMPHASIS ON POPULATIONS IN NEW MEXICO: A LITERATURE REVIEW

TAXONOMY AND NOMENCLATURE

The lesser prairie-chicken (*Tympanuchus pallidicinctus*) is in the Order Galliformes, Family Phasianidae, and Subfamily Tetraoninae (AOU, 1998). It was originally named *Cupidonia cupido* var. *pallidicincta* as a subspecies of the greater prairie-chicken by Ridgway (1873), who elevated it to specific rank in 1885 (Ridgway, 1885). The type specimen was collected on the "Prairie of Texas," near latitude 32° N (AOU, 1998) by Captain John Pope (Bailey, 1928). The species is monotypic (Madge et al., 2002).

Other members of the genus include *Tympanuchus cupido,* the greater prairie-chicken, and *Tympanuchus phasianellus,* the sharp-tailed grouse. The lesser and greater prairie-chickens constitute a superspecies, and have been considered to be conspecific (Short, 1967). When so considered, they are referred to as the prairie-chicken or pinneated grouse. The two species occasionally hybridize, sometimes extensively (AOU, 1998). However, differences in mating vocalizations, displays, and other behaviors, and ecological isolation probably act as reproductive isolation mechanisms (Jones, 1964; Sharpe, 1968).

The name *Tympanuchus* is derived from the Greek *tympanon*, meaning drum, and the Latin *nucha*, meaning neck, referring to the cervical air sacs. The specific epithet

pallidicinctus is from the Latin *pallidus,* meaning pale, and the Latin *cinctus,* meaning banded, and refers to bands of color on the bird, which are pale compared with those of the greater prairie-chicken (Choate, 1985). The common name is lesser prairie-chicken (AOU, 1998). Prairie is French and means meadow, which refers to habitat of this species. Chicken is from Middle English *chiken* and Anglo-Saxon *cicen,* meaning cock, and refers to its resemblance to domestic chickens (Choate, 1985); lesser is a reference to its smaller size relative to the greater prairie-chicken.

EVOLUTION

Grouse (Subfamily Tetraoninae) evolved in North America from a phasinanine ancestor; earliest fossils are *Paleoalectoris incertus* from the lower Miocene. The genus *Tympanuchus* split from other grouse relatively early, probably as a response to expansion of arid, deforested areas at the end of the Tertiary. The earliest fossil of the genus is *T. stirtoni,* from the middle Miocene (de Juana, 1994). Within the genus, *Tympanuchus phasianellus* may be closest to the ancestral form, because it has the most generalized morphology and behavior, including less-specialized pinnae and esophageal sacs (Short, 1967). Johnsgard (1983) suggested that structure of tail-feathers of *T. phasianellus* was specialized for its tail-rattling display, and that it diverged from a common ancestor of the other two species in the genus. Greater and lesser prairie-chickens diverged relatively recently, based on studies of morphology, behavior (Short, 1967), and analysis of mitochondrial DNA (Ellsworth et al., 1995). Remains of lesser prairie-chickens were found in the Guadalupe Mountains west of Carlsbad, New Mexico, in cave deposits that predate presence of humans (Howard and Miller, 1933; Wetmore, 1932). The species may have evolved from an ancestor similar to greater prairie-

chickens that may have lived in the Mexican highlands during the late Pleistocene. According to this theory, the ancestral species arose on the Great Plains, and was split into several fragments during the Wisconsin glacial period. These fragments included the greater prairie-chicken, *T. cupido pinnatus,* in the Nebraskan Refugium, Attwater's prairie-chicken, *T. c. attwateri,* in the Gulf Refugium, the heath hen, *T. c. cupido* in Florida, and the lesser prairie-chicken in the dry Chihuahuan Refugium (Hubbard, 1973). Living in these arid areas may have resulted in paler coloration and smaller size and allowed differentiation of mating displays and vocalizations that separate the two species (Johnsgard, 2002). Genetic evidence supports the idea that species may have been separated by Pleistocene glacial activity (Ellsworth et al., 1995).

DIAGNOSIS

The lesser prairie-chicken is a stocky bird with an oval body shape, small head, and short, rounded tail. It has uniformly barred brown and grayish plumage on back and sides, with a weakly barred belly and a dark eyestripe. It may be distinguished from the greater prairie-chicken by its slightly smaller size and reddish throat pouches. The greater prairie-chicken has yellow-orange throat pouches and a completely barred belly (Sibley, 2000). Feathers on the back of lesser prairie-chickens have a broad brown bar enclosed by two narrow black bars, while those of greater prairie-chickens have single, broad, solid black bars (Copelin, 1963). Breast feathers of lesser prairie-chickens have four to six alternating brown and white bars; breast feathers of greater prairie-chickens have one to four such bars (Short, 1967).

The sharp-tailed grouse has a sharply pointed tail. The only other grouse-like bird that occurs within the geographic range of the lesser prairie-chicken is the blue grouse,

Dendragapus obscurus, which is larger, darker, and lacks barring on the plumage (Sibley, 2000). Geographic range of the lesser prairie-chicken does not overlap with that of the sharp-tailed grouse (Giesen, 1998) and only overlaps that of the greater prairie-chicken in a small area of west-central Kansas (Johnsgard, 2002). Greater sympatry may have occurred just after settlement of the Great Plains by Europeans (Sharpe, 1968). In areas of overlap, lesser prairie-chickens occupy drier habitats than do greater prairie-chickens (Oberhoser, 1974).

GENERAL CHARACTERS AND MORPHOLOGY

The lesser prairie-chicken is a medium-sized grouse, with a length of body of 38-41 cm. Males are somewhat larger than females. Length of wing of males and females is 207-220 and 195-201 mm, respectively. Body mass of males and females is about 790 and 700 g, respectively (Madge et al., 2002). Average external measurements of museum specimens (in mm) of males and females (size of samples in parentheses), respectively, are: length of pinnae, 62.1 (19), 29.3 (8); length of middle tail feather, 79.6 (19), 75.1 (9); length of tarsus, 42.2 (19), 39.5 (11); length of middle toe, 39.7 (19), 38.8 (11—Sharpe, 1968). Average (range in parentheses) measurements of 8 males and 6 females, respectively, from Sand Ranch, Chaves Co., New Mexico, are: mass (g), 768 (741-816), 716 (616-766); length of left tarsus (mm), 53.4 (51.1-58.0), 51.2 (49.1-52.8); length of left wing (mm) 206 (200-210), 204 (200-210); length of culmen (mm), 13.7 (10.0-17.2), 15.3 (13.2-17.6); length of pinnae (mm), 68 (60-74), 35 (30-38—Johnson and Smith, 1999*a*).

Adult birds have alternating dark and pale bands over most of the body. Dark bands are mostly brown, but range from black to cinnamon. Pale bands are grayish

overall, but range from buff to white. Chin and throat mostly are unmarked. Tail is short, rounded, and brownish black (Giesen, 1998). Undertail coverts are clove brown, underwing coverts are whitish, and outer underwing coverts have drab buffy brown spots on terminal ends (Ridgway and Friedman, 1946). Males have a bright yellow eyecomb above the eye, dull red esophageal air sacs on side of neck, and a pair of pinnae made of elongated feathers on each side of neck. Eyecomb, air sacs, and pinnae are displayed during lekking (Giesen, 1998). Bill is dark brown. Iris of eye is dark brown (Oberholser, 1974). Tarsi are feathered to the toes. Feet are yellow and slightly webbed at base of toes, and claws are black (Edminster, 1954; Oberholser, 1974). *T. pallidicinctus* has 18 rectrices and 16 greater upper tail coverts. These numbers are similar to other members of the genus (Short, 1967).

Plumage of females is similar to that of males, but more richly colored (Oberholser, 1974). In addition, tails are different between sexes. The terminal band on dorsal side of tail of males is solid black, unlike that of females, which is broken up with paler color (Campbell, 1972). Tail feathers of females are partially or entirely barred, while those of males are black, sometimes with paler color on central feathers (Copelin, 1963). Females have poorly developed vocal sacs (Sharpe, 1968) and shorter pinnae compared to males. Young-of-the-year have plumage similar to adults, but more richly colored, especially on the throat (Giesen, 1998). The two outer pairs of primaries of younger birds are pointed, and outermost primary is spotted to tip, while that of adults is spotted only to within about 2.5 cm of tip. Upper covert of the outer primary of young birds is white in the distal portion of the shaft, unlike that of adults, which is completely

dark (Copelin, 1963). Downy young are described under Ontogeny and Reproduction below.

Vocal sacs are a pair of unfeathered, elastic structures of skin on either side of the cervical region of the neck, separated ventrally by a less elastic area of feathered skin (Sharpe, 1968). Inflation of vocal sacs is accomplished by distension of an internal air sack, which is an elastic portion of the esophagus. When inflated, sacs are round, and extend laterally rather than ventrally and are about 40 mm in diameter (Sharpe, 1968). Sacs are reddish-brown throughout the year (Sutton, 1977).

Digestive system changes in response to changes in diet. Lesser prairie-chickens that consume more foliage and less acorns and insects have longer small intestines, larger ceca, and less massive gizzards than those that have a less fibrous diet (Olawsky, 1987).

DISTRIBUTION

Lesser prairie-chickens originally were found throughout the southwestern Great Plains, from southeastern Colorado, through southwestern Nebraska and southwestern Kansas, south through western Oklahoma to northwestern Texas and eastern New Mexico (Madge et al., 2002). The exact historical distribution is uncertain due to confusion with the greater prairie-chicken and because a range expansion probably occurred after European settlers came to the area (Sharpe, 1968). Geographic range has been restricted to scattered populations that occupy about 10% of the historic range (Madge et al., 2002). Some greater or lesser prairie-chickens were released on Níihau Island, Hawaii, in the 1930s (Fisher, 1951), but probably do not occur there now (Giesen, 1998).

Populations of lesser prairie-chickens exist in all states where they originally occurred, except Nebraska (Johnsgard, 2002). In Kansas, lesser prairie-chickens occur in sandsage prairies of the southwestern quarter of the state (Thompson and Ely, 1989). In Oklahoma, populations occur in northwestern counties, including the Panhandle (Wood and Schnell, 1984). In Colorado, self-sustaining populations occur only in three southeastern counties (Giesen, 1994*a*). In Texas, lesser prairie-chickens occur in the northeastern Panhandle in an area near the Oklahoma border, and another area near the New Mexico border (Litton et al., 1994).

In New Mexico, the lesser prairie-chicken formerly occupied a range that encompassed about the easternmost one-third of the state, extending to the Pecos River, and 48 km west of the Pecos near Fort Sumner (Ligon, 1961). This covered about 38,000 km^2 (Bailey and Williams, 2000). By the beginning of the 20th Century, populations still existed in nine eastern counties (Union, Harding, Chaves, De Baca, Quay, Curry, Roosevelt, Lea, and Eddy—Johnsgard, 2002). An unsuccessful attempt was made in the 1930s to introduce lesser prairie-chickens into Doña Ana County (Snyder, 1967). Currently, populations exist only in parts of Lea, Eddy, Curry, Chaves, and Roosevelt counties (Johnsgard, 2002), comprising about 23% of the historical range (Bailey and Williams, 2000). The last reliable records from Union County are from 1993. A lek survey in April 1998, through formerly occupied habitat there revealed no active lek, and the New Mexico Department of Game and Fish considered the bird extirpated from northeastern New Mexico (New Mexico Department of Game and Fish, 1999). A few scattered records exist as far west as Roswell and Carlsbad Caverns National Park (Hubbard, 1978), but most lesser prairie-chickens in New Mexico live within 40 km of

Texas. Lesser prairie-chickens still occur in adjacent Bailey, Cochran, and Yoakum counties in Texas, with a few leks also in Andrews and Gaines counties (Johnsgard, 2002). About 59% of historic range in New Mexico is privately owned, 19% is owned by the state, and 21% is federal land administered by the Bureau of Land Management (New Mexico Department of Game and Fish, 1999).

Specimens of lesser prairie-chickens were first collected in New Mexico in the extreme southeastern part of the state, between Eunice and Jal, in 1854 (Bailey, 1928). Ligon (1927) included an area on the Lea-Eddy county line in his map of the range of lesser prairie-chickens, but referred to the area as "second rate chicken country" (Ligon, 1951:29). Bent (1932) believed that lesser prairie-chickens wintered near Carlsbad. Before, 1970, only a few scattered records existed south of US highway 380 in southeastern New Mexico. A small population existed in this area during the 1980s and 1990s; this population peaked at about 160 individuals in 1987 (Johnson and Smith, 1999*b*), but had all but disappeared by 1998 (Smith et al., 1998). An extensive 4-year survey (2000-2003) of this area documented only one active lek near Eunice (Best et al., 2003; Chapter 4). In southeastern New Mexico, about 53% of historic range is federal land administered by the Bureau of Land Management (New Mexico Department of Game and Fish, 1999).

ONTOGENY AND REPRODUCTION

Breeding.—Lesser prairie-chickens use a promiscuous breeding system in which males form display groups usually numbering 10-15, but occasionally >40 birds (Madge et al., 2002). These groups perform mating displays on arenas called leks. Leks often are described as being on knolls, ridges, or other raised areas (Giesen, 1998; Jones, 1963),

but in New Mexico, leks are just as likely to be on flat areas, such as roads, abandoned oil drill pads or dry playa lakes, or at the center of wide, shallow depressions. Leks may be completely bare, may be covered with short grass such as *Bouteloua,* or may have scattered clumps of grass or short tufts of plants such as *Guiterrezia* (Chapter 2; Taylor, 1980). The most important physical requirement for location of leks is visibility of surroundings (Davis et al., 1979), but the most important ultimate consideration is proximity of suitable nesting habitat and breeding females (Bergerud and Gratson, 1988).

Reported density of leks ranges from 0.10-0.43/km^2 (Giesen, 1998). Locations of leks are somewhat permanent, and males usually return to the same lek year after year (Copelin, 1963). However, some movement by males from one lek to another occurs, often to establish new leks (Jamison, 2000). Most leks in one study in Oklahoma were in use > 30 years, although not all of these were used continuously (Copelin, 1963). Females are less likely than males to return to the same lek each year, and females may mate at a different lek if renesting is necessary during a season. Juvenile males may visit several leks before establishing a territory (Taylor and Guthery, 1980*b*). Each male establishes a territory on the lek; younger males unable to establish a territory may form satellite leks nearby (Haukos and Smith, 1999). If population density is great enough, and satellite males are successful at attracting females, satellite leks may become permanent. Relatively small (4-7 m) territories on the lek are defended by threat displays and fighting. This activity reaches a peak in March and early April, and territories are established by mid-April. Position and size of each territory on the lek are a reflection of relative fitness of males (Johnsgard, 2002). Location of the lek may be moved a small

distance in response to disturbance or if a nearby area suddenly has increased visibility due to fire (Cannon and Knopf, 1979).

Mating displays begin about 1 h before sunrise and usually end 2-3 h after sunrise, with a peak in activity and number of birds on the lek from sunrise until 105 min after dawn (Crawford and Bolen, 1975). Another period of lekking displays may occur from late afternoon until just after sunset, and some activity may occur at any time during daylight hours (Johnsgard, 2002; J. L. Hunt and T. L. Best, pers. obs.). Displays usually are limited to crepuscular hours probably as a response to predators (Bergerud and Gratson, 1988). Breeding displays may occur from late January through early May, with most activity in New Mexico from 15 March to 30 April (Davis et al., 1979), and greatest intensity during the first 3 weeks of April, when males may spend the night on the lek. Early in the lekking season, displays may be sporadic, especially in windy or rainy weather (Davis et al., 1979), but once females begin frequenting leks, males display in all types of weather, from calm to high winds, in rain, sleet, or snow, and in bitter cold or relative warmth. In April 2002, males at a lek near Eunice, New Mexico, were observed displaying in 32-km/h winds immediately following a heavy thunderstorm (J. L. Hunt, in litt.). If disturbed, males fly from the lek, but soon return and begin displaying again (Bent, 1932; Davis et al., 1979). Displaying also occurs during autumn, probably as a method for older males to protect established territories (Bergerud and Gratson, 1988) and for younger males to learn the location and procedures of lekking. Older males display on their accustomed territories on the lek during autumn displays (Johnsgard, 2002), while younger males wander around the lek displaying sporadically. In New Mexico, autumn displays occur in September and October and are terminated by

onset of winter weather (Davis et al., 1979). Territories on leks in autumn are smaller, closer, and more poorly defined than during spring (Taylor and Guthery, 1980b). Mating displays, territorial behavior, and copulation are described below under Behavior.

Each female visits a lek for a few days immediately before start of egg-laying. This may occur from mid-March through the first week of May, with a peak in the third week of April. She usually selects the dominant male; this male may perform up to 85% of copulations at a given lek (Sharpe, 1968). The dominant male attacks any other male that attempts to copulate at his lek, but he never is interrupted. Greatest number of copulations occurs in the second and third week of April. Females may visit more than one lek during a breeding season, but mate only once unless renesting becomes necessary (Johnsgard 2002).

Nesting.—Nests are shallow depressions in grass (Giesen, 1998), or in sand, lined with grasses (Bent, 1932). Nests are placed in areas with good horizontal and vertical cover, often provided by sand sage (*Artemesia filifolia*) or shinnery oak (*Quercus havardii*—Johnsgard, 2002). In New Mexico, lesser prairie-chickens usually nest in bluestem (*Andropogon*). Bluestem, dropseed (*Sporobolus*), and shinnery oak are present in greater abundance within 3 m of the nest than in the overall vegetative composition (Davis et al., 1979). Nests may be placed beneath such cover when grazing by livestock is heavy, or in bunchgrasses when plenty of residual grasses are available. In Colorado, tallest vegetation over nests averaged 50.7 cm, and height of shrubs, forbs, and grasses at nests was greater than at nearby sites (Giesen, 1994*b*). In an ungrazed area of New Mexico, maximum vegetative height at nests was 102.2 cm, which was significantly taller than vegetation at control points. In New Mexico, nests were placed in areas with

significantly more stems of shinnery oak than at control points (Sutton Avian Research Center, 2000). Areas around nests tended to have more litter and less bare ground than did the overall substrate. Nests may be built on slight slopes with north or northeastern exposure or in depressions among sandhills to provide some shade and protection from prevailing southwestern winds (Davis et al., 1979). Nests are not reused from year to year; if renesting occurs within a season, a new nest is built (Giesen, 1998). Nests are built near the lek where mating occurred. In Colorado, average distance from lek to nest was 1.80 km (n = 31), which was greater than average distance between nest and nearest lek (1.04 km—Giesen, 1994*b*). In New Mexico, 12 of 16 females nested and raised broods < 1.5 km from the lek where they were marked (Ahlborn, 1980). Success of nesting is discussed below under Demographics.

Eggs are short subelliptical to short oval in shape, 42 by 32 mm. Color of eggs is pale ivory-buff to ivory-yellow, sometimes with minute speckling (Baicich and Harrison, 1997). Average mass of eggshell is 1.69 g. Clutches typically contain 10-12 eggs (average = 10 eggs, range = 8-14, n = 60 clutches—Giesen, 1998). Captive lesser prairie-chickens have produced clutches of 25 eggs (Coats, 1955). Size of brood varies among years, with larger broods being produced during years with greater amounts of precipitation (Johnsgard, 2002). Later nests, which usually are re-nests, contain 7-10 eggs. First clutches are laid in April or May (Madge et al., 2002). If the first nest is destroyed, a female may renest within 2 weeks (Giesen, 1998). Laying begins a few days after copulation (Johnsgard, 2002). Eggs are laid at just over 1-day intervals; a day may be skipped. Incubation, by females alone, begins just before or after the last egg is laid, and lasts 23-26 days (Baicich and Harrison, 1997). The female forms a brood patch, and

may use shed feathers for nest lining. The female covers the nest with vegetation when she leaves during laying, but not during incubation. She takes two breaks of < 30 min within 2 h of dawn and dusk to feed, at sites 0.25-2.0 km from the nest. No interspecific or intraspecific egg-dumping, nest parasitism, or cooperative breeding by lesser prairie-chickens is known (Giesen, 1998). Nesting females blend well into their surroundings. They remain on the nest even when approached closely, making them difficult to find (Bent, 1932).

Young.—Nestlings are precocious and downy (Baicich and Harrison, 1997). Nestlings are similar to those of greater prairie-chickens, but are paler, brighter, and slightly more yellow. Pileum and hindneck are honey yellow to cinnamon buff, with large black spots medially. Back and wings are grayish-yellow with a cinnamon wash. Rump is honey yellow with a tawny wash. Upper back has brownish black or olive brown, irregular, narrow bars running transversely, with spots of the same color on rest of back. Wings have large transverse spots. Lower back and rump have brownish-black spots. Sides of head and lower parts are buff, darker on jugulum and upper half of sides of head. There is a small, elongated, irregular black spot above the auriculars (Oberholser, 1974). Toes and bill of chicks are bright yellowish orange, except at base of mandible, which is pinkish-tan. The bright yellowish coloration fades with age. Unlike those of greater prairie-chickens, downy young of lesser prairie-chickens lack a definite middorsal streak (Sutton, 1968).

Young leave the nest 1-2 days after pipping begins. The female leaves unhatched eggs and eggshells in the nest. Young are tended only by the female, who broods them under her breast feathers or drooping wings frequently during the day and every night

during the first week, and less frequently thereafter. Young are able to feed upon hatching (Giesen, 1998). The brood is led by the female to forage in shrubby areas with abundant tall forbs, open understory with bare areas below, and high densities of insects (Bidwell, 2002; Davis et al., 1979; Jones, 1963). In New Mexico, average area of use by broods during the first 4 weeks was 23.4 ha, after the first 4 weeks was 34.1 ha, and cumulative area of use during the brood period was 47.0 ha. Broods used shinnery oak sandhills and shinnery oak-bluestem associations to a greater degree than would be expected by chance. Sandhills provide some relief from direct sunlight and prevailing winds. Broods occurred in areas with lower quantities of canopy cover than overall average for the habitat, with a canopy height of about 30 cm. This amount of canopy provides camouflage for the female and young, but allows the female to watch for predators (Ahlborn, 1980). Young grow rapidly and are capable of flight at 2 weeks (Giesen, 1998). Two or more broods may intermix at 6-8 weeks (Bidwell, 2002). Young are independent and broods break up in 12-15 weeks. Young resemble adults within 4 months (Giesen, 1998). After broods break up, the female molts (Taylor and Guthery, 1980*b*). Adult males also molt at this time (Copelin, 1963).

Young-of-the-year join mixed flocks with adults after breakup of broods. All females breed during the first year after hatching. Young males display at leks and attempt to breed, but usually only older males copulate successfully (Giesen, 1998). Autumn flocks typically contain about 50% young-of-the-year. Annual mortality rate is about 50% (Johnsgard, 2002).

Hybridization.—Because there currently is little overlap between geographic ranges of lesser and greater prairie-chickens, hybridization is not common. Although

hybrids produced in captivity are fertile, mating of second-generation hybrids produced a clutch that had only 11 of 26 fertile eggs, only four eggs hatched, and all chicks died within 1 week. Hybrids had characteristics intermediate between the two species, and male hybrids performed breeding displays with elements of displays of both greater and lesser prairie-chickens (Crawford, 1978). An area of contact between the two species occurs in western Kansas. In this area, greater and lesser prairie-chickens sometimes have been observed displaying on the same leks. On some of these leks, male prairie-chickens were observed with physical characteristics intermediate between the two species, and display calls with elements of those of both species. These birds may be hybrids (Bain and Farley, 2002). Hybridization occurs between lesser prairie-chickens and sharp-tailed grouse in areas of contact, and offspring of these matings also are fertile. Because geographic ranges of these species overlap only slightly, frequency of hybridization is low enough that it poses little danger to respective gene pools (Johnsgard, 2002).

The lek breeding system in lesser prairie-chickens (and in grouse in general) may have evolved as a system to lure predators away from nesting areas. According to this theory, loud, highly visible displays of male prairie-chickens act as a decoy for predators, which are lured away from females and nests. Females would select males with the longest, loudest displays as mates. This implies an optimum distance from a lek for the nest—it must be as far as possible to reduce the chance that a predator would stumble upon the nest, but close enough so that the display is still audible and visible (Phillips, 1990). However, other theories of evolution of lekking behavior state that leks form in hotspots of activity by females, that females prefer clusters of males from which to

choose, or that leks form because males tend to congregate around the most fit male because that is where females congregate (Beehler and Foster, 1988)

ECOLOGY

Habitat.—Lesser prairie-chickens originally were found throughout dry grasslands that contained shinnery oak or sand sage. Currently, they most commonly are found in sandy-soiled, mixed-grass vegetation, sometimes with short-grass habitats with clayey or loamy soils interspersed (Taylor and Guthery, 1980*b*). They occasionally are found in farmland and smaller fields, especially in winter (Madge et al., 2002).

Shinnery oak is an important component of habitat of lesser prairie-chickens in New Mexico. Most of the mass of shinnery oak consists of an underground root mass, which may extend over 0.4 ha and live for thousands of years (Peterson and Boyd, 1998). Above ground shoots rarely reach >60 cm in height and persist for 10-15 years. These shoots are used as cover and produce acorns, which are important food for lesser prairie-chickens (Johnsgard, 2002) and many other species of birds, such as the scaled quail (*Callipepla squamata*—Hunt and Best, 2001*b*), northern bobwhite (*Colinus virginianus*—Hunt and Best, 2001*a*), and mourning dove (*Zenaida macroura*—Hunt, 1999). Current geographic range of shinnery oak is nearly congruent with that of the lesser prairie-chicken, and these species sometimes are considered ecological partners (Johnsgard, 2002). Population densities of lesser prairie-chickens are greater in shinnery oak habitat than in sand sage habitat. In areas of shinnery oak, size of populations are positively correlated with percentage cover of grass and negatively correlated with amount of brushy cover, while in areas of sand sage, the opposite is true (Cannon, 1980).

Shinnery oak is considered poor forage for livestock, and in fact, shinnery oak blooms are poisonous to livestock (Peterson and Boyd, 1998). Efforts to control shinnery oak with tebuthiuron and by physical removal have been harmful to populations of lesser prairie-chickens and other wildlife (Johnsgard, 2002). Lesser prairie-chickens living in areas of tebuthiuron treatment consumed more foliage and less insects and acorns, resulting in differences in morphology of the small intestine, cecum, and gizzard necessary to process a lower quality, more fibrous diet. Lesser prairie-chickens in treated areas had lower body weight and smaller fat reserves than did those in untreated areas (Olawsky, 1987). While overall density of grass increased in areas of treatment, amount of *Andropogon,* which is most important to lesser prairie-chickens, stayed the same. Population density of lesser prairie-chickens was not different in treated and untreated areas (Olawsky and Smith, 1991).

Sand sage is important to lesser prairie-chickens for cover and as emergency food. It is a woody, long-lived aromatic shrub that usually is <90 cm in height. It grows best on well-drained, sandy soil. Leaves are long and narrow, have a bitter taste, and are rich in oils that repel insects. Sand sage is considered poor forage for livestock, but is an important food of mule deer (*Odocoileus hemionus*) and pronghorns (*Antilocapra americana*—Johnsgard, 2002). Chemical control of sand sage is harmful to populations of lesser prairie-chickens (Rodgers and Sexton, 1990)

Tallgrasses, particularly sand bluestem (*Andropogon halli*), are important components of habitat of lesser prairie-chickens in New Mexico. Lesser prairie-chickens spent more time in areas with substantial amounts of tallgrasses than in areas dominated by shortgrass or mesquite. Nests were located only in areas of tallgrass, and nesting

success was correlated with abundance of *Andropogon*. *Andropogon, Sporobolus,* and shinnery oak were all present in greater abundance within 3 m of nests than in overall vegetative composition (Davis et al., 1979). Comparison of successful and unsuccessful nests in the same area determined that successful nests were in areas with greater composition of sand bluestem and taller average height of plants (66.6 cm) than at unsuccessful nests (34.9 cm—Riley et al., 1992).

Geographic range of the lesser prairie-chicken once contained large populations of prairie dogs (*Cynomys*), but < 1% of historic prairie dog towns remain. Prairie dogs created disturbed areas that could be used as leks and, more importantly, allowed establishment of annual and perennial forbs that provided food for adult prairie-chickens and their broods. It has been postulated that declines in populations of prairie dogs result in changes in diversity of plants and contribute to declines in lesser prairie-chickens (Bidwell, 2002). No research has been conducted in this area.

Feeding.—Food is rarely a limiting factor for populations of lesser prairie-chickens (Bidwell, 2002). Across their geographic distribution, in autumn and winter, the lesser prairie-chicken eats acorns. In spring and summer, they consume buds and fruits of sumac (*Rhus*), legumes, and other plants, but their most important foods are catkins of shinnery oak. It consumes wheat, sorghum, and other grains when available, especially after heavy snows. Lesser prairie-chickens eat insects, especially beetles and grasshoppers (Olberholser, 1974; Madge et al., 2002), and galls formed by cyprinid wasps on shinnery oak (Johnsgard, 2002). A study in Oklahoma indicated that it eats more insects, especially grasshoppers, beetles, and hemipterans, in summer and autumn, more seeds in spring, and more green vegetation in winter; all three categories of food

were eaten throughout the year. In Oklahoma, *Guiterrezia sarothrae, Rhus aromatica, Festuca octoflora, Eriogonum annuum, Evax prolifera,* and *Artemesia filifolia* were the most important plants eaten by lesser prairie-chickens during winter. During summer, *Rhus aromatica* was most important (Jones, 1963). In Kansas, lesser prairie-chickens selected foraging areas that had higher biomass of invertebrates, especially acridid grasshoppers (Jamison et al., 2002). They ate small quantities of leaves and flower heads of sand sage; leaves and seeds may provide emergency food supplies in winter (Johnsgard, 2002). Seeds of prairie sunflowers (*Helianthus annulus*) may also be important in winter (Taylor, 1978).

In New Mexico, acorns of shinnery oak, other vegetative material, and insects were eaten year-round. Acorns comprised 21.4% of diet in summer, 39.2% in autumn, 69.3% in winter, and 15.2% in spring. Other vegetative material was 23.3% of diet in summer, 38.7% in autumn, 26.0% in winter, and 78.7% in spring. Shinnery oak was the most important item in the diet of adults year round. The combination of acorns, galls, catkins, and leaves made up 22.5% of diet in summer, 50.1% in autumn, 69.3% in winter, and 49.1% in spring. Other plants consumed included erect dayflower (*Commelina erecta*), fame flower (*Talinum parviflorum*), broom snakeweed (*Gutierrezia sarothrae*), and buckley penstemon (*Penstemon buckleyi*) in summer, broom groundsel (*Senecio spartioides*), dwarf dalea (*Dalea nana*), and wild buckwheat (*Eriogonum annuum*) in autumn, wild buckwheat and broom groundsel in winter, and wild buckwheat and broom snakeweed in spring. Insects comprised 55.3% of diet in summer, 18.1% in autumn, 4.7% in winter, and 5.9% in spring. Acridid grasshoppers were the most common insects consumed in summer and autumn, but were not consumed in winter or spring. Other

arthropods consumed in summer and autumn include tettigoniid grasshoppers, treehoppers, and ants. Beetles and treehoppers made up most of the insect portion of diet in winter and spring (Davis et al., 1979). Near Milnesand, New Mexico, lesser prairie-chickens may spend part of winter in sorghum fields, especially in years when natural foods are less abundant (Ahlborn, 1980). Sorghum made up 62% of autumn diet by weight in one study in nearby Cochran County, Texas (Crawford and Bolen, 1976*c*).

In Oklahoma, young <1 month old ate mostly insects, with orthopterans composing 41.7% of volume of food, carabid beetles 26.5%, scarab beetles 7.8%, and hemipterans 1.9%. Leafy green matter comprised 5.2 % of diet, with seeds of *Rhus aromatica* (4.8%) and *Lithospermum incisum* (2.9%), and pieces of grass (1.9%) making up most of the rest (Jones, 1963). In New Mexico, diet of birds <10 weeks old was 99% insects. Youngest birds consumed mostly treehoppers, with percentage of grasshoppers increasing with increasing age until 5 weeks, when diet was almost completely grasshoppers (Davis et al., 1979). Captive birds <3 weeks old did not instinctively take food off the ground, and had to be trained to do so (Coats, 1955).

In winter, lesser prairie-chickens may feed on crops, such as sorghum or wheat, and older accounts report flocks of thousands coming to fields to feed (Bent, 1932). However, reliance on such waste grain or cultivated food plots may not supply essential amino acids, leading to reduction in body condition and overall health (Bidwell, 2002).

Water relations.—Many mammals and birds adapted for dry climates survive without drinking, and obtain water from other sources, especially as a result of metabolic processes (Schmidt-Nielsen, 1964; Wiens, 1991). Like these animals, lesser prairie-chickens normally do not require open water (Giesen, 1998), but may obtain water from

leaves of sand sage, dew, insects, and from metabolizing food (Johnsgard, 2002). Although they do not need open water to survive under normal conditions, lesser prairie-chickens will drink water from stock tanks (Crawford and Bolen, 1973). Use of artificial water sources may expose them to predation and disease (Rosenstock et al., 1999). Although much effort has been expended to create artificial water sources for wildlife throughout the Southwest, little research has been conducted to study effects of such sources (Broyles, 1995; Rosenstock et al., 1999), and no study has examined effects of artificial water sources on populations of lesser prairie-chickens.

In periods of drought, stock tanks and streams may be used to obtain water, especially during times of egg production, when water needs of females increase (Crawford, 1974; Davis et al., 1979). Lesser prairie-chickens avoid creeks, rivers, and other low spots with reduced visibility that may allow predators to hide (Bidwell, 2002). Prairie-chickens seek shade under trees or brush on hot, dry days (Copelin, 1963).

Parasites and pathogens.—No information is available on ectoparasites (Giesen, 1998). In Kansas, lesser prairie-chickens tested positive for antibodies to *Mycoplasma meleagridis, Mycoplasma synoviae,* and *Mycoplasma gallisepticum,* all at rates <10%, although no infection was confirmed. Infections may be transmitted during winter and spring, when lesser prairie-chickens gather together to forage or perform breeding displays. Lesser prairie-chickens testing positive should be considered potential carriers of mycoplasmosis, a respiratory infection, and should not be used in translocation programs (Hagen et al., 2002). In Texas and New Mexico, there was a 10.8% infection rate for the malarial parasite *Plasmodium pedioecetii* (Stabler, 1978). A survey of lesser prairie-chickens from three states for reticuloendotheliosis produced no positive result

(Wiedenfeld et al., 2002); another survey of 181 individuals from New Mexico also produced no positive result (Sutton Avian Research Center, 2000). Specimens of *Oxyspirura lumsdeni*, a thelaziid nematode, were collected from orbits of lesser prairie-chickens in Oklahoma (Addison and Anderson, 1969).

Predators.—Predators of adults include red-tailed hawks (*Buteo jamaicensis*), rough-legged hawks (*Buteo lagopus*), ferruginous hawks (*Buteo regalis*), prairie falcons (*Falco mexicanus*), great horned owls (*Bubo virginianus*), golden eagles (*Aquila chrysaetos*), northern harriers (*Circus cyaneus*), coyotes (*Canis latrans*), bobcats (*Lynx rufus*), raccoons (*Procyon lotor*), and foxes (Bidwell, 2002; Ligon, 1961; Schroeder and Baydack, 2001). Harriers and Swainson's hawks (*Buteo swainsoni*) are the most common raptors in the habitat of lesser prairie-chickens in New Mexico, but they are largely ignored by lekking lesser prairie-chickens, and the few attacks that do occur usually are unsuccessful. Lesser prairie-chickens are more wary of prairie falcons and Cooper's hawks (*Accipiter cooperii*), which are less common in New Mexico (Davis et al., 1979).

Nest predators include coyotes, raccoons, opossums (*Didelphis virginiana*), badgers (*Taxidea taxus*), striped skunks (*Mephitis mephitis*), Chihuahuan ravens (*Corvus cryptoleucus*), bull snakes (*Pituophis melanoleucus*), ground squirrels (*Spermophilus*), and other rodents (Bidwell, 2002; Jamison, 2000; Ligon, 1961; Schroeder and Baydack, 2001). Nests may also be lost to trampling by livestock or by harvesting or cultivation in meadows or cropland (Bidwell, 2002).

There are several reports of interaction between introduced ring-necked pheasants (*Phasianus colchicus*) and greater prairie-chickens. Male pheasants disrupted breeding

displays and aggressively pursued and fought with male greater prairie-chickens. Female pheasants parasitized nests of greater prairie-chickens. These nests were less successful than nonparasitized nests (Vance and Westemeier, 1979). Although there is no report of agonistic interactions between lesser prairie-chickens and pheasants, one study in Kansas found a low (3%) rate of parasitism of nests of lesser prairie-chickens by ring-necked pheasants. Nesting success was the same for parasitized and unparasitized nests, and no chicks of ring-necked pheasants survived to independence (Hagen et al., 2002).

DEMOGRAPHICS

Survival.—In New Mexico, annual survival rate was about 50%. Males had a much higher survival rate than females. Greatest amount of mortality occurred in May, probably due to predation on incubating females (Sutton Avian Research Center, 2000). Another study in New Mexico reported an annual mortality rate for males of 64.2%, and a maximum life span of 5 years (Campbell, 1972). In Kansas, survival rate for chicks to fledging (14 days after hatching) was 31%, and half of broods studied suffered loss of all chicks prior to fledging (Jamison, 2000).

Population densities.—Population densities vary widely across the geographic distribution and with time. For example, densities in Oklahoma from 1956-1961 ranged from 0.6-7.1 males/km^2 (Copelin, 1963). Another study reported densities of 0.3-2.2 males/km^2 in Colorado (Hoffman, 1963). Size of populations of grouse may be regulated by density. When densities are high, juveniles may be forced to disperse to find territories (Boag et al., 1979). There is a linear relationship between number of active leks and size of population of lesser prairie-chickens (Cannon and Knopf, 1981).

Sex ratio.—Reported male-to-female sex ratios range from 1:0.53 to 1:1.25, with most reports being male biased and an overall ratio of 1:0.78. However, many reports are based on hunter checks, and sexes may be differentially susceptible to harvest (Taylor and Guthery, 1980*b*).

Age ratio.—Juveniles normally outnumbered adults in studies conducted from hunter checks. Adult-to-juvenile ratio ranged from 1:0.60 to 1:2.19, with an overall ratio of 1:1.12. It is unknown whether adults and juveniles are differentially susceptible to harvest (Taylor and Guthery, 1980*b*).

Nesting success.—Nesting success in eastern New Mexico was 27% ($n = 36$), with 63% of failures attributed to predation, and was strongly positively correlated with cover of *Andropogon* and negatively correlated with level of grazing by livestock (Davis et al., 1979). Successful nests in New Mexico tended to be in areas with more plant litter than average (Wilson, 1982). Nesting success in another study in eastern New Mexico was 43.5% ($n = 9$). All failures of nests in this study were attributed to predation, with all but one caused by mammals (Sutton Avian Research Center, 2000). Drought conditions may result in reduced nesting success (Merchant, 1982).

BEHAVIOR

Mating behavior.—Calls are similar to those of greater prairie-chickens, but higher pitched and shorter. The booming call is a bubbling hoot, unlike the low droning call of greater prairie-chickens (Madge et al., 2002) and may be audible for =1.6 km. The display is called booming, gobbling, or yodeling. This display may serve as a gamosematic display to advertise the lek to nearby females, as a threat and territorial display to other males, and as an epigamic display to females (Sharpe, 1968).

Gobbling display begins with rapid foot-stamping. Feet are stamped at a rate of 20/s (Hjorth, 1970). During this stamping, the neck is outstretched, pinnae are raised, tail is held vertically above the back (Grange, 1940), wings are drooped, primaries are spread, and the bird moves forward =1 m in a straight line or a slight arc. Foot-stamping ends as the call begins (Sharpe, 1968). The call is a quick series of three gobbles. During the first, the male spreads his tail, jerks his head downward, and inflates his throat sacs. The head is jerked upward during the second note. After the third note, throat sacs are deflated and the bird slowly resumes his normal posture (Johnsgard, 2002). Auditory portion of the display lasts about 0.6 s (Sharpe, 1968), has a frequency of 0.4-1.4 kHz and is audible to humans for =1.6 km (Hjorth, 1970). The gobble has been described as sounding like a high-pitched "*quoodle ook,*" and each gobble may be answered by the male toward which the call is directed. The duet may be ended with a high-pitched "*quat, quat, quat, quat*" (Grange, 1940). These duet displays, called antiphonal booming, are not seen in other prairie grouse, and may have evolved to reduce frequency of physical fighting between males, which spend a greater portion of time on the lek than greater prairie-chickens. Performance of displays reaches a higher intensity when females are present on a lek (Sharpe, 1968). Between gobbling displays, males may cackle and perform short vertical flights, called flutter-jumps (Bidwell, 2002). Flutter-jumps often are performed by peripheral males when females are present near the center of the lek, and may result in the male landing on a shrub (Sharpe, 1968).

Territorial disputes between males may result in ritualized fighting. Two males run at each other until they are <1 m apart. They raise their pinnae straight up above the neck, whine at each other and give a few cackling calls. They may engage in a face-off

in which they squat facing each other for up to several minutes, often whining the whole time. Finally, one runs at the other and they both jump into the air, sometimes slamming into each other. They may fight, sometimes seemingly violently, but use of bill, claws, or wings seldom occurs. If actual fighting occurs, attacks often are made toward the superciliary combs and vocal sacs, and bleeding and scratches of these areas may result. At any point, one bird may retreat, but often the two squat down again and repeat the process, or they may begin gobbling (Grange, 1940; Sharpe, 1968).

Males establish territories on the lek. Males may remain within their own territories without being challenged by other males, but if they approach boundaries of other territories, are met by displays or fighting. Disputes are frequent early in the breeding season, but occurrence dwindles as the season progresses and females begin to visit the lek. Large numbers of females visiting the lek may cause territorial boundaries to break down, and when one male copulates with a female, other males may invade his territory and attack the copulating male. The dominant male at each lek has the largest, most centrally located territory, wins most agonistic confrontations, and performs the majority of copulations. There is a decrease in dominance of males with distance from center of lek. Subordinate males may attack the dominant male during copulations, but usually back down before striking. During territorial disputes, they display appeasement responses, and are driven away by aggressive behavior of the dominant male (Sharpe, 1968).

Males perform an appeasement response by withdrawing the head, relaxing contour feathers and pinnae, dropping the tail, covering all but the tips of primaries with side feathers, and reducing and partially covering the superciliary combs. When on the

center of their own territories and not in conflict with other males, a male may assume a neutral posture in which tips of primaries are visible, contour feathers are relaxed, and head is held in a vertical position. As other males approach the territory, a more threatening posture is assumed. Components of threat posture are added to neutral posture in various combinations. Tail is elevated, primaries are spread and drooped, pinnae are elevated, and superciliary comb is displayed. Dominance hierarchy exhibited on the lek may be retained by flocks of males away from the lek, and a similar hierarchy may exist among flocks of females. Females sometimes display agonistic behavior toward other females, using behaviors that are similar to, but less intense than, those of males. Males are almost always dominant to females (Sharpe, 1968).

Epigamic display is similar to that described above, but is more intense. Primary feathers are more dramatically drooped, pinnae are held far forward over the head, and superciliary combs are more fully enlarged. This display is stimulated by any female appearing on the lek. If there is more than one female, the male displays toward any one that displays soliciting behavior. He performs booming displays, foot-stamps in wide arcs, and momentarily freezes with vocal sacs fully expanded. During a pause, he may perform a nuptial bow toward the female. The male quickly drops into a prone postion with pinnae and tail held erect and with wings spread with primaries lying on the ground and the bill held toward the ground. The male continues the bow for =7 seconds, as long as the female is paying attention. Dominant males are less likely to perform a bow during courtship than are less dominant-males. During these displays, the male may give a "*pike*" call, which has a pitch of about 1,000 hz, and a duration of about 0.23 s (Sharpe, 1968).

A female on the lek signals readiness for breeding by assuming a soliciting posture. She moves slowly around the lek with feathers sleeked down and head drawn in. She takes a few steps, pauses, then repeats, moving hesitantly. The female may then squat with wings slightly drooping, in a prone position. Often she must repeat these behaviors many times before the male begins copulation. Once the male begins to mount, the female may run ahead of him several times. Finally, she assumes a copulatory posture. She droops her wings and holds them slightly away from her body, and quivers her wings. She crouches down with her head held at about 45° from her body (Sharpe, 1968).

Once the female takes the copulatory position, copulation begins. The male circles around to the rear of the female and assumes an erect posture with his head and neck held back and his bill tucked down. Occasionally, the male may assume this erect posture in view of an apparently receptive female to solicit her to take the copulatory position. Once she is in position, he mounts and grasps her neck feathers with his bill, droops his wings on either side of her, and attempts to complete copulation. The female may still disengage at this point, and the male may have to attempt copulation several times before being successful. Copulation lasts 2-3 s, but may take longer if bodies or cloacas are improperly oriented. After copulation, the male may immediately begin displaying toward another female, while the female runs a few steps, and then ruffles her feathers in a vigorous manner. She usually leaves the lek within 0.5 h (Sharpe, 1968).

Movement, dispersal, and migration.—Lesser prairie-chickens are non-migratory. Large portions of the total population formerly were believed to winter in central Texas (Bent, 1932; Crawford, 1980), but little evidence for this exists (Giesen, 1998). Birds in

the southernmost portion of the range that were considered winter migrants were probably residents; suitable habitat existed in those areas (Taylor and Guthery, 1980*b*). Scattered records from eastern Kansas and eastern Texas probably represent accidental vagrants (Crawford, 1980; Thompson and Ely, 1989), and records from southwestern Missouri were probably birds collected in Kansas (Robbins and Easterla, 1992).

Lesser prairie-chickens usually spend most of their time within 3-4 km of the lek (Taylor and Guthery, 1980*b*). Juvenile males have been reported dispersing >12 km (Jamison, 2000; Taylor and Guthery, 1980*a*), and one adult male moved 44 km (Jamison, 2000). However, individuals are mostly sedentary, with few movements >10 km, and most <7 km. Movements tend to be greater in winter (Madge et al., 2002), when birds may leave home ranges in search of food (Sharpe, 1968), and travel =40 km to grain fields (Taylor and Guthery, 1980*b*). One study in Oklahoma reported that 79% of banded birds were recovered within 3.2 km of the banding site and 97% were recovered within 6.4 km (de Juana, 1994). Median daily movements in Kansas were 435-785 m in winter and 140-365 m in summer (Jamison, 2000).

In New Mexico, average size of home range for males was 9.57 km^2 (n = 13, range 0.31-53.38), and 5.25 km^2 for females (n = 3, range 1.30-9.89). Maximum distance moved by males was 2.90 km, and by females 1.88 km (Sutton Avian Research Center, 2000). Also in New Mexico, a study that included only females reported average size of home range as 2.31 km^2 for prenesting females, 0.92 km^2 for nesting females, and 0.73 km^2 for females with broods. Prenesting females moved an average of 390 m/day, nesting females moved an average of 250 m/day, and females with broods moved 280 m/day (Riley et al., 1994). Average size of home range in Oklahoma was 10 km^2;

combined size of home range for all birds at a lek may exceed 49 km^2 (Bidwell, 2002). Drought tends to increase size of home range (Merchant, 1982).

Lesser prairie-chickens spend most time on the ground, and they usually walk from place to place while feeding, loafing, brood-rearing, and roosting. They fly when disturbed, moving between feeding areas, roosting or loafing sites, or leks, during nest recesses, and when flying to water sources. Flights are usually <1 km in length and <100 m in altitude, although they may be much longer, and consist of alternate wing-flapping and gliding (Giesen, 1998). When disturbed, lesser prairie-chickens flush and fly toward the horizon, sometimes beyond sight distance (J. L. Hunt and T. L. Best, pers. obv.). They select shrubby areas for escape cover (Jones, 1963). They are not known to swim or dive (Giesen, 1998).

In Oklahoma, lesser prairie-chickens spent most of their foraging time in grassy areas, with less foraging time spent in shrubby areas. Shrubby areas were used to a greater extent in spring. During day, lesser prairie-chickens rested in shrubby areas. At night, they roosted in areas of short vegetation surrounded by taller vegetation. When snow was on the ground, they used more sheltered roosts in vegetation that was taller than surrounding vegetation, or roosted within snowdrifts (Jones, 1963). In New Mexico, they preferentially spent time in areas with more shinnery oak and less mesquite canopy cover and density, and greater height of canopy (Sutton Avian Research Center, 2000). Another study in New Mexico reported that, in autumn and winter, lesser prairie-chickens foraged, rested, and roosted almost exclusively in areas with a mixture of shinnery oak and tallgrasses, with more grasses present than in surrounding areas. Foraging areas in winter tended to have more shinnery oak, bare ground, and leaf litter than those used in

autumn, probably reflecting an increased reliance on acorns as food during winter. In summer, foraging areas tended to be more shrubby and less grassy than overall landscape, probably because these areas have more abundant insects (Davis et al., 1979). In autumn and winter, lesser prairie-chickens spend much time in flocks = 80 birds (Copelin, 1963), with flocks of 10-20 being typical (Smith, 1979). They were formerly seen in flocks of thousands when feeding on grain in winter (Bent, 1932), but such flocks are unknown now.

Feces consists of two types. Intestinal droppings are cylindrical and are soft and moist in summer, and hard and dry in winter. Cecal droppings are deposited once or twice daily (Giesen, 1998). Intestinal droppings are brown, tan, or white in color; cecal droppings appear black and tarry (J. L. Hunt and T. L. Best, pers. obs.). Both types of droppings often are observed at lek and roost sites (Elbroch and Marks, 2001; Giesen, 1998).

Lesser prairie-chickens forage on the ground alone or in small flocks. Adults feed in early morning and late afternoon; broods forage all day. Food is stored in the crop for later digestion. Some mechanical break-up of food with grit occurs in the muscular gizzard (Giesen, 1998). Lesser prairie-chickens may take dust baths during morning or afternoon rest periods in both spring and summer (Giesen, 1998; Jones, 1964).

GENETICS

Reduction in size of populations reduces genetic diversity in some prairie grouse (Bouzat et al., 1998). However, a study of nuclear and mitochondrial DNA that compared genetic variation between highly fragmented populations in Oklahoma and more stable populations in New Mexico reported that genetic diversity of lesser prairie-

chickens remains at high levels. Gene flow between populations was low (Van den Bussche et al., 2003).

Analysis of mitochondrial DNA indicates that the three species of *Tympanuchus* are extremely closely related. The low level of interspecific divergence and polyphyletic distribution of haplotypes is indicative of recent speciation (Ellsworth et al., 1995). Morphological and behavioral differences among species are subject to sexual selection, and may evolve more rapidly than mitochondrial DNA or allozymes (Ellsworth et al., 1994).

CONSERVATION AND MANAGEMENT

Population status.—Original range may have been 259,000-389,000 km^2 (Johnsgard, 2002). During the second half of the 1800s, the lesser prairie-chicken was abundant and broadly distributed across its range (Crawford, 1980). Estimates of size of populations are historically =3,000,000 across the range (Johnsgard, 2002). By the middle of the 20th Century, the population had been reduced to 40,000. Populations were reduced by indiscriminant hunting, by conversion of much of the range to agriculture, especially to grazing by livestock, and by periodic droughts. By 2001, the total population was estimated at 10,000-15,000 breeding birds, with 3,000 each in Texas and Oklahoma, 1,500 in Colorado, 1,000 in New Mexico, and 5,000-10,000 in Kansas (Johnsgard, 2002).

In New Mexico, the lesser prairie-chicken may have had a population of about 125,000 living in a range that encompassed 38,000 km^2, an average density of 3.3 individuals/km^2. The number of birds dropped to 40,000-50,000 by 1961, and to 8,000-10,000 by 1979. Extent of geographic distribution in New Mexico was reduced to about

20% of the original during this time. In 2001, the population in New Mexico was estimated at <1,000 birds during breeding season (Johnsgard, 2002). Declining populations also were evidenced when the ratio of juveniles to adult females at hunter check stations fell from 3.7:1 in the 1960s to 0.59:1 in 1995 (New Mexico Department of Game and Fish, 1999).

A sharp decline in populations in New Mexico beginning in 1989 corresponded to 2 years of drought. Drought often is given as a possible reason for reduction in size of populations of lesser prairie-chickens in New Mexico. Other suggested reasons for this decline include excessive grazing, an increase in production of oil and natural gas, control of sand sage and shinnery oak, and genetic problems associated with small, fragmented populations (Johnsgard, 2002).

Beginning in 1938, the state of New Mexico began accumulation of about 8,500 ha of land to create 18 Prairie-chicken Areas (Hamerstrom and Hamerstrom, 1961). Grazing is prohibited on these areas, which are managed specifically for lesser prairie-chickens. The areas often have been poorly funded and undermanned, and often are subject to invasion by trespassing livestock (New Mexico Department of Game and Fish, 1999).

Lesser prairie-chickens require a minimum area of 10,000 ha to maintain a viable population, and larger areas may be necessary, depending on vegetative composition and landscape pattern. A maximum of 30% of habitat may be cultivated, less if shelterbelts and fencerows with trees are used. Frequent crop rotation also impacts negatively on populations (Bidwell, 2002). In New Mexico, occupied range has not been significantly reduced by conversion to cropland since 1975. Some croplands were retired and planted

in conservation cover crops as part of the Conservation Reserve Program, in the late 1980s. Most of these fields previously were planted in cotton, and so would not have been used by lesser prairie-chickens for winter food (New Mexico Department of Game and Fish, 1999). One study in Yoakum County, Texas, reported greatest numbers of lesser prairie-chickens in areas with =37% of the area planted in sorghum, as long as most of the rest of the area was native rangeland (Crawford and Bolen, 1976*a*). Minimum tillage farming, which leaves residual stubble in fields, provides food and cover for lesser prairie-chickens (Litton et al., 1994).

Retirement of cropland into the Conservation Reserve Program was hoped to have created much new habitat for lesser prairie-chickens, but results have been mixed. Much land in the Conservation Reserve Program has been planted in non-native species that are not suitable nesting cover. Planting native warm-season bunch grasses that are responsive to management with grazing and fire is recommended (Litton et al., 1994).

Drought.—Drought often is cited as a cause for declines in populations of lesser prairie-chickens. Drought reduces amount of forbs available, causes emergence of catkins and leaves of shinnery oak to occur later than usual, and may cause shinnery oak to drop its leaves or fail to produce acorns (Merchant, 1982; Peterson and Boyd, 1988). Drought may force lesser prairie-chickens to delay reproductive displays and breeding, to delay or abstain from nesting or renesting, to use habitat that is less than optimal for nesting, and to increase size of home range during pre-nesting, nesting, and brood-rearing periods. Drought may reduce nesting success dramatically by reducing hatching success, lowering clutch size, or increasing mortality of chicks. Drought conditions may also result in lower body weight, increased predation, and decreased overall survival

(Merchant, 1982). Two years of drought in 1989 and 1990 correspond with the beginning of the current decline in populations in New Mexico (Johnsgard, 2002). However, the next 3 years had above-average precipitation, and populations continued to decline. There was a significant, but weak, correlation between number of lesser prairie-chickens and total precipitation from 2 years previously in the late 1990s. In the long term, fluctuations of populations in New Mexico do not closely follow patterns of precipitation (New Mexico Department of Game and Fish, 1999), and lesser prairie-chickens, which evolved in arid lands (Hubbard, 1973) have rebounded from other severe droughts across their geographic range (Hamerstrom and Hamerstrom, 1961). However, drought may exacerbate population declines from other causes. For example, effects of overgrazing may be worsened by drought conditions (Merchant, 1982).

Population density.—High population densities may increase rates of mortality by forcing dispersal of subordinates, forcing later nesting times for subordinate females, and increasing rates of predation (Schroeder and Baydack, 2001). This is not likely to be a problem in New Mexico, where population densities are relatively low. Instead, populations are subject to phenomena associated with small populations, such as reduced reproduction due to inbreeding depression, and increased effects of density-independent mortality, such as collision with power lines or vehicles, unusual weather events, or predation by generalist predators (New Mexico Department of Game and Fish, 1999). Small, isolated populations, such as those that remain in southeastern New Mexico, also are subject to loss of genetic diversity (Meffe and Carroll, 1994), and to extinction due to interactions between all of these small-population phenomena and lowered genetic diversity (Soulé and Mills, 1998).

Grazing.—Intensive grazing and early burning regimes have been associated with declines in populations of greater prairie-chickens (Robbins et al., 2002). Lesser prairie-chickens are adapted for grasslands that include grazing by large herbivores. Because elk (*Cervus elaphus*) and bison (*Bison bison*) have been extirpated from the geographic range of the lesser prairie-chicken, grazing by livestock may be required to maintain optimum conditions for the bird (Bidwell, 2002). Grazing, in conjunction with fire, is needed to prevent encroachment of woody species, such as eastern red-cedar (*Juniperus virginiana*) and honey mesquite (*Prosopis glandulosa*) from encroaching on grassland habitat (Bidwell, 2002; N. J. Silvy, pers. comm.). However, overgrazing has negative effects on populations of lesser prairie-chickens (Jackson and DeArment, 1963). Abandoned leks in southeastern New Mexico appeared to be associated with high levels of grazing (Johnson and Smith, 1999*b*). Nesting success in one study was negatively correlated with heavy grazing by livestock (Davis et al., 1979). A survey of randomly selected areas within formerly occupied range of the lesser prairie-chicken in New Mexico indicated that 4% of sites were good nesting habitat and 16% were fair. The remaining 80% had poor potential nesting habitat or none, and appeared overgrazed (Bailey et al., 2000).

Grazing by livestock impacts species composition, height, and amount of residual grasses that lesser prairie-chickens rely on to conceal nests (Bidwell, 2002). Grazing also reduces amount of plant litter on the surface of the ground (Tomanek, 1969). Nests are associated with areas of greater accumulation of litter (Wilson, 1982). The optimum grazing regimen for propagation of lesser prairie-chickens consists of uneven patterns of season-long and year-long grazing to create a mosaic of short grass, bare ground, and taller bunches of grass. Diversity of habitats allows easy travel for broods to abundant

seeds and insects with nearby cover for escape from predators (Bidwell, 2002). Grazing levels should be kept at <25% of annual growth, and average height of sand bluestem at >50 cm in areas that are to be used as nesting habitat (Riley et al., 1992).

Grazing by livestock results in higher levels of phenols, which are toxic to livestock, in catkins and leaves of shinnery oak, presumably as a defensive response. Effects of phenols on lesser prairie-chickens are unknown, but they have negative effects on other birds, such as Japanese quail (*Coturnix coturnix*) and domestic chickens (*Gallus gallus*), especially on young birds (Boyd et al., 2001). Effects of overgrazing on lesser prairie-chickens in New Mexico are discussed in Chapter 2.

Fire.—Lesser prairie-chickens occupy habitats with low to moderate densities of shrubs, with most shrubs < 1 m tall. In relatively mesic habitat, sand sage and shinnery oak should be burned about every 5 years to ensure proper height of overstory and amount of bare ground. Optimum cover is 80% grasses and forbs and 20% shrubs, but populations are healthy at densities with almost no shrubs, as long as residual grasses are available for use as nest sites (Bidwell, 2002). In Oklahoma, some food items, such as forbs and grasshoppers, increased after burns, but production of acorns, catkins, and leaves of shinnery oaks and residual cover necessary for successful nesting decreased. In xeric areas such as New Mexico, the shinnery oak community is not as well-adapated for fire. Nesting cover is at a premium, and fire probably should not be used as a tool to increase populations of lesser prairie-chickens (Boyd and Bidwell, 2001).

Oil and gas industry.—Noise caused by exploration for, and extraction of, oil and gas may disrupt reproductive behavior of lesser prairie-chickens. A non-quantitative survey of abandoned leks in southeastern New Mexico reported that 13 of 29 leks had a

moderate or high level of noise (Smith et al., 1998). Results of a comparison of levels of sound at active and abandoned leks are reported in Chapter 6.

Fragmentation.—Conversion of land to agricultural use and development of habitat for urban, suburban, or industrial use results in reduction of areas of unbroken habitat and increases distance between remaining areas. This process is fragmentation (Soulé and Orians, 2001). Fragmentation of habitat may increase risk of predation by forcing birds to nest in less than optimal habitat, increasing travel time through open habitats, and by increasing diversity and numbers of predators (Schroeder and Baydack, 2001). Fragmentation of habitat has been implicated in declines of populations of lesser prairie-chickens (Mote et al., 1999). Analysis of populations in the Oklahoma and Texas panhandles indicated that declines were associated with changes in habitat on several scales. Specifically, declining populations were associated with increase in amount of edge of habitat on smaller scales, with greater percentages of cropland and tree cover, and total landscape change on larger scales, and on smaller largest area of undisturbed habitat on all scales (Fuhlendorf et al., 2002). Effects of fragmentation of habitat on lesser prairie-chickens is discussed in Chapter 3.

Hunting.—Commercial hunting of lesser prairie-chickens was common before 1900, but was ended with the beginning of modern game laws (Jackson and DeArment, 1963). Hunting of the lesser prairie-chicken was first regulated by Kansas in 1861 (Horak, 1985), and by the other states in its range by the early 1900s (Giesen, 1998). Recreational hunting currently is allowed only in Kansas and Texas (Mote et al., 1999). Hunting may have significant effects on local populations, but generally is considered to have small effects compared with predation (Schroeder and Baydack, 2001). However,

one study (Bergerud, 1985) suggested that hunter-caused mortality of most grouse may be somewhat additive. In New Mexico, the lesser prairie-chicken was legally hunted until 1996. Average annual harvest in the 1960s was about 1,000, but this was reduced to 130 in 1979. Hunters took about 4,000 birds in 1987 and 1988, but these numbers declined rapidly (Johnsgard, 2002; New Mexico Department of Game and Fish, 1999). Closing of the hunting season in 1996 did not result in recovery of populations (New Mexico Department of Game and Fish, 1999).

Predation.—Most mortality is a result of some form of predation, either nest predation, predation on juveniles in the first weeks after hatching, or predation on breeding-age birds. Nest success rates are 0-67%. Although they have the potential to greatly affect size of population, it is difficult to obtain accurate information about survival rates of juveniles. Rates of predation on prairie grouse often are seen to be a reflection of quality of habitat. Inferior quality of habitat may increase risk of predation for lesser prairie-chickens unable to locate cover. Degradation of habitat that increases visibility at leks may lead to higher rates of predation during displaying. Destruction of feeding areas may lead to increased predation by causing birds to feed longer in riskier areas, or to travel farther (Schroeder and Baydack, 2001) or by attracting predators in areas where lesser prairie-chickens concentrate feeding efforts (Bidwell, 2002).

There is little information on effects of control of predators on lesser prairie-chickens. Although control of predators has been used successfully in management of populations of grouse in Europe, most instances of its use have involved small, isolated patches of habitat or captive-raised birds (Schroeder and Baydack, 2001). Because of the large variety of potential predators, resulting high cost of control, protected status of

many predators, public attitudes toward control of predators, and lack of information on effects (Messmer et al., 1999), control of predators probably is not a useful tool in management of lesser prairie-chickens in New Mexico under most circumstances (Schroeder and Baydack, 2001).

Power lines.—In eastern New Mexico in the late 1940s and early 1950s, there were anecdotal reports of large numbers of lesser prairie-chickens killed by collisions with newly erected power lines (Ligon, 1951). A study in Oklahoma indicated that 10-12% of lesser prairie-chickens died due to collisions with power lines or fences in low light (Bidwell, 2002), while a study in Kansas reported that about 5% of mortalities were from collisions with power lines (Jamison, 2000). Power lines are discussed further in Chapter 3.

Roads.—Ligon (1951) reported that lesser prairie-chickens were killed by collisions with automobiles. In Texas, roads constructed on or near leks of lesser prairie-chickens may result in abandonment or reduction of attendance at leks (Crawford and Bolen, 1976*b*), but lesser prairie-chickens may use little-used roads as leks (Crawford and Bolen, 1976*b*; Taylor, 1980). Roads contribute to fragmentation of habitat (Meffe and Carroll, 1994). Roads and fragmentation of habitat are discussed in Chapter 3.

Conservation.—The United States Fish and Wildlife Service was petitioned to list the lesser prairie-chicken as threatened in 1995. In 1997, the United States Fish and Wildlife Service began a formal status investigation, and in June 1998, issued a ruling that a listing was warranted but precluded by more seriously threatened species. Following this ruling, a group of federal and state agencies formed the Lesser Prairie-Chicken Interstate Working Group to help evaluate and coordinate management and

conservation activities (Johnsgard, 2002). The Lesser Prairie-Chicken Interstate Working Group works to coordinate conservation efforts between state and federal agencies, to monitor status and trends of populations and habitat, to develop and implement management strategies, and to stimulate education and research (Mote et al., 1999). About 32,000 ha of private lands in New Mexico and Oklahoma were designated for habitat improvement under conservation agreements between landowners and the High Plains Partnership for Species at Risk (Johnsgard, 2002).

In 1997, the New Mexico Department of Game and Fish began a study to determine whether the species merited listing as threatened or endangered within the state. In 1999, despite the recommendation of its Director, the New Mexico Game Commission refused to list the species as threatened, and announced an interim management plan that would delay the listing process for at least 6 years (Johnsgard, 2002; New Mexico Department of Game and Fish, 1999).

Efforts to transplant lesser prairie-chickens into favorable habitat often fail because transplanted birds return to their original home ranges (Ligon, 1961; Oberholser, 1974). A technique that was somewhat successful in establishment of artificial leks of sharp-tailed grouse has been suggested for use in transplanting lesser prairie-chickens (Rodgers, 1992). Areas under consideration for reintroduction of lesser prairie-chickens should be adjacent to currently occupied habitat and should be part of a block of 50 km^2 of suitable range habitat (Mote et al., 1999). Procedures to raise lesser prairie-chickens in captivity have been developed (Coats, 1955), but there have been no successful introductions of such birds into the wild (Giesen, 1998).

Because food usually is not a limiting factor, food plots are unnecessary for healthy populations. However, they may be temporarily helpful for small populations in fragmented habitat. Such plots should be >4 ha, and situated near active leks. If plots are too small, they are quickly overrun by other wildlife, attracting predators and exposing lesser prairie-chickens to disease. Food plots should be in areas without tall trees or power lines, to avoid attracting predators and to reduce risk of collision by lesser prairie-chickens (Bidwell, 2002). Supplemental watering devices might be useful in allowing populations to survive severe droughts (Davis et al., 1979), but such devices also could concentrate predators, spread disease, and cause more harm than good; further research is necessary (Broyles, 1995; Rosenstock et al., 1999).

In recent years, government agencies have promoted the lesser prairie-chicken as a tourist attraction to encourage private landowners to manage their land as habitat (Mote et al., 1999). Several ranches in the Texas Panhandle now conduct lek tours during the breeding season (Godfrey, 2002) and the New Mexico Department of Game and Fish and local ranchers sponsor the annual High Plains Prairie-chicken Festival at Milnesand, New Mexico (Scott, 2002).

LITERATURE CITED

Addison, E. M., and R. C. Anderson. 1969. *Oxyspirura lumsdeni* n. sp. (Nematoda: Thelaziidae) from Tetraonidae in North America. Canadian Journal of Zoology, 47:1223-1227.

Ahlborn, G. G. 1980. Brood-rearing habitat and fall-winter movements of lesser prairie chickens in eastern New Mexico. M.S. thesis, New Mexico State University, Las Cruces, 73 pp.

American Ornithologists Union. 1998. Check-list of North American birds. 7th edition. American Ornithologists Union, Washington, D. C., 829 pp.

Baicich, P. J., and C. J. O. Harrison. 1997. A guide to the nests, eggs, and nestlings of North American Birds. 2nd edition. Academic Press, San Diego, California, 347 pp.

Bailey, F. M. 1928. Birds of New Mexico. New Mexico Department of Game and Fish, [Santa Fe], 807 pp.

Bailey, J. A., J. Klingel, and C. A. Davis. 2000. Status of nesting habitat for lesser prairie-chicken in New Mexico. The Prairie Naturalist, 32:149-156.

Bailey, J. A., and S. O. Williams, III. 2000. Status of the lesser prairie-chicken in New Mexico, 1999. The Prairie Naturalist, 32:157-168.

Bain, M. R., and G. H. Farley. 2002. Display by apparent hybrid prairie-chickens in a zone of geographic overlap. The Condor, 104:683-687.

Beehler, B. M., and M. S. Foster. 1988. Hotshots, hotspots, and female preference in the organization of lek mating systems. The American Naturalist, 131:203-219.

Bent, A. C. 1932. Life histories of North American gallinaceous birds. Bulletin of the United States National Museum, 162:1-490.

Bergerud, A. T. 1985. The additive effect of hunting mortality on the natural mortality rates of grouse. Pp. 345-366 *in* Game harvest management (S. L. Beasom and S. F. Roberson, eds.). Caesar Kleberg Wildlife Research Institute, Kingsville, Texas, 374 pp.

Bergerud, A. T., and M. W. Gratson. 1988. Survival and breeding strategies of grouse. Pp. 473-577 *in* Adaptive strategies and population ecology of northern grouse (A.

T. Bergerud and M. T. Gratson, eds.). University of Minnesota Press, Minneapolis, 2 vols., 809 pp.

Best, T. L., K. Geluso, J. L. Hunt, and L. A. McWilliams. 2003. The lesser prairie chicken (*Tympanuchus pallidicinctus*) in southeastern New Mexico: a population survey. The Texas Journal of Science, 55:225-234.

Bidwell, T. B. (ed.). 2002. Ecology and management of the lesser prairie chicken. Oklahoma Cooperative Extension Service, Oklahoma State University, Stillwater, 15 pp.

Boag, D. A., K. H. McCourt, P. W. Herzog, and J. H. Always. 1979. Population regulation in spruce grouse: a working hypothesis. Canadian Journal of Zoology, 57:2275-2284.

Bouzat, J. L., H. A. Lewin, and K. N. Paige. 1998. The ghost of genetic diversity past: historical DNA analysis of the greater prairie chicken. American Naturalist, 152:1-6.

Boyd, C. S., and T. G. Bidwell. 2001. Influence of prescribed fire on lesser prairie-chicken habitat in shinnery oak communities in western Oklahoma. Wildlife Society Bulletin, 29:938-947.

Boyd, C. S., L. T. Verveire, T. G. Bidwell, and R. L. Lochmiller. 2001. Nutritional quality of shinnery oak buds and catkins in response to burning or herbivory. The Southwestern Naturalist, 46:295-301.

Broyles, B. 1995. Desert wildlife water developments: questioning use in the Southwest. Wildlife Society Bulletin, 23:663-675.

Campbell, H. 1972. A population study of lesser prairie chickens in New Mexico. The Journal of Wildlife Management, 36:689-699.

Cannon, R. W. 1980. Current status and approaches to monitoring populations and habitat of lesser prairie chickens in Oklahoma. M.S. thesis, Oklahoma State University, Stillwater, 62 pp.

Cannon, R. W., and F. L. Knopf. 1979. Lesser prairie chicken responses to range fires at the booming ground. Wildlife Society Bulletin, 7:44-46.

Cannon, R. W., and F. L. Knopf. 1981. Lek numbers as a trend index to prairie grouse populations. The Journal of Wildlife Management, 45:776-778.

Choate, E. A. 1985. The dictionary of American bird names. Revised edition. The Harvard Common Press, Boston, Massachusetts, 226 pp.

Coats, J. 1955. Raising lesser prairie chickens in captivity. Kansas Fish and Game, 13(2):16-20.

Copelin, F. F. 1963. The lesser prairie chicken in Oklahoma. Pittman-Robertson Project Number W-62-R, Oklahoma Wildlife Conservation Department, Technical Bulletin, 6:1-58.

Crawford, J. A. 1974. The effects of land use on lesser prairie chicken populations in West Texas. Ph.D. dissertation, Texas Tech University, Lubbock, 63 pp.

Crawford, J. A. 1978. Morphology and behavior of greater x lesser prairie chicken hybrids. The Southwestern Naturalist, 23:591-596.

Crawford, J. A. 1980. Status, problems, and research needs of the lesser prairie chicken. Pp. 1-7, *in* Proceedings of the prairie grouse symposium, 17-18 September 1980

(P. A. Vohs, Jr. and F. L. Knopf, eds.). Oklahoma State University, Stillwater, 89 pp.

Crawford, J. A., and E. G. Bolen. 1973. Spring use of stock ponds by lesser prairie chickens. The Wilson Bulletin, 85:471-472.

Crawford, J. A., and E. G. Bolen. 1975. Spring lek activity of the lesser prairie chicken in west Texas. The Auk, 92:808-810.

Crawford, J. A., and E. G. Bolen. 1976*a*. Effects of land use on lesser prairie chickens in Texas. The Journal of Wildlife Management, 40:96-104.

Crawford, J. A., and E. G. Bolen. 1976*b*. Effects of lek disturbances on lesser prairie chickens. The Southwestern Naturalist, 21:238-240.

Crawford, J. A., and E. G. Bolen. 1976*c*. Fall diet of lesser prairie chickens in West Texas. The Condor, 78:142-144.

Davis, C. A, T. Z Riley, R. A. Smith, H. R. Suminski, and M. J. Wisdom. 1979. Habitat evaluation of lesser prairie chickens in eastern Chaves County, New Mexico. Department of Fishery and Wildlife Sciences, New Mexico State University, Las Cruces, 141 pp.

De Juana, E. 1994. Family Tetraonidae (grouse). Pp. 376-410, *in* Handbook of birds of the World: New World vultures-guineafowl (J. del Hoyo, A. Elliot, and J. Sargatal, eds.). Lynx Edicions, Barcelona, Spain, 2:1-638.

Edminster, F. C. 1954. American game birds of field and forest: their habits, ecology and management. Charles Scribner's Sons, New York, 490 pp.

Elbroch, M., and E. Marks. 2001. Bird tracks & sign: a guide to North American species. Stackpole Books, Mechanicsburg, Pennsylvania, 456 pp.

Ellsworth, D. L., R. L. Honeycutt, and N. J. Silvy. 1995. Phylogenetic relationships among North American grouse inferred from restriction endonuclease analysis of mitochondrial DNA. The Condor, 97:492-502.

Ellsworth, D. L., R. L. Honeycutt, N. J. Silvy, K. D. Rittenhouse, and M. H. Smith. 1994. Mitochondrial-DNA and nuclear-gene differentiation in North American prairie grouse (genus *Tympanuchus*). The Auk, 111:661-671.

Fisher, H. I. 1951. The avifauna of Niihau Island, Hawaiian Archipelago. The Condor, 53:31-42.

Fuhlendorf, S. D., A. J. W. Woodward, D. M. Leslie, Jr., and J. S. Shackford. 2002. Multi-scale effects of habitat loss and fragmentation on lesser prairie-chicken population of the US Southern Great Plains. Landscape Ecology, 17:627-628.

Giesen, K. M. 1994*a*. Breeding range and population status of lesser prairie-chickens in Colorado. The Prairie Naturalist, 26:175-182.

Giesen, K. M. 1994*b*. Movements and nesting habitat of lesser prairie-chicken hens in Colorado. The Southwestern Naturalist, 39:96-98.

Giesen, K. M. 1998. *Tympanuchus pallidicinctus:* lesser prairie-chicken. The Birds of North America, 364:1-20.

Godfrey, C. D. 2002. The chickens of Canadian. Grouse Partnership News, 3:26-27.

Grange, W. 1940. A comparison of the displays and vocal performances of the greater prairie chicken, lesser prairie chicken, sharp-tailed grouse and sooty grouse. The Passenger Pigeon, 2:127-133.

Hagen, C. A., S. S. Crupper, R. D. Applegate, and R. J. Robel. 2002. Prevalence of Mycoplasma antibodies in lesser prairie-chicken sera. Avian Diseases, 46:708-712.

Hagen, C. A., B. E. Jamison, R. J. Robel, and R. D. Applegate. 2002. Ring-necked pheasant parasitism of lesser prairie-chicken nests in Kansas. The Wilson Bulletin, 114:522-524.

Hamerstrom, F., and F. Hamerstrom. 1961. Status and problems of North American grouse. The Wilson Bulletin, 73:284-294.

Haukos, D. A., and L. M. Smith. 1999. Effects of lek age on age structure and attendance of lesser prairie-chickens (Tympanuchus pallidicinctus). The American Midland Naturalist, 142:415-420.

Hjorth, I. 1970. Reproductive behavior in Tetraonidae, with special reference to males. Viltrevy, Swedish Wildlife, 7:183-596.

Hoffman, D. M. 1963. The lesser prairie chicken in Colorado. The Journal of Wildlife Management, 27:726-732.

Horak, G. J. 1985. Kansas chickens. Kansas Fish and Game Commission, Wildlife Bulletin, 3:1-65.

Howard, H., and A. H. Miller. 1933. Bird remains from cave deposits in New Mexico. The Condor, 35:15-18.

Hubbard, J. P. 1973. Avian evolution in the aridlands of North America. The Living Bird, 12:155-196.

Hubbard, J. P. 1978. Revised check-list of the birds of New Mexico. New Mexico Ornithological Society, Albuquerque, 110 pp.

Hunt, J. L. 1999. Dietary overlap and potential competition among scaled quail, mourning doves, and northern bobwhites in southeastern New Mexico. M.S. thesis, Auburn University, Alabama, 72 pp.

Hunt, J. L., and T. L. Best. 2001*a*. Foods of northern bobwhites (*Colinus virginianus*) in southeastern New Mexico. The Southwestern Naturalist, 46:239-243.

Hunt, J. L., and T. L. Best. 2001*b*. Foods of scaled quail (*Callipepla squamata*) in southeastern New Mexico. The Texas Journal of Science, 32:147-156.

Jackson, A. S., and R. DeArment. 1963. The lesser prairie chicken in the Texas Panhandle. The Journal of Wildlife Management, 27:733-737.

Jamison, B. E. 2000. Lesser prairie chicken chick survival, adult survival, and habitat selection and movements of males in fragmented rangelands of southwestern Kansas. M.S. thesis, Kansas State University, Manhattan, 197 pp.

Jamison, B. E., R. J. Robel, J. S. Pontius, and R. D. Applegate. 2002. Invertebrate biomass: associations with lesser prairie-chicken habitat use and sand sagebrush density in southwestern Kansas. Wildlife Society Bulletin, 30:517-526.

Johnsgard, P. A. 1983. The grouse of the world. University of Nebraska Press, Lincoln, 413 pp.

Johnsgard, P. A. 2002. Grassland grouse and their conservation. Smithsonian Institution Press, Washington, D. C., 157 pp.

Johnson, K., and H. Smith. 1999*a*. Lesser prairie-chicken habitat use on the Sand Ranch and population status in the Caprock Wildlife Habitat Management Area, 1999. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 19 pp.

Johnson, K., and H. Smith. 1999*b*. Survey of the lesser prairie chicken on Bureau of Land Management lands, Carlsbad Resource Area, NM. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 44 pp.

Jones, R. E. 1963. Identification and analysis of lesser and greater prairie chicken habitat. The Journal of Wildlife Management, 27:757-778.

Jones, R. E. 1964. The specific distinctness of the greater and lesser prairie chickens. The Auk, 81:65-73.

Ligon, J. S. 1927. Wild life of New Mexico: its conservation and management. State Game Commission. Department of Game and Fish, Santa Fe, New Mexico, 212 pp.

Ligon, J. S. 1951. Prairie chickens, highways, and power lines. New Mexico Magazine, 29(5):29.

Ligon, J. S. 1961. New Mexico birds and where to find them. The University of New Mexico Press, Albuquerque, 360 pp.

Litton, G., R. L. West, D. F. Dvorak, and G. T. Miller 1994. The lesser prairie chicken and its management in Texas. Texas Parks and Wildlife Department Booklet, N7100-025:1-22.

Madge, S., P. McGowan, and G. M. Kirwan. 2002. Pheasants, partridges, and grouse: a guide to the pheasants, partridges, quails, grouse, guineafowl, buttonquails, and sandgrouse of the world. Princeton University Press, Princeton, New Jersey, 488 pp.

Meffe, G. K., and C. R. Carroll (eds.). 1994. Principles of conservation biology. Sinauer Associates, Inc., Sunderland, Massachusetts, 600 pp.

Merchant, S. S. 1982. Habitat-use, reproductive success, and survival of female lesser prairie chickens in two years of contrasting weather. M.S. thesis, New Mexico State University, Las Cruces, 62 pp.

Messmer, T. A., M. W. Brunson, D. Reiter, and D. G. Hewitt. 1999. United States public attitudes regarding predators and their management to enhance avian recruitment. Wildlife Society Bulletin, 27:75-85.

Mote, K. D., R. D. Applegate, J. A. Bailey, K. E. Giesen, R. Horton, and J. L. Sheppard (eds.). 1999. Assessment and conservation strategy for the lesser prairie-chicken (*Tympanuchus pallidicinctus*). Kansas Department of Wildlife and Parks, Emporia, 51 pp.

New Mexico Department of Game and Fish. 1999. Status and trend of the lesser prairie-chicken in New Mexico and recommendation to the list the species as threatened under the New Mexico Wildlife Conservation Act. New Mexico Department of Game and Fish, Santa Fe, 32 pp.

Oberhoser, H. C. 1974. The bird life of Texas. University of Texas Press, Austin, 530 pp.

Olawsky, C. D. 1987. Effects of shinnery oak control with tebuthiuron on lesser prairie-chicken populations. M.S. thesis, Texas Tech University, Lubbock, 83 pp.

Olawsky, C. D., and L. M. Smith. 1991. Lesser prairie-chicken densities on tebuthiuron-treated and untreated shinnery oak rangelands. Journal of Range Management, 44:364-368.

Peterson, R. S., and C. S. Boyd. 1998. Ecology and management of sand shinnery communities: a literature review. United States Department of Agriculture Forest Service, Rocky Mountain Research Station, General Technical Report, RMRS-GTR-16:1-44.

Phillips, J. B. 1990. Lek behaviour in birds: do displaying males reduce nest predation? Animal Behaviour, 39:555-565.

Ridgway, R. 1873. A new variety of prairie chicken. Bulletin of the Essex Institute, 5:199.

Ridgway, R. 1885. Some emended names of North American birds. Proceedings of the United States National Museum, 8:354-356.

Ridgway, R., and H. Friedmann. 1946. The birds of North and Middle America. Part X. United States National Museum Bulletin, 50:1-484.

Riley, T. Z., C. A. Davis, M. A. Candelaria, and H. R. Suminski. 1994. Lesser prairie-chicken movements and home ranges in New Mexico. The Prairie Naturalist, 26:183-186.

Riley, T. Z., C. A. Davis, M. Ortiz, and M. J. Wisdom. 1992. Vegetative characteristics of successful and unsuccessful nests of lesser prairie chickens. The Journal of Wildlife Management, 56:383-387.

Robbins, M. B., and D. A. Easterla. 1992. Birds of Missouri: their distribution and abundance. University of Missouri Press, Columbia, 399 pp.

Robbins, M. B., A. T. Peterson, and M. A. Ortega-Huerta. 2002. Major negative impacts of early intensive cattle stocking on tallgrass prairies: the case of the greater prairie-chicken (*Tympanuchus cupido*). North American Birds, 56:239-244.

Rodgers, R. D. 1992. A technique for establishing sharp-tailed grouse in unoccupied range. Wildlife Society Bulletin, 20:101-106.

Rodgers, R.D., and M. L. Sexton. 1990. Impacts of extensive chemical control of sand sagebrush on breeding birds. Journal of Soil and Water Conservation, 45:494-497.

Rosenstock, S. S., W. B. Ballard, and J. C. DeVos, Jr. 1999. Viewpoint: benefits and impacts of wildlife water developments. Journal of Range Management, 52:302-311.

Schmidt-Nielsen, K. 1964. Desert animals: physiological problems of heat and water. Oxford University Press, London, United Kingdom, 277 pp.

Schroeder, M. A., and R. K. Baydack. 2001. Predation and the management of prairie grouse. Wildlife Society Bulletin, 29:24-32.

Scott, M. 2002. The first, annual, High Plains Prairie Chicken Festival. Grouse Partnership News, 3:28-29.

Sharpe, R. S. 1968. The evolutionary relationships and comparative behavior of prairie chickens. Ph.D. dissertation, University of Nebraska, Lincoln, 188 pp.

Short, L. L., Jr. 1967. A review of the genera of grouse (Aves, Tetraoninae). American Museum Novitates, 2289:1-39.

Sibley, D. A. 2000. The Sibley guide to birds. Alfred A. Knopf, New York, 544 pp.

Smith, H., K. Johnson, and L. De Lay. 1998. Survey of the lesser prairie chicken on Bureau of Land Management lands, Carlsbad Resource Area, NM, 1998. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, 12 pp.

Smith, R. A. 1979. Fall and winter habitat of lesser prairie chickens in southeastern New Mexico. M.S. thesis, New Mexico State University, Las Cruces, 71 pp.

Snyder, W. A. 1967. Lesser prairie chicken. Pp. 121-128 *in* New Mexico wildlife management. New Mexico Department of Game and Fish, Santa Fe, 250 pp.

Soulé, M. E., and L. S. Mills. 1998. No need to isolate genetics. Science, 282:1658-1659.

Soulé, M. E., and G. H. Orians. 2001. Conservation biology: research priorities for the next decade. Island Press, Washington, D.C., 307 pp.

Stabler, R. M. 1978. *Plasmodium* (*Giovannolaia*) *pedioecetii* from the lesser prairie chicken, *Tympanuchus pallidicinctus*. The Journal of Parasitology, 64:1125-1126.

Sutton Avian Research Center. 2000. Final report, New Mexico lesser prairie-chicken project 2000. George Miksch Sutton Avian Research Center, Bartlesville Oklahoma, 43 pp.

Sutton, G. M. 1968. The natal plumage of the lesser prairie chicken. The Auk, 85:679.

Sutton, G. M. 1977. The lesser prairie chicken's inflatable neck sacs. The Wilson Bulletin, 89:521-522.

Taylor, M. A. 1978. Fall and winter movements and habitat use of lesser prairie chickens. M.S. thesis, Texas Tech University, Lubbock, 52 pp.

Taylor, M. A. 1980. Lesser prairie chicken use of man-made leks. The Southwestern Naturalist, 24:706-707.

Taylor, M. A., and F. S. Guthery. 1980*a*. Dispersal of a lesser prairie chicken (*Tympanuchus pallidicinctus*). The Southwestern Naturalist, 24:124-125.

Taylor, M. A., and F. S. Guthery. 1980*b*. Status, ecology, and management of the lesser prairie chicken. United States Department of Agriculture Forest Service, General Technical Report, RM-77:1-15.

Thompson, M. C., and C. Ely. 1989. Birds in Kansas. University of Kansas, Museum of Natural History, Lawrence, 1:1-404 pp.

Tomanek, G. W. 1969. Dynamics of mulch layer in grassland ecosystems. Colorado State University Range Science Series, 2:225-240.

Vance, D. R., and R. L. Westemeier. 1979. Interactions of pheasants and prairie chickens in Illinois. Wildlife Society Bulletin, 7:221-225.

Van den Bussche, R. A., S. R. Hoofer, D. A. Wiedenfeld, D. H. Wolfe, and S. K. Sherrod. 2003. Genetic variation within and among fragmented populations of lesser prairie-chickens (*Tympanuchus pallidicinctus*). Molecular Ecology, 12:675-683.

Wetmore, A. 1932. Additional records of birds from cavern deposits in New Mexico. The Condor, 34:141-142.

Wiedenfeld, D. A., D. H. Wolfe, J. E. Toepfer, L. M. Mechlin, R. D. Applegate, and S. K. Sherrod. 2002. Survey for reticuloendotheliosis viruses in wild populations of greater and lesser prairie chickens. The Wilson Bulletin, 114:142-144.

Wiens, J. A. 1991. The ecology of desert birds. Pp. 278-310 *in* The ecology of desert communities (G. A. Polis, ed.). The University of Arizona Press, Tucson, 456 pp.

Wilson, D. L. 1982. Nesting habitat of lesser prairie chickens in Roosevelt and Lea counties, New Mexico. M. S. thesis, New Mexico State University, Las Cruces, 36 pp.

Wood, D. S., and G. D. Schnell. 1984. Distributions of Oklahoma birds. University of Oklahoma Press, Norman, 209 pp.

CHAPTER 2

VEGETATIVE CHARACTERISTICS OF ACTIVE AND ABANDONED LEKS OF LESSER PRAIRIE-CHICKENS (*Tympanuchus pallidicinctus*) IN SOUTHEASTERN NEW MEXICO

ABSTRACT

Populations of lesser prairie-chickens (*Tympanuchus pallidicinctus*) have declined sharply across the geographic range of the species, including southeastern New Mexico. Several possible causes for this decline have been suggested, including overgrazing by livestock. To test this hypothesis, several vegetative characters of active and abandoned leks of lesser prairie-chickens were measured using the line-point sampling method. Vegetative cover and composition of active leks and associated control points were significantly different from those of abandoned leks and control points in all 3 years of the study. Active leks and control points had significantly more *Andropogon* and less *Sporobolus* than did abandoned leks and control points. Abandoned leks were more likely to be near *Prosopis* >60 cm in height than were active leks. Vegetative structure as measured by the Robel method was not significantly different for active and abandoned leks. Results are symptomatic of overgrazing, which is detrimental to populations of lesser prairie-chickens. Reduction of grazing levels will be necessary if populations are to be reestablished in the study area.

INTRODUCTION

Animals depend on plants for food, cover, and shelter (Solomon et al., 1999). Because of their strongly vegetarian diets, the relationship between grouse and vegetation in their habitats is especially close (De Juana, 1994). For example, the lesser prairie-

chicken (*Tympanuchus pallidicinctus*) occurs only in habitat that contains shinnery oak (*Quercus havardii*) or sand sage (*Artemesia filifolia*—Johnsgard, 2002). It depends on shrubs, forbs, and grasses for food, shelter, cover against predators, and camouflage and shelter for nests (Bidwell, 2002; Copelin, 1963; Davis et al., 1979). Change in composition and structure of plant communities has negative impacts on many species of birds (Cox, 1997), including lesser prairie-chickens (Fuhlendorf et al., 2002).

Range-wide declines in populations of lesser prairie-chickens have been well documented. Populations have declined up to 97% since the 1800s (Taylor and Guthery, 1980*c*). The lesser prairie-chicken originally inhabited rangelands of Texas, New Mexico, Oklahoma, Kansas, Colorado, and Nebraska. Although fragmented populations still exist in all of these states except Nebraska, the area occupied by the species has been reduced by 92% (Giesen, 1998). A similar decline in populations has occurred in southeastern New Mexico. Surveys in the 1980s and 1990s suggested that the lesser prairie-chicken had nearly disappeared from central Eddy and Lea counties, New Mexico. These populations persisted into the mid-1990s (Johnson and Smith, 1999*c*). Reasons for declines in populations of lesser prairie-chickens are not well understood. Suggested causes include drought, conversion of habitat to agricultural use, improper grazing management, chemical control of shinnery oak, hunting, and disturbance caused by petroleum development (Giesen, 1998; Johnson and Smith, 1999*c*; New Mexico Department of Game and Fish, 1999; Peterson and Boyd, 1998).

Conversion of suitable habitat to cropland has been implicated in the decline of several species of grouse in North America (De Juana, 1994; Schroeder and Robb, 1993; Westemeier et al., 1998), including the lesser prairie-chicken (Giesen, 1998; Johnsgard,

2002). However, land-use patterns within the habitat of lesser prairie-chickens in southeastern New Mexico have remained relatively stable (New Mexico Department of Game and Fish, 1999). Perhaps of greater importance to populations in southeastern New Mexico are changes in habitat associated with grazing by livestock. Anecdotal evidence indicates that abandoned breeding display areas, or leks, east of Carlsbad seemed to be associated with areas of overgrazing (Johnson and Smith, 1999*c*). Overgrazing by livestock has detrimental impacts upon rangelands by altering species composition, vegetative structure, and overall density of plants (Fleischner, 1994; Heady and Child, 1994). Lesser prairie-chickens have greater nesting success in areas with taller cover of grasses (Riley et al., 1992), suggesting that overgrazing by livestock may be detrimental to populations of lesser prairie-chickens. Effects of grazing on breeding behavior are not known. Because males return to the same lek year after year (Campbell, 1972; Copelin, 1963), modification of vegetative composition of lek sites by livestock could lead to smaller populations of lesser prairie-chickens if reproductive success is affected or if there is greater exposure to predators.

An indirect effect of grazing by livestock is destruction of shinnery oak. Shinnery oak is sometimes toxic to livestock (Peterson and Boyd, 1998). Since 1974, large tracts of shinnery oak in New Mexico have been treated with tebuthiuron, which kills shinnery oak after 2-3 years (Jones and Petit, 1984). Shinnery oak communities are a favored habitat of lesser prairie-chickens (Giesen, 1998). Although diversity of grasses increases after removal of shinnery oak, body mass (Peterson and Boyd, 1998) and size of populations of lesser prairie-chickens may decline (Martin, 1990).

In New Mexico, honey mesquite (*Prosopis glandulosa*) may be an indicator of overgrazing by livestock (Clements, 1920). Invasion by shrubs has been cited as a possible cause for declines in populations of Attwater's prairie-chicken (*Tympanuchus cupido attwateri*) and lesser prairie-chickens (New Mexico Department of Game and Fish, 1999). Shrubs may act as perches or camouflage for predators, and cause abandonment of leks. It is possible that a similar situation could occur with lesser prairie-chickens (N. J. Silvy, pers. comm.).

Objectives of this study were to evaluate height and composition of vegetation, including shinnery oak and honey mesquite, and to compare historically and currently active leks and control sites. Differences in vegetation that correspond to overgrazing may be evidence that populations of lesser prairie-chickens have been negatively impacted by overgrazing.

MATERIALS AND METHODS

The study site was located in Eddy, Lea, Chaves, and Roosevelt counties in southeastern New Mexico, and contains about 303,750 ha (750,000 acres) of shinnery oak, which is a primary habitat component of the lesser prairie-chicken (Peterson and Boyd, 1998). With the exception of some refuges specifically set aside for lesser prairie-chickens, most of the shinnery oak community is grazed by livestock throughout the year under a variety of grazing-management schemes. Some of the area has been treated with tebuthiuron to control shinnery oak. Oil and gas development is scattered throughout the shinnery oak community, with some areas of high concentration of development. The study area contains areas where lesser prairie-chickens have remained present with some fluctuation in size of populations, and other areas in which populations have disappeared

(Best, 2001; Best et al., 2003; Johnson and Smith, 1999*a,* 1999*b*, 1999*c*; Smith et al., 1998).

Lesser prairie-chickens use a breeding system in which males display at leks for females. A lek is an area where males set up and defend territories on which they perform elaborate mating displays (Johnsgard, 2002). Females come to leks to choose a male with which to mate, then build a nest usually within 1.2-3.4 km (0.7-2.0 miles) of the lek (Giesen, 1998). Individual males usually return to the same lek year after year, so lek sites are fairly permanent (Johnsgard, 2002). Females raise broods usually within 2 km (1.2 miles) of the lek (Giesen, 1994; Ahlborn, 1980). Because leks are central to the life history of grouse, they are traditionally used as a focus for studies.

In 2001, 60 active or previously active leks were selected and located with assistance of personnel from the Bureau of Land Management and New Mexico Department of Game and Fish. Status of leks as active or abandoned was determined through extensive surveys of leks during each of 3 years of the study. All leks determined to be active during 2003 were assumed to have been active in all 3 years.

Because vegetative characteristics may change from year to year (Heady and Child, 1994), measurements were taken for each of 3 years (2001-2003). Vegetative cover and composition were measured at 33 active and 27 historically active leks, using the line-point sampling method described by Bonham (1989) and Johnson and Smith (1999*a*). A control plot was established 300 m (1,000 feet) from the center of each of the leks. At the center of each of the 60 leks and each of the 60 control plots, 4 100-m (330-foot) transects were conducted in four directions. Vegetation was identified to genus and recorded at 1-m intervals along each transect. This resulted in 400 data points for each

lek and 400 for each control plot, for a total of 48,000 data points. Surveys were repeated in 2002 and 2003. Percentage cover of each genus of plant, bare ground, and plant litter were computed, and percentages were transformed into log-ratios by taking natural logarithm of percentage divided by percentage of *Artemesia* (Aebischer and Robertson, 1992; Aitchison, 1986). *Artemesia* was selected because of its low occurrence in most surveys of leks. Percentages of *Artemeisa* were compared using Student's *t*-tests (Green et al., 1997) to ensure that use as a divisor would not impact results of statistical procuedures, and no significant difference was found in any year between leks and controls or between active and abandoned leks, or between controls of active and abandoned leks (all $P = 0.173$). Vegetative composition was computed by deleting bare ground and litter from consideration and re-computing percentages and log-ratios. Vegetative cover and composition were compared at active and historically active leks, and at control plots, using discriminant-function analyses with associated ANOVAs. No more than 12 variables were used in discriminant-function analyses to maintain the minimum recommended 5:1 ratio of observations to variables (Hair et al., 1998). Discriminant-function analyses were cross-validated using the leave-one-out protocol of SPSS 10.0 (Green et al., 1997). Presence or absence of honey mesquite >60 cm (24 inches) in height within 200 m (660 feet) of the center of the lek was recorded for each lek, and a comparison of active and historical leks was made using a chi-square test (Gould and Gould, 2002).

Vegetative structure was measured using the Robel visual-obstruction method (Robel et al., 1970). The Robel value thus obtained often is used as a measure of intensity of grazing by livestock, with lower values indicating high usage, and is

recommended for evaluation of habitat of lesser prairie-chickens (Mote et al., 1999). The Robel measurement device (Robel pole) is a pole marked off in 2.54 cm (1-inch) increments. To begin each transect, 10 steps were taken from a central point. The measurement pole was placed in the ground at the point where the toe of the boot was placed on the 10th step. Four readings of the Robel pole were taken in a circle around the pole, from a distance of 4 m (158 inches) and a height of 1 m (39 inches). The four readings were averaged to give a value for each point; the procedure was repeated 25 times and values were averaged to give a value for each transect. Two more transects were conducted at 120° angles from the first, beginning at the original point of origin; the three values obtained were averaged to give an overall Robel value for the pasture. Robel visual-obstruction values were taken in pastures where leks occurred, but away from leks to avoid changes in vegetative structure caused by lesser prairie-chickens themselves. Only one Robel procedure was conducted for multiple leks located in a single pasture, because grazing pressures were assumed to be relatively equal throughout a particular pasture. This resulted in completion of 31 Robel procedures, with 300 data points in each one, for a total of 9,300 data points each year. In addition, some data from Robel procedures conducted on lands administered by the Roswell Field Office were obtained from personnel of the Bureau of Land Management. Robel values in pastures containing active leks and in pastures containing historically active leks, but no active leks, were compared using Student's *t*-tests (Green et al., 1997).

RESULTS

Vegetative cover of leks and control plots were determined (Table 1, Appendix 1). According to results of discriminant-function analyses, vegetative cover of leks

differed from that of controls in 2001 (Wilks' ? = 0.262, $P < 0.001$), 2002 (Wilks' ? = 0.791, $P = 0.001$), and 2003 (Wilks' ? = 0.794, $P = 0.012$). According to structure matrices of discriminant-function analyses, bare ground was the most important determinant of differences in 2001 and 2002, and *Gutierrezia* was the most important determinant in 2003.

Discriminant-function analyses indicated that vegetative cover of active leks in 2001 was significantly different from that of abandoned leks (Table 2—Wilks' ? = 0.262, $P < 0.001$). According to the structure matrix, most important variables in determining difference in cover between active and abandoned leks in 2001, in decreasing order of importance, were *Sporobolus, Muhlenbergia, Andropogon, Gutierrezia,* and *Bouteloua.* Vegetative cover of active leks in 2002 was significantly different from that of abandoned leks (Table 2—Wilks' ? = 0.337, $P < 0.001$). Most important variables in determining difference in cover between active and abandoned leks in 2002 were *Andropogon, Gutierrezia, Muhlenbergia, Bouteloua,* and *Sporobolus*. Vegetative cover of active leks in 2003 was significantly different from that of abandoned leks (Table 2—Wilks' ? = 0.373, $P < 0.001$). Most important variables in determining difference between cover of active and abandoned leks in 2003 were *Eriogonum, Andropogon, Muhlenbergia,* and *Gutierrezia.*

Discriminant-function analyses indicated that vegetative cover of control points of active leks in 2001 was significantly different from that of control points of abandoned leks (Table 2—Wilks' ? = 0.272, $P < 0.001$). Most important variables in determining difference between cover of control points of active and abandoned leks in 2001 were *Andropogon, Sporobolus, Muhlenbergia, Gutierrezia,* and *Bouteloua.* Vegetative cover

of control points of active leks in 2002 was significantly different from control points of abandoned leks (Table 2—Wilks' ? = 0.330, $P < 0.001$). Most important variables in determining difference between cover of control points of active and abandoned leks in 2002 were *Muhlenbergia, Andropogon, Bouteloua,* and *Gutierrezia.* Vegetative cover of contol points of active leks in 2003 was significantly different from that of control points of abandoned leks (Table 2—Wilks' ? = 0.324, $P < 0.001$). Most important variables in determining difference between cover of control points of active and abandoned leks in 2003 were *Muhlenbergia, Eriogonum, Andropogon,* and *Gutierrezia.*

Vegetative compositions of leks and control plots were determined (Table 3, Appendix 1). Discriminant-function analysis indicated that vegetative composition of leks and control plots was not significantly different in 2001 (Wilks' ? = 0.843, $P = 0.086$), 2002 (Wilks' ? = 0.844, $P = 0.088$) or 2003 (Wilks' ? = 0.396, $P = 0.892$).

Vegetative composition of active leks was significantly different from that of abandoned leks in 2001 (Table 4—Wilks' ? = 0.272, $P < 0.001$). Most important variables in determining this difference during 2001 were *Sporobolus, Muhlenbergia, Gutierrezia, Andropogon,* and *Bouteloua.* Vegetative composition of active leks was significantly different from that of abandoned leks in 2002 (Table 4—Wilks' ? = 0.364, $P < 0.001$). Most important variables in making this determination were *Gutierrezia, Andropogon, Muhlenbergia,* and *Bouteloua.* Vegetative composition of active leks also was significantly different from that of abandoned leks in 2003 (Table 4—Wilks' ? = 0.352, $P < 0.001$). Most important variables in determining this difference were *Eriogonum, Muhlenbergia, Andropogon,* and *Gutierrezia.*

Vegetative composition of control points of active leks was significantly different from that of control points of abandoned leks in 2001 (Table 4—Wilks' ? = 0.312, $P < 0.001$). Most important variables in determining difference in composition between controls of active and abandoned leks in 2001 were *Sporobolus, Muhlenbergia, Andropogon, Gutierrezia,* and *Bouteloua.* Differences in composition of control points of active and abandoned leks also were significant in 2002 (Table 4—Wilks' ? = 0.352, $P < 0.001$). Most important variables in determining these differences in 2002 were *Muhlenbergia, Andropogon,* and *Bouteloua.* Vegetative composition of control points of active leks was significantly different from that of control points of abandoned leks in 2003 (Table 4—Wilks' ? = 0.393, $P < 0.001$). Most important variables in this determination were *Muhlenbergia, Eriogonum, Andropogon,* and *Gutierrezia.*

Presence or absence of *Prosopis* = 60 cm (24 inches) in height was observed at each lek, and active and abandoned leks were compared. Thirty of 39 abandoned leks (76.9%) were associated with large *Prosopis*, while 9 of 33 active leks (27.3%) had large *Prosopis*. This difference was significant ($?^2 = 8.122$, $P < 0.01$).

Robel values (Appendix I) for pastures containing active leks and those containing only abandoned leks were compared. In 2001, the Robel index in pastures that contained active leks was greater than that in pastures that did not contain an active lek ($t = 3.294$, $P = 0.002$). In 2002 and 2003, there was no significant difference between pastures with active leks and those without an active lek (2002—$t = 0.173$, $P = 0.864$; 2003—$t = 2.128$, $P = 0.051$).

DISCUSSION

Habitat of the lesser prairie-chicken consists of a combination of shinnery oak, sand sage, sand dropseed (*Sporobolus cryptandrus*), sand bluestem (*Andropogon hallii*), little bluestem (*A. scorparium*), a variety of forbs, including spectacle pod (*Dithyrea wislizenii*) and annual buckwheat (*Eriogonum annuum*), and in some cases, honey mesquite and broom snakeweed (*Gutierrezia sarothrae*). Use of this habitat by lesser prairie-chickens has been well documented (Davis et al., 1979; Giesen, 1998; Peterson and Boyd, 1998; Sell, 1979; Taylor, 1978; Taylor and Guthery, 1980*b,* 1980*c*). This habitat has been used for grazing by livestock since the mid-1800s (Beck, 1962).

Excessive grazing by livestock often has been suggested as a possible cause for declines in populations of prairie grouse, including lesser prairie-chickens (Jackson and DeArment, 1963; Johnsgard, 2002), but no study has established a correlation between overgrazing and these declines in southeastern New Mexico. This study demonstrates a link between reduction in numbers of lesser prairie-chickens in southeastern New Mexico and vegetative characteristics associated with overgrazing.

Reproductive display, mating, and nesting of lesser prairie-chickens occur in late winter and early spring (Davis et al., 1979) before the beginning of plant growth in spring. This means that residual grasses from the previous growing season are vital to provide cover for escape from predators and for nesting (Davis et al., 1979; Giesen, 1994). Height of residual grasses is important. Females build nests in areas with greater height of grasses than surrounding areas (Giesen, 1994), and nests in tall vegetation are more likely to be successful than those in shorter vegetation (Riley et al., 1992). However, the present study did not demonstrate a difference between height of vegetation

in pastures that contained active leks and those that did not. This does not mean that height of grasses was not an important factor in decline of lesser prairie-chickens, but instead, may be due to the fact that some of the abandoned leks had been inactive for a number of years before the study began. Height of residual grasses changes from year to year due to differences in grazing regimes and rainfall patterns. For example, precipitation totals for 2001 were low across the study area (NOAA, 2001). In the southern part of the study area, where there was a lesser amount of residual vegetation from 2000 (Appendix 1), ranchers were forced to remove livestock from pastures (J. S. Sherman, pers. comm.). Rainfall in late summer 2001 (NOAA, 2001) resulted in some growth of grass. In southern areas, where livestock had been removed, this growth was reflected in greater Robel values in these areas in 2002. Livestock remaining in the northern part of the study area kept Robel values lower there. Because amount of residual vegetation is changeable from year to year, use of the Robel procedure in studies such as this one, which attempts to explain events that happened several years previously, was not particularly useful. The Robel procedure, however, would be useful to monitor residual vegetation on a year-to-year basis in areas where populations of lesser prairie-chickens remain, and data gathered in this study may be used as a starting point for such monitoring.

Vegetative cover of leks was different from that of control points in the same pasture each of the 3 years. According to structure matrices of discriminant-function analyses, the difference was mostly due to differences in amount of bare ground. However, direction of this difference was not consistent from year to year. In 2001, there was more bare ground on leks than at control points, but in the other 2 years, the situation

was reversed. This is surprising because displaying activities of males would be expected to increase amount of bare ground on active leks. Display of lesser prairie-chickens includes a great deal of foot-stamping (Grange, 1940), and flutter-jumps of males often end on any plant left on the lek (Sharpe, 1968). These activities were expected to increase amount of bare ground on leks compared to control points. The common selection of abandoned oil well drill pads and little-used roads as lek sites (Crawford and Bolen, 1976; Taylor, 1980) also was expected to increase amount of bare ground at leks compared to control points. However, ANOVAs conducted concurrently with discriminant-function analyses indicated no significant difference in amount of bare ground at leks and control points in any of the 3 years. Results were the same, even when bare ground and litter were combined for consideration. In fact, these ANOVAs indicated no significant difference in any year between any tested variables. Analysis of vegetational information indicates that vegetative composition is not involved in choice of lek sites. Instead, sites probably are chosen to allow for maximum visibility (Davis et al., 1979) and for proximity to suitable nesting and brood-rearing habitat (Bergerud and Gratson, 1988).

Vegetative composition was computed to eliminate expected effects of activities of lesser prairie-chickens on vegetation at leks. Because results of analyses of vegetative cover and vegetative composition were similar, only vegetative composition will be discussed here. Vegetative composition of active and abandoned leks, and of their corresponding control points, was different among years, but patterns of composition were not different among years. Active leks and pastures in which they occurred had greater percentage composition of *Andropogon, Bouteloua,* and *Gutierrezia*, and lower

percentage composition of *Sporobolus, Muhlenbergia,* and *Eriogonum,* than did abandoned leks and their corresponding pastures, although not all of these variables contributed equally to overall annual differences. Most striking are differences in percentage composition of *Andropogon* and *Sporobolus*. Active leks had >5 times as much *Andropogon* as did abandoned leks. *Andropogon* grows in thick clumps that often have a slightly open spot at the center. These clumps are ideal nesting cover for ground-nesting birds such as lesser prairie-chickens. Lesser prairie-chickens preferentially select *Andropogon* as nest sites, and nesting success is much greater for those that select *Andropogon* (Davis et al., 1979; Riley et al., 1992). *Sporobolus* grows in clumps that are not as thick as those of *Andropogon* (Powell, 1994). Nests placed in *Sporobolus* would be much more visible to predators than those placed in *Andropogon* (Davis et al., 1979).

Andropogon is better forage for livestock than is *Sporobolus* (Vallentine, 1989); it is highly palatable, and is selected by livestock over other grasses. *Sporobolus*, while consumed by livestock, is not selected preferentially, and its value as forage declines rapidly as it matures (Stubbendieck et al., 1997). Under heavy grazing, amount of *Andropogon* decreases and *Sporobolus* increases (Ross and Bailey, 1967; Stubbendieck et al., 1997), thus *Sporobolus* is considered an indicator of overgrazing (Stubbendieck et al., 1997). Relative amounts of the two grasses indicate that abandoned leks are more likely to be in areas of heavy grazing than are active leks. *Andropogon* also is less well adapted for areas of poor, sandy soil, while *Sporobolus* is well adapted for such soils (Ross and Bailey, 1967; Stubbendieck et al., 1997). Quality of soil at abandoned leks often is poor (Chug et al., 1971; Lenfesty 1983; Ross and Bailey, 1967; Turner et al.,

1974). Poor soils will not support high levels of grazing by livestock (Ross and Bailey, 1967).

Percentage cover of *Gutierrezia* was greater on active leks than on abandoned leks, but it also was greater on leks than on controls. This suggests that greater levels of *Gutierrezia* may be a result of activities of lesser prairie-chickens. *Gutierrezia* is associated with disturbances such as grazing (Bowers, 1993; Dick-Peddie, 1993), and is an indicator of overgrazing (Stubbendieck et al., 1997). I believe that in this case, however, disturbance caused by the foot-stamping of displaying male lesser prairie-chickens probably has a greater role than overgrazing in creating patterns of occurrence of *Gutierrezia* on leks. Grazing is no heavier at leks than at controls; if increased occurrence of *Gutierrezia* was caused by grazing, percentage cover should be the same at leks and controls. Conversely, *Eriogonum* occurred in about equal percentages at leks and controls, but was more common at abandoned leks than at active leks. *Eriogonum* also is an indicator of overgrazing (Clements, 1920).

Percentage composition of *Prosopis* was not significantly greater for abandoned leks than for active leks, but large *Prosopis* were more likely to be found at abandoned leks than at active leks. *Prosopis* can be spread by livestock (Heady, 1975; Kneuper et al., 2003; Kramp et al., 1998) and is an indicator of overgrazing (Clements, 1920). *Prosopis* or other tall plants nearby may cause abandonment of leks (N. J. Silvy, pers. comm.).

Shinnery oak is important as brood-rearing cover (Davis et al., 1979) and as a source of food (Davis et al., 1979; Oberholser 1974). Lesser prairie-chickens preferentially spend time in areas with greater concentrations of shinnery oak (Sutton

Avian Research Center, 2000), and there is such a close relationship with shinnery oak that they sometimes are considered to be ecological partners (Johnsgard, 2002). However, shinnery oak is considered a pest plant by ranchers, it sometimes is toxic to livestock, and it is believed to compete with grasses used as forage by livestock (Peterson and Boyd, 1998). Some control of shinnery oak has occurred on the study site, but treatments ceased in the early 1990s (J. S. Sherman, pers. comm.). Because shinnery oak grows slowly (Peterson and Boyd, 1998), differences in percentage cover of shinnery oak would be apparent for many years after removal. However, there was no significant difference in percentage composition of shinnery oak at abandoned or active leks, or in pastures that contained them. Lack of difference in percentage cover of shinnery oak between abandoned and active leks indicates that control of shinnery oak probably has not contributed to decline in populations of lesser prairie-chickens in southeastern New Mexico. This should not be construed to mean that removal of shinnery oak in areas where populations currently exist would have no adverse effects. Lesser prairie-chickens living in areas of treatment with tebuthiuron consumed more foliage and less insects and acorns, resulting in differences in morphology of the small intestine, cecum, and gizzard necessary to process a lower quality, more fibrous diet. Lesser prairie-chickens in treated areas had lower body weight and smaller fat reserves than did those in untreated areas (Olawsky, 1987).

Abandoned leks in the study area were associated with plants that usually were recognized as symptoms of overgrazing. Recent sightings of lesser prairie-chickens in areas where breeding populations no longer exist (T. L. Best, pers. comm.) indicate that there is some movement back into the area. For example, several individuals were

observed on the Hat Mesa in southwestern Lea County in 2004 (S. Belinda and T. L. Best, pers. comm.), where none were found during breeding surveys. Some consideration has been given to reintroduction of lesser prairie-chickens into the study area. However, when birds are reintroduced or naturally return to the area, they will be unable to maintain a viable population as long as the area is overgrazed. If breeding populations are to become reestablished in eastern Eddy and southern Lea counties, it is essential that excessive grazing is eliminated or reduced in large enough areas to provide adequate breeding territories.

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LITERATURE CITED

Aebischer, N. J., and P. A. Robertson. 1992. Practical aspects of compositional analysis as applied to pheasant habitat utilization. Pp. 285-293 *in* Wildlife telemetry: remote monitoring and tracking of animals (I. G. Pride and S. M. Swift, eds.). Ellis Horwood, New York, 708 pp.

Ahlborn, G. G. 1980. Brood-rearing habitat and fall-winter movements of lesser prairie chickens in eastern New Mexico. M.S. thesis, New Mexico State University, Las Cruces, 73 pp.

Aitchison, J. 1986. The statistical analysis of compositional data. Chapman and Hall, London, United Kingdom, 416 pp.

Beck, W. A. 1962. New Mexico: a history of four centuries. University of Oklahoma Press, Norman, 363 pp.

Bergerud, A. T., and M. W. Gratson. 1988. Survival and breeding strategies of grouse. Pp. 473-577 *in* Adaptive strategies and population ecology of northern grouse (A. T. Bergerud and M. T. Gratson, eds.). University of Minnesota Press, Minneapolis, 2 vols., 809 pp.

Best, T. L. 2001. Status of the lesser prairie chicken (*Tympanuchus pallidicinctus*) on lands administered by the Bureau of Land Management in southeastern New Mexico. Oil and Gas Consortium, Artesia, New Mexico, 517 pp.

Best, T. L., K. Geluso, J. L. Hunt, and L. A. McWilliams. 2003. The lesser prairie chicken (*Tympanuchus pallidicinctus*) in southeastern New Mexico: a population survey. The Texas Journal of Science, 55:225-234.

Bidwell, T. B. (ed.). 2002. Ecology and management of the lesser prairie chicken. Oklahoma Cooperative Extension Service, Oklahoma State University, Stillwater, 15 pp.

Bonham, C. D. 1989. Measurements for terrestrial vegetation. John Wiley & Sons, New York, 338 pp.

Bowers, J. E. 1993. Shrubs and trees of the Southwest deserts. Southwest Monuments and Parks Association, Tucson, Arizona, 140 pp.

Campbell, H. 1972. A population study of lesser prairie chickens in New Mexico. The Journal of Wildlife Management, 36:689-699.

Chug, J. C., G. W. Anderson, D. L. King, and L. H. Jones. 1971. Soil survey of Eddy area, New Mexico. United States Department of Agriculture, Soil Conservation Service, Washington, D. C., 82 pp.

Clements, F. E. 1920. Plant indicators: the relation of plant communities to process and practice. Carnegie Institution of Washington, Washington, D.C., 388 pp.

Copelin, F. F. 1963. The lesser prairie chicken in Oklahoma. Oklahoma Wildlife Conservation Department, Technical Bulletin, 6:1-58.

Cox, G. W. 1997. Conservation biology: concepts and applications. 2nd edition. Wm. C. Brown Publishers, Dubuque, Iowa, 362 pp.

Crawford, J. A., and E. G. Bolen. 1976. Effects of lek disturbances on lesser prairie chickens. The Southewestern Naturalist, 21:238-240.

Davis, C. A., T. Z. Riley, R. A. Smith, H. R. Suminski, and D. M. Wisdom. 1979. Final report: habitat evaluation of lesser prairie-chickens in eastern Chaves County, New Mexico. Department of Fish and Wildlife Sciences, New Mexico Agricultural Experiment Station, Las Cruces, 141 pp.

De Juana, E. 1994. Family Tetraonidae (grouse). Pp. 376-410, *in* Handbook of birds of the World: New World vultures-guineafowl (J. del Hoyo, A. Elliot, and J. Sargatal, eds.). Lynx Edicions, Barcelona, Spain, 2:1-638.

Dick-Peddie, W. A. 1993. New Mexico vegetation: past, present, and future. University of New Mexico Press, Albuquerque, 244 pp.

Fleischner, T. L. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology, 8:629-644.

Fuhlendorf, S. D., A. J. W. Woodward, D. M. Leslie, Jr., and J. S. Shackford. 2002. Multi-scale effects of habitat loss and fragmentation on lesser prairie-chicken population of the US Southern Great Plains. Landscape Ecology, 17:627-628.

Giesen, K. M. 1994. Movements and nesting habitat of lesser prairie-chicken hens in Colorado. The Southwestern Naturalist, 39:96-98.

Giesen, K. M. 1998. *Tympanuchus pallidicinctus:* lesser prairie chicken. The Birds of North America, 364:1-19.

Gould, J. L., and G. F. Gould. 2002. Biostats basics: a student handbook. W. H. Freeman and Company, New York, 422 pp.

Grange, W. 1940. A comparison of the displays and vocal performances of the greater prairie chicken, lesser prairie chicken, sharp-tailed grouse and sooty grouse. The Passenger Pigeon, 2:127-133.

Green, S. B., N. J. Salkind, and T. M. Akey. 1997. Using SPSS for Windows. Prentice Hall, Upper Saddle River, New Jersey, 494 pp.

Hair, J. F., Jr., R. E. Anderson, R. L. Tatham, and W. C. Black. 1998. Multivariate data analysis. Fifth edition. Prentice Hall, Upper Saddle River, New Jersey, 730 pp.

Heady, H. F. 1975. Rangeland management. McGraw-Hill, New York, 460 pp.

Heady, H. F., and R. D. Child. 1994. Rangeland ecology and management. Westview Press, Boulder, Colorado, 519 pp.

Jackson, A. S., and R. DeArment. 1963. The lesser prairie chicken in the Texas Panhandle. The Journal of Wildlife Management, 27:733-737.

Johnsgard, P. A. 2002. Grassland grouse and their conservation. Smithsonian Institution Press, Washington, D.C.,157 pp.

Johnson, K., and H. Smith. 1999*a*. Lesser prairie-chicken habitat use on the Sand Ranch and population status in the Caprock Wildlife Habitat Management Area, 1999. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 19 pp.

Johnson, K., and H. Smith. 1999*b*. Lesser prairie-chicken surveys on New Mexico Department of Game and Fish prairie-chicken management areas. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 65 pp.

Johnson, K., and H. Smith. 1999*c*. Survey of the lesser prairie-chicken on Bureau of Land Management lands, Carlsbad Resources Area, NM, 1999. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 44 pp.

Jones, V. E., and R. D. Petit. 1984. Low rates of tebuthiuron for control of sand shinnery oak. Journal of Range Management, 37:488-490.

Kneuper, C. L., C. B. Scott, and W. E. Pinchak. 2003. Consumption and dispersion of mesquite seeds by ruminants. Journal of Range Management, 56:255-259.

Kramp, B. A., R. J. Ansley, and T. R. Tunnell. 1998. Survival of mesquite seedlings emerging from cattle and wildlife feces in a semi-arid grassland. The Southwestern Naturalist, 43:300-312.

Lenfesty, C. D. 1983. Soil survey of Chaves County, New Mexico, northern part. United States Department of Agriculture, Soil Conservation Service, Washington, D. C., 224 pp.

Martin, B. H. 1990. Avian and vegetation research in the shinnery oak ecosystem of southeastern New Mexico. M.S. thesis, New Mexico State University, Las Cruces, 116 pp.

Mote, K. D., R. D. Applegate, J. A. Bailey, K. E. Giesen, R. Horton, and J. L. Sheppard, technical editors. 1999. Assessment and conservation strategy for the lesser prairie-chicken (*Tympanuchus pallidicinctus*). Kansas Department of Wildlife and Parks, Emporia, 51 pp.

New Mexico Department of Game and Fish. 1999. Status and trend of the lesser prairie-chicken in New Mexico and recommendation to list the species as threatened under the New Mexico Conservation Act. New Mexico Department of Game and Fish, Santa Fe, 32 pp.

NOAA. 2001. Climatological data (monthly temperature and precipitation data for New Mexico). United States Department of Commerce, National Oceanic and Atmospheric Administration Environmental Data Service, National Climatic Center, Asheville, North Carolina, volume 105.

Oberhoser, H. C. 1974. The bird life of Texas. University of Texas Press, Austin, Texas, 530 pp.

Olawsky, C. D. 1987. Effects of shinnery oak control with tebuthiuron on lesser prairie-chicken populations. M.S. thesis, Texas Tech University, Lubbock, 83 pp.

Peterson, R. S., and C. S. Boyd. 1998. Ecology and management of sand shinnery communities: a literature review. United States Department of Agriculture Forest Service, Rocky Mountain Research Station, General Technical Report, RMRS-GTR-16:1-44.

Powell, A. M. 1994. Grasses of the Trans-Pecos and adjacent areas. University of Texas Press, Austin, 377 pp.

Riley, T. Z., C. A. Davis, M. Ortiz, and M. J. Wisdom. 1992. Vegetative characteristics of successful and unsuccessful nests of lesser prairie chickens. The Journal of Wildlife Management, 56:383-387.

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

Ross, W. J., and O. F. Bailey. 1967. Soil survey of Roosevelt County, New Mexico. United States Department of Agriculture, Soil Conservation Service, Washington, D. C., 74pp.

Schroeder, M. A., and L. A. Robb. 1993. Greater prairie-chicken (*Tympanuchus cupido*). The Birds of North America, 36:1-24.

Sell, D.L. 1979. Spring and summer movements and habitat use by lesser prairie chicken females in Yoakum County, Texas. M.S. thesis, Texas Tech University, Lubbock, 42 pp.

Sharpe, R. S. 1968. The evolutionary relationships and comparative behavior of prairie chickens. Ph.D. dissertation, University of Nebraska, Lincoln, 188 pp.

Solomon, E. P., L. R. Berg, and D. W. Martin. 1999. Biology. 5th edition. Saunders College Publishing, Fort Worth, Texas, 1232 pp.

Smith, H., K. Johnson, and L. DeLay. 1998. Survey of lesser prairie chicken on Bureau of Land Management lands, Carlsbad Resource Area, NM 1998. New Mexico

Natural Heritage Program, Department of Biology, University of New Mexico, 12 pp.

Stubbendieck, J., S. L. Hatch, and C. H. Butterfield. 1997. North American range plants. 5th edition. University of Nebraska Press, Lincoln, 501 pp.

Sutton Avian Research Center. 2000. Final report, New Mexico lesser prairie-chicken project 2000. George Miksch Sutton Avian Research Center, Bartlesville Oklahoma, 43 pp.

Taylor, M. A. 1978. Fall and winter habitat use of lesser prairie chickens. M.S. thesis, Texas Tech University, Lubbock, 52 pp.

Taylor, M. A. 1980. Lesser prairie chicken use of man-made leks. The Southwestern Naturalist, 24:706-707.

Taylor, M. A., and F. S. Guthery. 1980*a*. Dispersal of a lesser prairie chicken (*Tympanuchus pallidicinctus*). The Southwestern Naturalist, 24:124-125.

Taylor, M. A., and F. S. Guthery. 1980*b*. Fall-winter movements, ranges, and habitat uses of lesser prairie chickens. The Journal of Wildlife Management, 44:521-524.

Taylor, M. A., and F. S. Guthery. 1980*c*. Status, ecology, and management of the lesser prairie chicken. United States Department of Agriculture Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report, RM-77:1-15.

Turner, M. T., D. N. Cox, B. C. Mickelson, A. J. Roath, and C. D. Wilson. 1974. Soil survey of Lea County, New Mexico. United States Department of Agriculture, Soil Conservation Service, Washington, D.C., 89 pp.

Vallentine, J. F. 1989. Range development and improvments. 3rd Edition. Academic Press, San Diego, California, 524 pp.

Westemeier, R. L., J. D. Brawn, S. A. Simpson, T. L. Esker, R. W. Jansen, J. W. Walk, E. L. Kershner, J. L. Bouzat, and K. N. Paige. 1998. Tracking the long-term decline and recovery of an isolated population. Science, 282:1695-1698.

Table 1.—Percentage vegetative cover of leks of lesser prairie-chickens (*Tympanuchus pallidicinctus*) and associated control points in southeastern New Mexico, Winter 2001-2003.

	2001		2002		2003	
Plant	Lek	Control	Lek	Control	Lek	Control
Andropogon	7.9	10.3	13.1	1.9	16.8	3.8
Aristida	4.5	6.0	4.5	4.5	6.9	5.1
Artemesia	0.5	0.8	0.5	0.4	0.7	0.9
Bouteloua	8.2	7.2	11.6	4.4	9.3	5.0
Eriogonum	0.5	0.5	0.4	0.7	0.5	0.5
Gutierrezia	3.1	1.6	4.9	1.9	2.8	0.5
Muhlenbergia	1.5	2.1	<0.1	3.2	<0.1	4.2
Prosopis	0.8	0.6	0.6	1.0	0.8	0.4
Quercus	8.3	9.2	8.2	8.4	9.9	8.4
Sporobolus	2.2	1.6	<0.1	4.8	<0.1	3.1
Yucca	2.3	2.8	2.9	1.7	3.3	2.3
Bare	41.1	31.8	34.9	48.1	22.9	40.8
Litter	17.1	24.1	16.4	17.9	24.5	23.8
Other[a]	2.0	1.4	1.8	1.1	1.4	1.2

[a]Includes *Amaranthus, Ambrosia, Croton, Euphorbia, Helianthus, Mentzelia, Munroa, Opuntia, Panicum, Paspalum, Salsola, Senecio,* and unidentified plants.

Table 2.—Percentage of vegetative cover of active and abandoned leks of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in southeastern New Mexico.

	Active			Abandoned		
Plant	(*n*)	Lek	Control	(*n*)	Lek	Control
Andropogon						
2001	32	13.1	17.2	28	1.9	2.4
2002	33	10.7	14.8	27	1.7	2.4
2003	33	9.3	13.0	27	1.4	1.8
Aristida						
2001	32	4.5	6.6	28	4.5	5.2
2002	33	4.6	5.8	27	4.5	5.1
2003	33	3.8	4.2	27	4.4	5.2
Artemesia						
2001	32	0.5	0.7	28	0.4	0.9
2002	33	0.5	0.7	27	0.6	1.2
2003	33	0.7	0.7	27	0.6	1.0
Bouteloua						
2001	32	11.6	9.1	28	4.4	5.0
2002	33	7.2	5.5	27	4.5	3.4
2003	33	7.8	4.4	27	3.9	3.6
Eriogonum						
2001	32	0.4	0.5	28	0.7	0.5
2002	33	1.0	1.5	27	1.5	1.9
2003	33	0.1	0.1	27	3.4	3.7
Gutierrezia						
2001	32	4.9	2.7	28	1.1	0.4
2002	33	6.5	3.5	27	1.6	0.6
2003	33	5.3	2.9	27	1.2	0.5
Muhlenbergia						
2001	32	<0.1	<0.1	28	3.2	4.5
2002	33	0.1	<0.1	27	2.4	3.5
2003	33	0.2	0.3	27	3.1	3.8

Table 2. Continued.

Panicum						
2001	32	0.3	0.6	28	0.1	0.2
2002	33	0.3	0.3	27	0.1	<0.1
2003	33	0.2	0.1	27	<0.1	<0.1
Prosopis						
2001	32	0.6	0.7	28	1.0	0.4
2002	33	0.5	0.8	27	1.3	0.5
2003	33	0.5	0.8	27	1.1	0.5
Quercus						
2001	32	8.2	10.2	28	8.4	8.0
2002	33	8.2	11.0	27	7.3	8.8
2003	33	7.7	11.8	27	6.3	8.1
Sporobolus						
2001	32	<0.1	<0.1	28	4.8	3.3
2002	33	0.9	1.2	27	7.0	5.8
2003	33	2.0	1.7	27	6.4	5.9
Yucca						
2001	32	2.9	3.4	28	1.7	2.1
2002	33	2.9	3.5	27	2.0	2.0
2003	33	2.9	3.7	27	1.5	1.8
Bare						
2001	32	34.9	22.3	28	48.1	42.7
2002	33	26.6	16.8	27	37.1	31.7
2003	33	35.6	25.9	27	38.7	32.7
Litter						
2001	32	16.4	24.8	28	17.9	23.4
2002	33	28.8	33.6	27	26.5	31.7
2003	33	23.1	29.8	27	26.0	30.0
Other[a]						
2001	32	1.5	1.0	28	1.8	1.0
2002	33	1.2	0.9	27	1.9	1.7
2003	33	0.8	0.6	27	1.9	1.3

[a]Includes *Amaranthus, Ambrosia, Croton, Euphorbia, Helianthus, Mentzelia, Munroa, Opuntia, Paspalum, Salsola, Senecio,* and unidentified plants.

Table 3.—Percentage vegetative composition (bare ground and litter removed) of leks of lesser prairie-chickens (*Tympanuchus pallidicinctus*) and associated control points in southeastern New Mexico, Winter 2001-2003.

	2001		2002		2003	
Plant	Lek	Control	Lek	Control	Lek	Control
Andropogon	17.2	20.0	14.8	18.7	14.1	17.8
Aristida	11.1	13.3	11.4	12.5	10.3	11.2
Artemesia	1.2	2.2	1.5	2.3	1.6	2.1
Bouteloua	15.6	13.3	12.3	8.9	14.8	9.8
Eriogonum	1.3	1.3	3.4	4.1	4.6	4.2
Gutierrezia	7.2	3.1	9.8	4.5	8.9	4.5
Muhlenbergia	4.7	6.5	3.2	4.2	3.9	4.9
Prosopis	2.1	1.4	2.3	1.6	2.3	1.7
Quercus	22.6	23.3	20.3	24.3	19.0	25.3
Senecio	0.8	0.2	1.1	1.3	1.2	1.0
Sporobolus	6.2	5.4	10.0	8.5	10.4	8.9
Yucca	5.7	6.7	6.3	6.6	6.0	7.0
Other[a]	4.3	3.3	3.6	2.5	2.9	1.6

[a]Includes *Amaranthus, Ambrosia, Croton, Euphorbia, Helianthus, Mentzelia, Munroa, Opuntia, Panicum, Paspalum, Salsola,* and unidentified plants.

Table 4.—Percentage of vegetative composition (bare ground and litter removed) of active and abandoned leks of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in southeastern New Mexico.

	Active			Abandoned		
Plant	(*n*)	Lek	Control	(*n*)	Lek	Control
Andropogon						
2001	32	27.5	32.7	28	5.4	5.5
2002	33	23.6	29.2	27	4.2	6.0
2003	33	22.1	28.4	27	4.3	4.9
Aristida						
2001	32	9.1	12.1	28	13.4	14.7
2002	33	10.7	11.7	27	12.3	13.5
2003	33	9.1	9.4	27	11.7	13.4
Artemesia						
2001	32	1.1	1.3	28	1.3	3.4
2002	33	1.3	1.2	27	1.7	3.6
2003	33	1.7	1.5	27	1.5	2.8
Bouteloua						
2001	32	21.4	16.0	28	9.0	10.2
2002	33	15.2	10.4	27	8.7	7.1
2003	33	18.1	9.7	27	10.7	10.1
Eriogonum						
2001	32	0.7	0.9	28	2.0	1.7
2002	33	2.5	3.1	27	4.4	5.4
2003	33	0.4	0.2	27	9.9	9.0
Gutierrezia						
2001	32	10.0	5.0	28	3.1	1.0
2002	33	14.7	7.1	27	3.9	1.4
2003	33	13.3	6.9	27	3.5	1.4
Helianthus						
2001	32	0.1	0.1	28	0.3	0.2
2002	33	0.3	0.2	27	0.1	0.1
2003	33	<0.1	0.1	27	0.5	0.3

Table 4. Continued.

Muhlenbergia						
2001	32	0.1	<0.1	28	9.9	13.9
2002	33	0.3	0.1	27	6.6	9.2
2003	33	0.5	0.8	27	8.0	9.8
Panicum						
2001	32	0.5	1.2	28	0.4	0.5
2002	33	0.6	0.6	27	0.3	<0.6
2003	33	0.4	0.2	27	0.1	0.1
Prosopis						
2001	32	1.0	1.2	28	4.3	1.7
2002	33	1.0	1.5	27	3.9	1.7
2003	33	1.4	1.9	27	3.4	1.6
Quercus						
2001	32	18.2	21.2	28	27.6	25.8
2002	33	19.2	23.5	27	21.7	25.2
2003	33	19.3	27.9	27	18.6	22.2
Senecio						
2001	32	0.8	0.2	28	0.9	0.2
2002	33	0.9	1.2	27	1.3	1.4
2003	33	0.1	0.2	27	2.4	1.8
Sporobolus						
2001	32	<0.1	0.1	28	13.2	11.4
2002	33	1.9	2.3	27	19.8	16.0
2003	33	4.7	3.4	27	17.5	15.8
Yucca						
2001	32	5.8	6.4	28	5.7	7.0
2002	33	6.3	7.3	27	6.3	5.7
2003	33	7.1	8.6	27	4.7	4.9
Other[a]						
2001	32	2.0	1.5	28	3.5	2.8
2002	33	1.5	0.6	27	1.1	3.1
2003	33	1.7	0.8	27	3.2	1.9

[a]Includes *Amaranthus, Ambrosia, Croton, Euphorbia, Mentzelia, Munroa, Opuntia, Paspalum, Salsola,* and unidentified plants.

CHAPTER 3

RELATIONSHIP BETWEEN PETROLEUM DEVELOPMENT AND DECLINE IN POPULATIONS OF LESSER PRAIRIE-CHICKENS (*Tympanuchus pallidicinctus*) IN SOUTHEASTERN NEW MEXICO

ABSTRACT

Populations of lesser prairie-chickens (*Tympanuchus pallidicinctus*) have declined sharply across the geographic range of the species, including southeastern New Mexico. Several possible causes for this decline have been suggested, including effects of petroleum development. To test this hypothesis, several aspects of petroleum development were measured at active and abandoned leks, including number of active and inactive oil wells within 1.6 km (1 mile), presence or absence of power lines, and length of road within 1.6 km (1 mile). Abandoned leks had more active wells, more total wells, and greater length of road than active leks, and were more likely than active leks to be near power lines. Effects on lesser prairie-chickens may include increased mortality due to collision with power lines, increased disturbance due to increased presence of humans, destruction of habitat due to installation of roads and drill pads, and fragmentation of habitat. Petroleum development at intensive levels probably is not compatible with populations of lesser prairie-chickens.

INTRODUCTION

Declines in populations of lesser prairie-chickens (*Tympanuchus pallidicinctus*) have been well documented across the range of this species. Populations may have declined 97% since the 1800s (Taylor and Guthery, 1980). The lesser prairie-chicken originally inhabited rangelands of Texas, New Mexico, Oklahoma, Kansas, Colorado, and Nebraska. Although populations still exist in all of these states except Nebraska, the geographic range occupied by

the species has been reduced by 92% (Giesen, 1998). A similar decline has occurred in southeastern New Mexico. Surveys suggest that the lesser prairie-chicken has nearly disappeared from breeding leks first documented in Eddy and southern Lea counties, New Mexico, in the mid-1980s (Best et al., 2003; Johnson and Smith, 1999*c*).

Lesser prairie-chickens use a breeding system in which males display at leks for females. A lek is an area where males set up and defend territories on which they perform elaborate mating displays (Johnsgard, 2002). Females come to the leks to choose a male with which to mate, then build a nest usually within 1.2-3.4 km (0.7-2.0 miles) of the lek (Giesen, 1998). Individual males usually return to the same lek year after year, so lek sites are fairly permanent (Johnsgard, 2002). Females raise broods usually within 2 km (1.2 miles) of the lek (Giesen, 1994; Ahlborn, 1980).

Reasons for decline in populations of lesser prairie-chickens are not well understood. Suggested causes include drought, conversion of habitat to agricultural use, improper grazing management, chemical control of shinnery oak (*Quercus havardii*), hunting, and disturbance caused by petroleum development, which includes exploration for and extraction of oil and natural gas (Giesen, 1998; Johnson and Smith, 1999*c*; New Mexico Department of Game and Fish, 1999; Peterson and Boyd, 1998). Of the postulated reasons for declines in populations, most do not represent changes that have occurred in southeastern New Mexico. For example, hunting often is cited as a possible cause for these declines, but there is no evidence that harvest by hunters results in additive mortality, and hunting of lesser prairie-chickens has been prohibited in New Mexico since 1996 (Giesen, 1998; Johnsgard, 2002). Conversion of rangeland for agricultural use usually is implicated in declines in other areas (Johnsgard, 2002; Woodward et al., 2001), but the amount of such conversion has been small in southeastern New

Mexico (New Mexico Game and Fish, 1999). Overgrazing by livestock often is suggested as a possible reason for declines in populations of prairie grouse (Johnsgard, 2002), including lesser prairie-chickens (Jackson and DeArment, 1963; Davis et al., 1979). A study conducted concurrently with the present study found a correlation between symptoms of overgrazing and abandonment of leks of lesser prairie-chickens (Chapter 2). However, southeastern New Mexico has been heavily grazed since the second half of the 19th Century (Beck, 1962), and it seems unlikely that grazing alone has caused the severe declines in populations observed in the past 25 years.

Much of the area formerly and presently occupied by lesser prairie-chickens in southeastern New Mexico is heavily used for petroleum development. Although oil and natural gas production has occurred in southeastern New Mexico since the 1920s (Rundell, 1982), a dramatic increase in such activity has occurred in the past 20 years. Although amount of petroleum produced in New Mexico has remained fairly constant, number of new wells drilled in eastern New Mexico each year also has remained constant (American Petroleum Institute, 1984, 1987, 1998; United States Bureau of the Census, 1990; United States Census Bureau 2003). Average number of active wells within 1.6 km (1 mile) of leks included in this study increased from 3.4 in 1980 to 6.5 in 2003 (Bureau of Land Management files). These activities require destruction of significant amounts of habitat, installation of a large number of pumpjacks and other equipment, erection of an extensive network of power lines, and construction and use of a substantial number of roads (Weller et al., 2002). Each of these could have negative effects on lesser prairie-chickens. Drilling for oil and natural gas requires construction of drill pads, each of which consumes ca. 1.6 ha (4 acres) of habitat (Oliva, 2002). A producing oil well usually has a pumpjack that can be 10 m (33 feet) tall, and other equipment may be even taller (Berger and

Anderson, 1981). Such objects in the habitat could be used as perches by predators. One group of researchers noted that several abandoned leks were near new drilling operations (Johnson and Smith, 1999*c*; Smith et al., 1998). However, no study has been conducted to determine whether there is a correlation between petroleum development and decline in populations of lesser prairie-chickens.

Studies of changes in behavior of animals due to petroleum development have been conducted in the Arctic. A study of behavior of caribou (*Rangifer tarandus*) in Alaska revealed that pipelines and associated roads changed patterns of movement compared to controls (Curatolo and Murphy, 1986). Caribou sometimes used inactive drill pads as refuges from mosquitoes and botflies (Noel et al., 1998; Pollard et al., 1996). Bradshaw et al. (1997, 1998) reported that frequent loud noise associated with production of oil could cause differences in rates of movement and loss of body mass in caribou. Caribou may move calving grounds to less productive sites in response to petroleum development (Cameron et al., 1992; Nellemann and Cameron, 1996). Blix and Lentfer (1992) concluded that noise and vibration caused by exploration for oil and subsequent drilling and transport did not disturb denning polar bears (*Ursus maritimus*). Amstrub (1993) also reported that polar bears were highly tolerant of such disturbances.

Studies of effects of petroleum development on reproductive behavior of birds also have produced mixed results. Truett et al. (1997) reported no change in distribution, abundance, or reproduction of brants (*Branta bernicula*) or snow geese (*Chen caerulescens*) that could be attributed to oil-field development. Lutz (1979) reported that reproductive success of Attwater's prairie-chickens in areas used for petroleum extraction was not different from areas where no extraction was occurring; in fact, prairie-chickens used drill pads and roads for leks. Crawford

and Bolen (1976) and Taylor (1980) reported that many leks of lesser prairie-chickens in a study in the Texas Panhandle were abandoned drill pads or little-used roads. Lyon and Anderson (2003) reported that natural gas development had a negative impact on breeding behavior of sage grouse (*Centrocercus urophasianus*). Females captured on leks within 3.2 km (2 miles) of natural gas development had lower rates of initiation of nesting than females from leks >3.2 km (2 miles) from such development. Braun et al. (2002) concluded that petroleum development had negative effects on sage grouse (*C. urophasianus* and *C. minimus*) and other birds in Wyoming, Colorado, and Alberta.

Many pumpjacks are operated by electric motors, so that an increase in petroleum development results in increase in amount of power lines in the area. Some studies have shown that grouse are susceptible to mortality due to collisions with power lines (Bevanger, 1995), and there is evidence that lesser prairie-chickens in New Mexico may be subject to such mortality (Ligon, 1951). A study in Oklahoma indicated that 10-12% of lesser prairie-chickens died due to collisions with power lines or fences in low light (Bidwell 2002). Such mortality usually is considered compensatory, but may contribute to declines in population in endangered populations (Bevanger, 1998).

The increase in petroleum development in southeastern New Mexico has been accompanied by construction of an extensive network of roads. Roads may act as barriers to movement of animals, resulting in fragmentation of habitat (Meffe and Carroll, 1994), but no study has been conducted to evaluate effects of roads on lesser prairie-chickens. Fragmentation due to destruction of habitat and construction of roads has been suggested as a reason for declines in populations of the sage grouse (*Centrocercus urophasianus*) over portions of its range (Braun, 1998; Weller et al., 2002). Such fragmentation could impact populations of lesser

prairie-chickens (Mote et al., 1999). A study of lesser prairie-chickens in Oklahoma and Texas indicated that declining populations were associated with many of the effects of fragmentation of habitat (Fuhlendorf et al., 2002). Fragmentation is only one possible negative ecological effect of roads on habitat of wildlife. Other effects include mortality from collision with vehicles, modification of animal behavior, alteration of the physical and chemical environment, spread of exotic species, and increased use of areas by humans (Trombulak and Frissell, 2000).

The purpose of this study was to investigate the relationship between petroleum development and decline in populations of lesser prairie-chickens in southeastern New Mexico. It is postulated that if oil wells, power lines, or roads are detrimental to lesser prairie-chickens, then active leks should be in areas with lower densities of these installations than abandoned leks.

MATERIALS AND METHODS

The study site is located in Eddy, Lea, Chaves, and Roosevelt counties in southeastern New Mexico, and contains about 303,750 ha (750,000 acres) of shinnery oak, which is a primary habitat component of the lesser prairie-chicken in this region (Peterson and Boyd, 1998). Petroleum development is scattered throughout the shinnery oak community, with some areas of high concentration of development. The study area contains areas where populations of lesser prairie-chickens have remained present with some fluctuation in size of population, and other areas in which populations have disappeared (Best et al., 2003; Johnson and Smith, 1999*a*, 1999*b*, 1999*c*; Smith et al., 1998).

A comparison was made of amount of petroleum development near active and abandoned leks. Historical data on drilling of oil and gas wells were obtained by examination of Individual Well Records in files of the Bureau of Land Management. Location and date of drilling were

obtained for each well within 1.6 km (1 mile) of each historically active lek. Numbers of active and inactive oil wells within 1.6 km (1 mile) of currently and historically active leks during the last year of use by lesser prairie-chickens were compared using Student's *t*-tests (Green et al., 1997).

Each lek was evaluated for presence or absence of power lines within 800 m (2,600 feet) of center of lek. Presence or absence of power lines on active and abandoned leks was compared using a chi-square test (Gould and Gould, 2002).

To test the hypothesis that roads are detrimental to lesser prairie-chickens, Geographic Information Systems (GIS) was used to compare density of roads within a 1.6-km (1 mile) radius of active and abandoned leks of lesser prairie-chickens in southeastern New Mexico. The Bureau of Land Management and the New Mexico Department of Game and Fish have annually monitored status of leks in the study area since the mid-1980s. Forty-one active and 32 abandoned leks were selected and located with assistance of personnel from the Bureau of Land Management and New Mexico Department of Game and Fish. Location of leks was determined with a hand-held locator (Garmin International, Olathe, KS) using the Global Positioning System and entered into a GIS coverage map.

Data for roads were obtained from Digital Orthophoto Quarter Quad maps produced by the United States Geological Survey from aerial photographs made in 1996. For each of the selected leks, a buffer was created that extended 1.6 km (1 mile) from center of lek. Roads that fell within this circle were digitized from the Digital Orthophoto Quarter Quad maps into a GIS coverage using ArcView 3.2 (ESRI, Inc., Redlands, CA) at a scale of 1:10,000. No attempt was made to differentiate intensity of use of various roads; all roads, from seldom-used pipeline roads to four-lane paved roads were treated equally. Length of road within each circle was computed

with the GIS program. Buffers were then created at distances of 31 m (100 feet) and 152 m (500 feet) from roads. Distances were chosen to allow comparisons with earlier research on impact of roads in habitat of sage grouse (Weller et al., 2002) and were assumed to be conservative estimates of extent of effects caused by roads (Forman, 2000). Length of road and percentage of each circle within the two buffers was computed for each lek. Length of road within active and inactive leks was compared using Student's *t*-tests with SPSS 10.0 for Windows (Green et al., 1997). Because four comparisons were made, a Bonferroni adjustment was applied to statistical tests, resulting in an adjusted a value of 0.012 (Hair et al., 1998).

RESULTS

Average number of active wells near active leks was 1, while average number of active wells within 1.6 km (1 mile) of abandoned leks during their last active year was 8. This difference was significant ($t = 3.845$, $P < 0.001$). Average total number of wells near active leks was 7, while average total number of wells within 1.6 km (1 mile) of abandoned leks during their last active year was 15. This difference also was significant ($t = 3.363$, $P = 0.001$).

Eighteen of 40 abandoned leks (45%) were within 800 m (2,600 feet) of at least one power line, while only 1 of 33 active leks (3%) was near a power line. This difference was significant ($?^2 = 14.383$, $P < 0.01$).

Abandoned leks had a significantly greater length of road within 1.6 km (1 mile) than did active leks (Student's *t*-test, $t = 3.132$, $P = 0.003$—Table 1). Expressed another way, abandoned leks had an average of 26.7 km (16.0 miles) of road and density of roads of 3.3 km/km^2 (5.1 miles/miles^2). Active leks had an average of 20.0 km (12.0 miles) of road and density of roads of 2.4 km/km^2 (3.7 miles/miles^2). Abandoned leks had a greater proportion of area within 1.6 km (1 mile) that was within 31 m (100 feet) and 152 m (500 feet) of roads than did active leks.

DISCUSSION

One way in which habitat of lesser prairie-chickens has changed in southeastern New Mexico is increase in exploration for, and extraction of, oil and natural gas. This has necessitated installation of hundreds of pumpjacks, many of which operate electrically. Oil fields often are characterized by extensive networks of power lines and poles (Newton, 1960). Power lines are an important source of mortality for many birds (Bevanger, 1998; Faanes, 1987; McNeil et al., 1985), especially grouse (Berell, 1939; Bevanger, 1995, 1998; Leopold, 1931; Silvy, 1968). Lesser prairie-chickens are known to suffer mortality due to collision with power lines (Bidwell, 2002; Ligon, 1951). Birds with high wing loading, such as grouse, are unable to effectively navigate around power lines, especially multiple power line sets that include a ground wire (Bevanger, 1998; Faanes, 1987; Janss, 2000). When flushed, lesser prairie-chickens fly toward the horizon. It is possible that if they are using the horizon as a landmark, they may mistake power lines for the horizon, and fly directly into them (J. L. Hunt and T. L. Best, pers. obs.). Although deaths due to collisions with power lines usually are considered compensatory, they may be additive in small or endangered populations (Bevanger, 1998). Nearly half of abandoned leks in this study were associated with power lines, while only one active lek was within 800 m (2,600 feet) of a power line.

Trombulak and Frissell (2000) listed several possible effects of roads on wildlife. Some of these effects may have little impact on populations of lesser prairie-chickens in southeastern New Mexico. For example, death due to collision with vehicles, although it does occur (Ligon, 1951), probably does not make a major contribution to mortality of lesser prairie-chickens. Other effects are more likely to impact lesser prairie-chickens. Roads may cause alteration of the physical and chemical environment, and removal of usable area from the habitat (Spellerberg,

2002). Roads lead to increased use of habitat by humans, with resulting noise and visual disturbance (Trombulak and Frissell, 2000; Chapter 6). Use of roads by humans may cause changes in behavior of animals (Lyon, 1979; Trombulak and Frissell, 2000). Female greater sage grouse (*Centrocercus urophasianus*) traveled twice as far to nest sites and were less likely to initiate a nest when they mated at a lek <3 km (1.8 mile) from a road with traffic disturbance as low as 1-12 vehicles/day (Lyon and Anderson, 2003). Increases in volume of traffic on roads in Colorado decreased attendance at leks by male greater sage grouse (Braun, 1986).

In this study, density of roads within 1.6 km (1 mile) of abandoned leks was significantly greater than that of active leks. Density of roads = 0.3 km/km^2 (0.5 miles/miles^2) causes avoidance behavior in some animals, such as elk (*Cervus elaphus*—Lyon, 1979). In areas with sparse vegetative cover, habitat may be rendered completely useless for large animals at density of roads >0.5 km/km^2 (0.8 miles/miles^2—Lyon, 1979). Abandoned leks in the present study had density of roads of 3.3 km/km^2 (5.1 miles/miles^2), nearly twice the national average, and roughly comparable to the density of roads in New York state (Forman et al., 2003).

Roads may also facilitate movement of animals harmful to lesser prairie-chickens. Coyotes (*Canis latrans*) often use roads to move through sandy habitat in New Mexico, and other predators, such as bobcats (*Lynx rufus*) and pumas (*Puma concolor*), use roads (Forman et al., 2003). Livestock also use roads to walk through difficult terrain (Forman et al., 2003; Heady and Child, 1994). Livestock tend to graze alongside roads (Heady and Child, 1994), creating what appear to be wide swaths of overgrazed habitat. These swaths occur on both sides of roads and do not appear to be associated more with north-south roads than east-west roads, and so are not caused by erosion due to wind (J. L. Hunt, pers. obs.).

Another effect of roads is fragmentation of habitat (Forman et al., 2003). Fragmentation of habitat has been implicated in declines of lesser prairie-chickens in Oklahoma (Fuhlendorf et al., 2002). Fragmentation may increase predation by forcing lesser prairie-chickens into less-protected habitat or by increasing travel time through such habitats (Schroeder and Baydack, 2001). Fragmentation increases edge effects, which are associated with declining populations of lesser prairie-chickens in Oklahoma (Fuhlendorf et al., 2002).

One possible result of fragmentation of habitat is loss of genetic diversity. As small populations become isolated, inbreeding depression can lead to reduced genetic diversity, fitness, and fecundity, especially in species that are poor dispersers (Meffe and Carroll, 1994; Westemeier et al., 1998). The lesser prairie-chicken is such a species (de Juana, 1994; Madge et al., 2002). Although movement of >40 km (24 miles) has been reported (Jamison, 2000), most movements are <7 km (4 miles—Madge et al., 2002). The problem of low ability to disperse may be compounded by the lek-based breeding system used by lesser prairie-chickens. Most breeding at any particular lek is done by one dominant male (Sharpe, 1968). Females may visit more than one lek during a breeding season, but copulate only once (Johnsgard, 2002). An individual male may be the dominant breeding male of more than one lek. This would tend to spread better genes through a healthy population, but could result in reduction in genetic diversity when small populations are isolated by fragmentation of habitat. However, a comparison of genetic diversity between the stable population in Roosevelt County, New Mexico, and declining populations in Oklahoma found no major difference in amount of genetic diversity between populations (Van den Bussche et al., 2003).

Analysis of populations of lesser prairie-chickens in the Oklahoma and Texas panhandles indicated that declines were associated with changes in habitat on several scales. Specifically,

declining populations were associated with increase in amount of habitat edge per unit area on smaller scales, with greater percentages of cropland and tree cover and total landscape change on larger scales, and on smaller size of largest contiguous area of habitat on all scales (Fuhlendorf et al., 2002). The present study measured smaller-scale fragmentation caused by roads, but larger-scale fragmentation of habitat may also be at work.

Herein an association between roads and abandoned leks of lesser prairie-chickens was demonstrated. These results are somewhat conservative, because no provisions were made for differences in size or usage of individual roads. Many roads in areas without petroleum development are seldom-used, two-track, ranch roads, which probably have much less negative impacts on lesser prairie-chickens than would wider roads under heavier usage. It seems probable that a study that took difference in road usage and size into account would demonstrate an even greater association between roads and abandonment of leks.

Some leks in this study have remained active in areas with low amounts of petroleum development for several years, indicating that such extraction is not completely incompatible with populations of lesser prairie-chickens. However, political and economic forces continue to exert pressure to increase oil and gas production (Energy Information Administration, 2004; Karliner, 1997). Removal of oil is most efficiently accomplished with larger numbers of wells in proximity to each other (Conaway, 1999). Once petroleum development is allowed in an area, these forces will tend to interact to increase number of wells, density of roads, and number of power lines to a point at which populations of lesser prairie-chickens cannot survive.

The results of this study support the idea that petroleum development, especially at high levels, is not compatible with healthy populations of lesser prairie-chickens. Exploration for oil and building of roads should be greatly limited or not allowed in areas that contain healthy

populations of lesser prairie-chickens. Areas of suitable habitat should be closely monitored for breeding populations, and no new areas should be opened to petroleum development without first being surveyed extensively for lesser prairie-chickens. Any attempt to reintroduce lesser prairie-chickens into parts of the study area where they once occurred should be made in areas with low concentrations of petroleum activity, power lines, and roads.

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LITERATURE CITED

Ahlborn, G. G. 1980. Brood-rearing habitat and fall-winter movements of lesser prairie chickens in eastern New Mexico. M.S. thesis, New Mexico State University, Las Cruces, 73 pp.

American Petroleum Institute. 1984. Quarterly review of drilling statistics for the United States, 17(4):1-39.

American Petroleum Institute. 1987. Quarterly Completion Report, 2(4):1-82.

American Petroleum Institute. 1998. Quarterly Well Completion Report, 14(4):1-58.

Amstrub, S. C. 1993. Human disturbances of denning polar bears in Alaska. Arctic, 45:20-24.

Beck, W. A. 1962. New Mexico: a history of four centuries. University of Oklahoma Press, Norman, 363 pp.

Berger, B. D., and K. E. Anderson. 1981. Modern petroleum: a basic primer of the industry. 2nd edition. PennWell Books, Tulsa, Oklahoma, 255 pp.

Best, T. L., K. Geluso, J. L. Hunt, and L. A. McWilliams. 2003. The lesser prairie chicken (*Tympanuchus pallidicinctus*) in southeastern New Mexico: a population survey. The Texas Journal of Science, 55:225-234.

Bevanger, K. 1995. Estimates and population consequences of tetraonid mortality caused by collisions with high tension power lines in Norway. The Journal of Applied Ecology, 32:745-753.

Bevanger, K. 1998. Biological and conservation aspects of bird mortality caused by electricity power lines: a review. Biological Conservation, 86:67-76.

Bidwell, T. B. (ed.). 2002. Ecology and management of the lesser prairie chicken. Oklahoma Cooperative Extension Service, Oklahoma State University, Stillwater, 15 pp.

Blix, A. S., and J. W. Lentfer. 1992. Noise and vibration levels in artificial polar bear dens as related to selected petroleum-exploration and developmental activities. Arctic, 45:20-24.

Borrell, A. E. 1939. Telephone wires fatal to sage grouse. The Condor, 41:85-86.

Bradshaw, C. J. A., S. Boutin, and D. M. Hebert. 1997. Effects of petroleum exploration on woodland caribou in northeastern Alberta. The Journal of Wildlife Management, 61:1127-1133.

Bradshaw, C. J. A., S. Boutin, and D. M. Hebert. 1998. Energetic implications of disturbance caused by petroleum exploration to woodland caribou. Canadian Journal of Zoology, 76:1319-1324.

Braun, C. E. 1986. Changes in sage grouse lek counts with advent of surface coal mining. Proceedings of Issues and Technology in the Management of Impacted Western Wildlife, 2:227-231.

Braun, C. E. 1998. Sage grouse declines in western North America: what are the problems? Proceedings of the Western Association of Fish and Wildlife Agencies, 78:139-156.

Braun, C. E., O. O. Oedekoven, and C. L. Aldridge. 2002. Oil and gas development in western North America: effects on sagebrush steppe avifauna with particular emphasis on sage grouse. Transactions of the North American Wildlife and Natural Resources Conference, 67:337-349.

Cameron, R. D., D. J. Reed, J. R. Dau, and W. T. Smith. 1992. Redistribution of calving caribou in response to oil-field development on the Arctic Slope of Alaska. Arctic, 45:338-342.

Campbell, C. J. 1997. The coming oil crisis. Multi-science Publishing Company, Essex, United Kingdom, 210 pp.

Conaway, C. F. 1999. The petroleum industry: a nontechnical guide. PennWell Publishing, Tulsa, Oklahoma, 289 pp.

Crawford, J. A., and E. G. Bolen. 1976. Effects of lek disturbances on lesser prairie chickens. The Southewestern Naturalist, 21:238-240.

Curatolo, J. A., and S. M. Murphy. 1986. The effects of pipelines, roads, and traffic on the movements of caribou, *Rangifer tarandus*. The Canadian Field-Naturalist, 100:218-224.

Davis, C. A, T. Z Riley, R. A. Smith, H. R. Suminski, and M. J. Wisdom. 1979. Habitat evaluation of lesser prairie chickens in eastern Chaves County, New Mexico.

De Juana, E. 1994. Family Tetraonidae (grouse). Pp. 376-410, *in* Handbook of birds of the World: New World vultures-guineafowl (J. del Hoyo, A. Elliot, and J. Sargatal, eds.). Lynx Edicions, Barcelona, Spain, 2:1-638.

Energy Information Administration. 2004. Country analysis briefs: United States of America. United States Department of Energy, Washington, D.C., 22 pp.

Faanes, C. A. 1987. Bird behavior and mortality in relation to power lines in prairie habitats. United States Department of the Interior, Fish and Wildlife Service, Fish and Wildlife Technical Report, 7:1-24.

Forman, R. T. T. 2000. Estimate of the area affected ecologically by the road system in the United States. Conservation Biology, 14:31-35.

Forman, R. T. T., D. Sperling, J. A. Bissonette, A. P. Clevenger, C.D.Cutshall, V. H. Dale, L. Fahrig, R. France, C. R. Goldman, K. Heanue, J. A. Jones, F. J. Swanson, T. Turrentine, and T. C. Winter. 2003. Road ecology: science and solutions. Island Press, Washington, D.C., 481 pp.

Fuhlendorf, S. D., A. J. W. Woodward, D. M. Leslie, Jr., and J. S. Shackford. 2002. Multi-scale effects of habitat loss and fragmentation on lesser prairie-chicken populations of the US southern Great Plains. Landscape Ecology, 17:617-628.

Giesen, K. M. 1994. Movements and nesting habitat of lesser prairie-chicken hens in Colorado. The Southwestern Naturalist, 39:96-98.

Giesen, K. M. 1998. *Tympanuchus pallidicinctus:* lesser prairie chicken. The Birds of North America, 364:1-19.

Gould, J. L., and G. F. Gould. 2002. Biostats basics: a student handbook. W. H. Freeman and Company, New York, 422 pp.

Green, S. B., N. J. Salkind, and T. M. Akey. 1997. Using SPSS for Windows. Prentice Hall, Upper Saddle River, New Jersey, 494 pp.

Hair, J. F., R. E. Anderson, R. L. Tatham, and W. C. Black. 1998. Multivariate data analysis. Prentice Hall, Upper Saddle River, New Jersey, 730 pp.

Heady, H. F., and R. D. Child. 1994. Rangeland ecology & management. Westview Press, Boulder, Colorado, 519 pp.

Jackson, A. S., and R. DeArment. 1963. The lesser prairie chicken in the Texas Panhandle. The Journal of Wildlife Management, 27:733-737.

Jamison, B. E. 2000. Lesser prairie chicken chick survival, adult survival, and habitat selection and movements of males in fragmented rangelands of southwestern Kansas. M.S. thesis, Kansas State University, Manhattan, 197 pp.

Janss, G. F. E. 2000. Avian mortality from power lines: a morphologic approach of a species-specific mortality. Biological Conservation, 95:353-359.

Johnsgard, P. A. 2002. Grassland grouse and their conservation. Smithsonian Institution Press, Washington, D.C., 157 pp.

Johnson, K., and H. Smith. 1999*a*. Lesser prairie-chicken habitat use on the Sand Ranch and population status in the Caprock Wildlife Habitat Management Area, 1999. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 19 pp.

Johnson, K., and H. Smith. 1999*b*. Lesser prairie-chicken surveys on New Mexico Department of Game and Fish prairie-chicken management areas. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 65 pp.

Johnson, K., and H. Smith. 1999*c*. Survey of the lesser prairie-chicken on Bureau of Land Management lands, Carlsbad Resources Area, NM, 1999. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 44 pp.

Karliner, J. 1997. The corporate planet. Sierra Club Books, San Francisco, California, 298 pp.

Leopold, A. 1931. Report on a game survey of the north central states. Sporting Arms and Ammunition Manufacturers Institute, Madison, Wisconsin, 63 pp.

Ligon, J. S. 1951. Prairie chickens, highways, and power lines. New Mexico Magazine, 29(5):29.

Lutz, R. S. 1979. The response of Attwater's prairie chicken to petroleum development. M.S. thesis, Texas A&M University, College Station, 82 pp.

Lyon, A. G., and S. H. Anderson. 2003. Potential gas development impacts on sage grouse nest initiation and movement. Wildlife Society Bulletin, 31:486-491.

Lyon, L. J. 1979. Habitat effectiveness for elk as influenced by roads and cover. Journal of Forestry, 77:658-660.

Madge, S., P. McGowan, and G. M. Kirwan. 2002. Pheasants, partridges, and grouse: a guide to the pheasants, partridges, quails, grouse, guineafowl, buttonquails, and sandgrouse of the world. Princeton University Press, Princeton, New Jersey, 488 pp.

McNeil, R., J. R. Rodriquez-S., and H. Ouellet. 1985. Bird mortality at a power transmission line in northeastern Venezuela. Biological Conservation, 31:153-165.

Meffe, G. K., and C. R. Carroll. 1994. Principles of conservation biology. Sinauer Associates, Inc., Sunderland, Massachusetts, 600 pp.

Mote, K. D., R. D. Applegate, J. A. Bailey, K. E. Giesen, R. Horton, and J. L. Sheppard, technical editors. 1999. Assessment and conservation strategy for the lesser prairie-

chicken (*Tympanuchus pallidicinctus*). Kansas Department of Wildlife and Parks, Emporia, 51 pp.

Nelleman, C., and R. D. Cameron. 1996. Effects of petroleum development on terrain preferences of calving caribou. Arctic, 49:23-28.

New Mexico Department of Game and Fish. 1999. Status and trend of the lesser prairie-chicken in New Mexico and recommendation to list the species as threatened under the New Mexico Conservation Act. New Mexico Department of Game and Fish, Santa Fe, 32 pp.

Newton, J. A. 1960. Electricity in the oil fields. Pp. 54-71 *in* The uses of electricity in the oil industry (E. A. Reeves, ed.). Ernest Benn Limited, London, United Kingdom, 296 pp.

Noel, L. E., R. H. Pollard, W. B. Ballard, and M. A. Cronin. 1998. Activity and use of active gravel pads and tundra by caribous, *Rangifer tarandus granti,* within the Prudhoe Bay oil field, Alaska. The Canadian Field-Naturalist, 112:400-409.

Oliva, J. 2002. Lesser prairie-chicken (*Tympanuchus pallidicinctus*) Area of Critical Environmental Concern (ACEC): a petition to the New Mexico BLM. Forest Guardians, Albuquerque, New Mexico, 54 pp.

Peterson, R. S., and C. S. Boyd. 1998. Ecology and management of sand shinnery communities: a literature review. United States Department of Agriculture Forest Service, Rocky Mountain Research Station, General Technical Report, RMRS-GTR-16:1-44.

Pollard, R. H., W. B. Ballard, L. E. Noel, and M. A. Cronin. 1996. Parasitic insect abundance and microclimate of gravel pads and tundra within the Prudhoe Bay Oil Field, Alaska, in relation to use by caribou, *Rangifer tarandus granti*. The Canadian Field-Naturalist, 110:649-658.

Rundell, W., Jr. 1982. Oil in West Texas and New Mexico: a pictorial history of the Permian Basin. Texas A&M University Press, College Station, 183 pp.

Schroeder, M. A., and R, K. Baydack. 2001. Predation and the management of prairie grouse. Wildlife Society Bulletin, 29:24-32.

Sharpe, R. S. 1968. The evolutionary relationships and comparative behavior of prairie chickens. Ph.D. dissertation, University of Nebraska, Lincoln, 188 pp.

Silvy, N. J. 1968. Movements, monthly ranges, reproductive behavior, and mortality of radio-tagged greater prairie chickens (*Tympanuchus cupido pinnatus*). M.S. thesis, Kansas State University, Manhattan, 135 pp.

Smith, H., K. Johnson, and L. DeLay. 1998. Survey of lesser prairie chicken on Bureau of Land Management lands, Carlsbad Resource Area, NM 1998. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, 12 pp.

Spellerberg, I. F. 2002. Ecological effects of roads. Science Publishers, Enfield, New Hampshire, 251 pp.

Taylor, M. A. 1980. Lesser prairie chicken use of man-made leks. The Southwestern Naturalist, 24:706-707.

Taylor, M. A., and F. S. Guthery. 1980. Status, ecology, and management of the lesser prairie chicken. United States Department of Agriculture Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report, RM-77:1-15.

Trombulak, S. C., and C. A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology, 14:18-30.

Truett, J. C., M. E. Miller, and K. Kertell. 1997. Effects of Arctic Alaska oil development on brant and snow geese. Arctic, 50:138-146.

United States Bureau of the Census. 1990. Statistical abstract of the United States: 1990. 110th edition. United States Bureau of the Census, Washington, D.C., 991 pp.

United States Census Bureau. 2003. Statistical abstract of the United States: 2003. 123rd edition. United States Census Bureau, Washington, D.C., 1030 pp.

Van den Bussche, R. A., S. R. Hoofer, D. A. Wiedenfeld, D. H. Wolfe, and S. K. Sherrod. 2003. Genetic variation within and among fragmented populations of lesser prairie-chickens (*Tympanuchus pallidicinctus*). Molecular Ecology, 12:675-683.

Weller, C., J. Thomson, P. Morton, and G. Aplet. 2002. Fragmenting our lands: the ecological footprint from oil and gas development. The Wilderness Society, Washington, D. C., 24 pp.

Westemeier, R. L., J. D. Brawn, S. A. Simpson, T. L. Esker, R. W. Jansen, J. W. Walk, E. L. Kershner, J. L. Bouzat, and K. N. Paige. 1998. Tracking the long-term decline and recovery of an isolated population. Science, 282:1695-1698.

Woodward, A. J. W., S. D. Fuhlendorf, D. M. Leslie, Jr., and J. Shackford. 2001. Influence of landscape composition and change on lesser prairie-chicken (Tympanuchus pallidicinctus) populations. The American Midland Naturalist, 145:261-274.

Table 1.—Average length of roads within 1.6 km (1 mile), density of roads, and percentage of area within 31 m (100 feet) and 152 m (500 feet) of roads for active and abandoned leks of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in southeastern New Mexico, 2003.

	Active leks	Abandoned leks
Average length of roads (km)	20.0	26.7
Average density of roads (km/km^2)	2.4	3.3
Average percentage of area within 31 m of road	13.9	18.5
Average percentage of area within 152 m of road	52.1	64.3

CHAPTER 4

RESULTS OF SURVEYS FOR LESSER PRAIRIE-CHICKENS (*Tympanuchus pallidicinctus*) ON LANDS ADMINISTERED BY THE CARLSBAD FIELD OFFICE OF THE BUREAU OF LAND MANAGEMENT IN SOUTHEASTERN NEW MEXICO

ABSTRACT

The lesser prairie-chicken (*Tympanuchus pallidicintus*) is declining across most of its geographic range, including southeastern New Mexico. In April 2002 and 2003, surveys were conducted in the Carlsbad Field Office of the Bureau of Land Management to determine whether active breeding leks existed there. Ten routes were established and surveyed three times each year. At 0.8-km (0.5-mile) intervals on each route, observers listened for calls of lesser prairie-chickens for 3-5 minutes, for a total of 2,256 observations. One active lek was detected in both years. Except for this lek, near Eunice, no breeding population of lesser prairie-chickens exists on public lands in Eddy or southern Lea counties.

INTRODUCTION

One of the first steps in determining a conservation strategy for a population of interest is to determine the status of the population. Although Lea and Eddy counties, New Mexico, have long been considered within the range of the lesser prairie-chicken (Ligon, 1927; Giesen, 1998; Bailey and Williams, 1999), no scientific voucher specimens were collected there until 1970, and no leks were documented there until the mid-1980s (Best, 2001). Surveys in the 1990s suggested that the lesser prairie-chicken had nearly disappeared from these areas (Johnson and Smith, 1999*c*). An extensive survey of the area in 2000 and 2001 documented only one active lek within the Carlsbad Field Office of the Bureau of Land Management; that lek was northeast of Eunice near the Texas state line (Best, 2001; Best et al., 2003). A survey by personnel of the

Texas Parks and Wildlife Department suggested that populations of lesser prairie-chickens had been significantly reduced from adjacent areas of Texas (Sullivan et al., 2000). However, scattered observations were made in other areas of Lea and Eddy counties during 2001-2003 (Best, 2001; S. Belinda and J. S. Sherman, pers. comm.). A well-established population occurs in the Roswell Field Office, in Roosevelt and Chaves counties (Johnson and Smith, 1999*a*, 1999*b*), and extends into the extreme northern portion of the Carlsbad Field Office (T. L. Best, pers. comm.). It was desirable to perform further surveys in the Carlsbad Field Office to determine whether some active leks have been overlooked, or whether lesser prairie-chickens may have re-entered the area, reoccupied abandoned leks, or established new leks.

MATERIALS AND METHODS

The study area primarily was the sandy-soiled, shinnery-oak (*Quercus havardii*) habitat within the range of the lesser prairie-chicken in New Mexico (Giesen, 1998), located in Eddy and Lea counties, New Mexico. However, our survey also included some areas with finer-textured soils and other vegetation types, and two of our survey routes extended into extreme southern Chaves County, New Mexico. The entire survey took place within the Carlsbad Field Office of the Bureau of Land Management.

Routes of survey transects were determined in consultation with biologists from the Bureau of Land Management, by examination of topographic maps, and by field exploration (Best, 2001). Survey routes were chosen to include areas that contained known historical leks, areas of recent sightings of lesser prairie-chickens, and locations that were judged to be especially promising as possible habitat, but also included some areas where no observation of the lesser prairie-chicken had occurred. Two routes near Loco Hills were established because of proximity to established populations in Roosevelt and Chaves counties; most recorded dispersals

of lesser prairie-chickens are =13 km (8 miles—Giesen, 1998; Taylor and Guthery, 1980*a*). Survey routes were numbered consecutively with initials of the observer as a prefix (observers were J. L. Hunt and T. L. Best). Designations of names for historical leks were assigned by the personnel of the Bureau of Land Management.

Surveys were conducted 5-19 April 2002 and 1-15 April 2003. Survey transects were begun 1 hour before sunrise. At each monitoring site along survey transects, the observer listened for 3-5 minutes for calls made by lesser prairie-chickens on leks, recorded weather conditions, GPS coordinates, observations of other wildlife, and other data, then moved ca. 0.8 km (0.5 miles) and repeated this protocol. This process was continued until =3 hours after sunrise. Ten such survey routes were established, and each route was surveyed three times each year, at about 5-day intervals. Details of each route and observations made during the surveys are listed in Appendix II.

RESULTS

During April 2002 and 2003, 376 sites were monitored each year on 10 survey routes along ca. 290 km (181 miles) of transects, covering 36,000 ha (89,000 acres) in Chaves, Eddy, and Lea counties. Each site was monitored on 3 separate occasions each year, for a total of 2,256 monitoring events. Active leks were detected during 6 monitoring events in 2002, and 3 monitoring events in 2003; however, all nine of these observations were of the same lek (E-new) on 2 days in 2002 and 2 days in 2003 on transect JLH-005 (Appendix II). No other lek was detected, and no other observation of the lesser prairie-chicken was made during surveys or during scouting forays before and after survey routes were monitored.

DISCUSSION

Extensive field surveys have been conducted in Lea and Eddy counties during the breeding season of lesser prairie-chickens each year beginning in 1998. Smith et al. (1998), Johnson and Smith (1999*c*), Best (2001), Best et al. (2003), and the current study each surveyed large areas of suitable habitat; each study has included most locations of historically active leks. In addition, extensive surveys have been conducted by personnel of the Bureau of Land Management and by biological consultants employed by petroleum exploration companies (J. S. Sherman, pers. comm). Only one active lek (E-new) has been located during these surveys. Apart from this lek, one historically active lek, QP-22 (Appendix I), is known to have been active in 2000 (J. S. Sherman, pers. comm.). A lesser prairie-chicken was sighted 6 km (3.6 miles) south of Maljamar (Best, 2001) and one was seen northeast of Eunice, near E-new on 18 January 2002 (J. L. Hunt, pers. obs.). A few tracks were seen near QP-22 in 2001 and 2002 (J. S. Sherman, pers. comm.), and calls of lesser prairie-chickens were heard near QP-7 (Appendix I) and north of Loco Hills in 2002 (S. Belinda, pers. comm.). Scattered observations of lesser prairie-chickens also were made in 2003 by personnel of the Bureau of Land Management (S. Belinda, pers. comm.). In addition to these observations, >70 active leks were observed on surveys in the extreme northern part of the Carlsbad Field Office in 2003 (T. L. Best, pers. comm.).

Transects of the type used in this survey should not be used to construct estimates of population density (Applegate, 2000; Thompson, 2002). Such surveys do not take into account non-reproductive males, and suffer from bias caused by using roads and trails as survey routes, especially when population levels are low (Thompson, 2002). However, these transects are useful for gathering presence-absence data (Eng, 1986). Repetition of transects within the same breeding season should help reduce error caused by weather or disturbance. No lesser prairie-

chicken was detected on transect JLH-005 the first time it was surveyed, although fresh tracks were found on lek E-new the next day. Lesser prairie-chickens were detected on two subsequent surveys.

Most surveys reported in this and previous studies (Best, 2001; Best et al., 2003; Johnson and Smith, 1999*c*) primarily were conducted on public lands. However, 59% of lands included in the historic range of lesser prairie-chickens in New Mexico are privately owned (New Mexico Department of Game and Fish, 1999). Conversations with local residents in the Eunice area indicate that some lesser prairie-chickens may remain on private lands (S. Belinda, pers. comm.; J. L. Hunt, pers. obs.). It is important to gain permission to conduct surveys on these private lands to determine the true state of populations in extreme eastern Lea County. However, results of this study, combined with those of previous studies (Best, 2001; Best et al., 2003; Johnson and Smith, 1999*c*) indicate that no breeding population of lesser prairie-chickens exists anywhere else on public lands in Eddy or southern Lea counties.

Although lesser prairie-chickens usually are non-migratory, there are numerous records of individuals appearing outside their usual geographic range (Giesen, 1998). Flocks sometimes move outside their usual home ranges in winter in search of food (Sharpe, 1968). Female grouse may move to new areas if they find suitable habitat, and young males may follow and establish new leks (Bergerud and Gratson, 1988). Lesser prairie-chickens could move into areas of suitable habitat, or reoccupy former habitat in this manner. Annual monitoring of possible habitat is recommended.

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LITERATURE CITED

Applegate, R. D. 2000. In my opinion: use and misuse of prairie chicken lek surveys. Wildlife Society Bulletin, 28:457-463.

Bailey, J. A., and S. O. Williams, 1999. Status of the lesser prairie-chicken in New Mexico, 1999. The Prairie Naturalist, 32:157-168.

Bergerud, A. T., and M. W. Gratson. 1988. Survival and breeding strategies of grouse. Pp. 473-577 *in* Adaptive strategies and population ecology of northern grouse (A. T. Bergerud and M. T. Gratson, eds.). University of Minnesota Press, Minneapolis, 2 vols., 809 pp.

Best, T. L. 2001. Status of the lesser prairie chicken (*Tympanuchus pallidicinctus*) on lands administered by the Bureau of Land Management in southeastern New Mexico. Oil and Gas Consortium, Artesia, New Mexico, 517 pp.

Best, T. L., K. Geluso, J. L. Hunt, and L. A. McWilliams. 2003. The lesser prairie chicken (*Tympanuchus pallidicinctus*) in southeastern New Mexico: a population survey. The Texas Journal of Science, 55:225-234.

Eng, R. L. 1986. Upland game birds. Pp. 407-428 *in* Inventory and monitoring of wildlife habitat (A. Y. Cooperrider, R. J. Boyd, and H. R. Stuart, eds.). United States Department of the Interior, Denver, Colorado, 858 pp.

Giesen, K. M. 1998. *Tympanuchus pallidicinctus:* lesser prairie chicken. The Birds of North America, 364:1-19.

Johnson, K., and H. Smith. 1999*a*. Lesser prairie-chicken habitat use on the Sand Ranch and population status in the Caprock Wildlife Habitat Management Area, 1999. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 19 pp.

Johnson, K., and H. Smith. 1999*b*. Lesser prairie-chicken surveys on New Mexico Department of Game and Fish prairie-chicken management areas. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 65 pp.

Johnson, K., and H. Smith. 1999*c*. Survey of the lesser prairie-chicken on Bureau of Land Management lands, Carlsbad Resources Area, NM, 1999. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 44 pp.

Ligon , J. S. 1927. Wild life of New Mexico: its conservation and management. New Mexico State Game Commission, Santa Fe, 212 pp.

New Mexico Department of Game and Fish. 1999. Status and trend of the lesser prairie-chicken in New Mexico and recommendation to the list the species as threatened under the New Mexico Wildlife Conservation Act. New Mexico Department of Game and Fish, Santa Fe, 32 pp.

Sharpe, R. S. 1968. The evolutionary relationships and comparative behavior of prairie chickens. Ph.D. dissertation, University of Nebraska, Lincoln, 188 pp.

Smith, H., K. Johnson, and L. DeLay. 1998. Survey of lesser prairie chicken on Bureau of Land Management lands, Carlsbad Resource Area, NM 1998. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, 12 pp.

Sullivan, R. M., J. P. Hughes, and J. E. Lionberger. 2000. Review of the historical and present status of the lesser prairie chicken (*Tympanuchus pallidicinctus*) in Texas. The Prairie Naturalist, 32:177-178.

Taylor, M. A., and F. S. Guthery. 1980*a*. Dispersal of a lesser prairie chicken (*Tympanuchus pallidicinctus*). The Southwestern Naturalist, 24:124-125.

Thompson, W. L. 2002. Towards reliable bird surveys: accounting for individuals present but not detected. The Auk, 119:18-25.

CHAPATER 5

FACTOR ANALYSIS OF VARIABLES INVOLVED IN DECLINE IN POPULATIONS OF LESSER PRAIRIE-CHICKENS (*Tympanuchus pallidicinctus*) IN SOUTHEASTERN NEW MEXICO

ABSTRACT

Populations of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in southeastern New Mexico have declined sharply in the past 20 years. Declines are associated with overgrazing and increase in activities associated with petroleum development. Other causes for decline have been suggested, including chemical control of shinnery oak (*Quercus havardii*) and drought. Factor analysis of characters associated with active and abandoned leks was conducted to determine which potential causes are associated with decline in populations. Two factors accounted for 50.1% of variation within the dataset. The first factor, which loaded heavily for variables associated with petroleum development accounted for 31.5% of variation. The second factor, which loaded heavily for variables associated with overgrazing, accounted for 18.6% of variation. Discriminant-function analysis of these factors indicated that petroleum development was more important than overgrazing in explaining the difference between active and abandoned leks.

INTRODUCTION

Lesser prairie-chickens (*Tympanuchus pallidicinctus*) are grouse that inhabit semi-arid grasslands of the southern Great Plains. The species uses a breeding system in which males display at leks for females. Females come to leks to choose a male with which to mate, then build a nest, usually within 1.2-3.4 km (0.7-2.0 miles) of the lek (Giesen, 1998). Individual

males usually return to the same lek year after year, so lek sites are fairly permanent (Johnsgard, 2002). Females raise broods usually within 2 km of the lek (Giesen, 1994; Ahlborn, 1980).

Declines in populations of lesser prairie-chickens have been well documented across its range. Populations may have declined 97% since the 1800s (Taylor and Guthery, 1980); it originally inhabited rangelands of Texas, New Mexico, Oklahoma, Kansas, Colorado, and Nebraska. Although populations still exist in all of these states except Nebraska, the area occupied has been reduced by 92% (Giesen, 1998). A similar decline in distribution has occurred in southeastern New Mexico. Surveys suggest the species has nearly disappeared from breeding leks first documented in Eddy and southern Lea counties, New Mexico, in the mid-1980s (Best et al., 2003; Johnson and Smith, 1999*c*).

Reasons for declines in populations of lesser prairie-chickens are not well understood. Suggested causes for declines include drought, conversion of habitat to agricultural use, improper grazing management, chemical control of shinnery oak (*Quercus havardii*), hunting, disturbance caused by petroleum development, and habitat fragmentation caused by roads (Fuhlendorf et al., 2002; Giesen, 1998; Johnson and Smith, 1999*c*; New Mexico Department of Game and Fish, 1999; Peterson and Boyd, 1998).

Results of studies conducted in southeastern New Mexico have demonstrated a correlation between overgrazing by cattle and abandonment of leks of lesser prairie-chickens (Chapter 2). Relative to active leks, abandoned leks were in pastures with greater percentage composition of *Sporobolus* and *Eriogonum*, which are indicators of overgrazing (Clements, 1920; Stubbendieck et al., 1997). Active leks were in pastures with greater percentage composition of *Andropogon*, which decreases under heavy grazing pressure (Ross and Bailey, 1967; Stubbendieck et al., 1997). *Andropogon* is favorable nesting habitat for lesser prairie-

chickens, and is associated with greater nesting success (Davis et al., 1979; Riley et al., 1992). Several studies have suggested that overgrazing is detrimental to populations of lesser prairie-chickens (Davis et al., 1979; Jackson and DeArment, 1963; Johnson and Smith, 1999*c*; Riley et al., 1992; Chapter 2).

Disturbance due to petroleum development also has been suggested as a cause for declines in populations of lesser prairie-chickens in southeastern New Mexico (Johnson and Smith, 1999*c*; Smith et al., 1998). Few previous studies of effects of such disturbance have been conducted, and lesser prairie-chickens have coexisted in some places in southeastern New Mexico with moderate amounts of oil and gas extraction (Merchant, 1982). However, number of wells near leks in southeastern New Mexico has increased dramatically since 1980 (Chapter 3). A study in southeastern New Mexico demonstrated a significant correlation between abandoned leks and activities associated with oil and gas extraction (Chapter 3). Abandoned leks had greater density of roads and more oil and gas wells than did active leks. Besides disturbance caused by presence and activity of humans at wells and on roads, fragmentation of habitat caused by roads also may be detrimental (Forman et al., 2003; Fuhlendorf et al., 2002; Schroeder and Baydack, 2001). Abandoned leks were also much more likely to be associated with power lines than were active leks (Chapter 3). Collisions with power lines may be an important source of mortality among lesser prairie-chickens, especially in small, fragmented populations (Bidwell, 2002; Jamison, 2000; Ligon, 1951).

Although previous studies have determined that both overgrazing and petroleum development are associated with abandoned leks, it is unclear which of these factors is most detrimental to populations of lesser prairie-chickens. Factor analysis is a multivariate technique that can be used to identify factors that statistically explain variation and covariation within a

dataset (Green et al., 1997). The purpose of this study was to conduct a factor analysis of variables associated with abandonment of leks of lesser prairie-chickens in southeastern New Mexico, and thus, to clarify reasons for this abandonment.

MATERIALS AND METHODS

The study site is located in Eddy, Lea, Chaves, and Roosevelt counties in southeastern New Mexico, and contains about 303,750 hectares (750,000 acres) of shinnery oak, which is a primary habitat component of the lesser prairie-chicken in this region (Peterson and Boyd, 1998). Petroleum development is scattered throughout the shinnery oak community, with some areas of high concentration of development. The study area contains areas where populations of lesser prairie-chickens have remained present with some fluctuation in size of population, and other areas in which populations no longer exist (Best et al., 2003; Johnson and Smith, 1999*a,* 1999*b*, 1999*c*; Smith et al., 1998).

Factor analysis (Green et al., 1997) was conducted to determine relative importance of variables associated with abandoned leks of lesser prairie-chickens. Most variables were selected from those measured in concurrent studies of vegetative characters associated with leks (Chapter 2) and effects of petroleum development on leks (Chapter 3). In 2001, 60 active or previously active leks were selected and located with assistance of personnel from the Bureau of Land Management and New Mexico Department of Game and Fish. Status of leks as active or abandoned was determined through extensive surveys of leks (Chapter 4).

Vegetative characters used in factor analysis include percentage composition of *Andropogon, Sporobolus,* and *Quercus*. These data were gathered at 33 active and 27 historically active leks, using the line-point sampling method described by Bonham (1989) and Johnson and Smith (1999*a*). Percentage composition of each genus of plant was computed, and

percentages were transformed into log-ratios by taking the natural logarithm of percentage divided by percentage of *Artemesia* (Aebischer and Robertson, 1992; Aitchison, 1986). *Andropogon, Sporobolus,* and *Quercus* were selected for inclusion in factor analysis because of their importance in the life cycle of lesser prairie-chickens (Ahlborn, 1980; Davis et al., 1979; Johnsgard, 2002). Relative amounts of *Andropgon* and *Sporobolus* are useful in determination of overgrazing (Clements, 1920; Ross and Bailey, 1967; Stubbendieck et al., 1997), and percentage composition of the two grasses was significantly different in active and abandoned leks (Chapter 2). In addition, chemical control of *Quercus* has been suggested as a reason for decline in populations of lesser prairie-chickens (Peterson and Boyd, 1998). The final vegetative character included in analysis was presence or absence of honey mesquite (*Prosopis glandulosa*) = 60 cm (24 inches) in height within 200 meters (660 feet) of the center of each lek. Honey mesquite is an indicator of overgrazing (Clements, 1920), and tall honey mesquites may cause abandonment of leks (Chapter 2).

Quality of soil influences type and amount of vegetation that grows in an area (Ross and Bailey, 1967), and so may impact health of populations of lesser prairie-chickens. Quality of soil was included in factor analysis and data were obtained from United States Department of Agriculture soil surveys (Chug et al., 1971; Lenfesty 1983; Ross and Bailey, 1967; Turner et al., 1974). These surveys map types of soils and rate quality of each type using several criteria. One criterion measured is compatibility of each type to tall grasses. Types of soil are rated as good, fair, poor, or very poor for grasses. Because categorical variables work best with fewer categories in multivariate analyses (D. M. Shannon, pers. comm.), good and fair soils were combined into one category, and poor and very poor soils were combined.

Several aspects of petroleum development were correlated with abandoned leks of lesser prairie-chickens (Chapter 3). These variables were included in factor analysis. Number of active oil wells and total number of active and abandoned oil wells within 1.6 km (1 mile) of active and abandoned leks were determined from examination of files of the Bureau of Land Management. Data for roads were obtained from Digital Orthophoto Quarter Quad maps produced by the United States Geological Survey from aerial photographs made in 1996. For each lek, a buffer was created that extended 1.6 km (1 mile) from the center of the lek. Roads that fell within this circle were digitized from the Digital Orthophoto Quarter Quad maps into a Geographic Information System coverage using ArcView 3.2 (ESRI, Inc., Redlands, CA) at a scale of 1:10,000. Length of road within each circle was computed with the Geographic Information System program. Each lek was evaluated for presence or absence of power lines within 800 m (2,600 feet) of center of lek.

Ambient sound levels at active and abandoned leks were included in factor analysis. Noise from oil and gas equipment has been suggested as a possible reason for decline in populations of lesser prairie-chickens in southeastern New Mexico; such noise may interfere with reproductive activities (Smith et al., 1998). At each lek, sound levels were recorded with a CEL-231 Digital Sound Survey Meter (CEL Instruments Limited, Kempston, United Kingdom). Measurements of sound levels were made at times when lesser prairie-chickens were not present on leks and wind speeds were < 8 km/h (5 miles/h).

Because drought often is implicated in declines of lesser prairie-chickens (Merchant, 1982; New Mexico Department of Game and Fish, 1999), rainfall was included in factor analysis. Rainfall totals for 5 years prior to last known use of each lek were obtained for the weather station closest to each lek (NOAA, 1980-2003). Five-year totals were used because this

is the average maximum life span of lesser prairie-chickens (Campbell, 1972), so that ecological effects could have up to a 5-year time lag (New Mexico Department of Game and Fish, 1999).

Variables were entered into a factor analysis using SPSS 10.0 (Green et al., 1997). Because there were 60 leks studied, number of variables used was limited to 12 (Hair et al., 1998). Categorical variables, including mesquite, power lines, and soil type, were converted to numerical variables (Shannon and Davenport, 2001). Data were first analyzed using principal-components analysis. The two strongest resulting factors with an eigenvalue > 1.0 were selected for further analysis. Remaining factors were rotated using unweighted least-squares and varimax procedures (Green et al., 1997). Individual case scores were saved for each factor, and scores for active and abandoned leks were compared using discriminant-function analysis (Green et al., 1997).

Use of categorical variables in factor analysis is somewhat problematic. The only assumption of factor analysis is that measured variables are linearly related to factors, and categorical variables often violate this assumption (Green et al., 1997). Most multivariate procedures are fairly robust to violations of assumptions (Hair et al., 1998), and use of only two categories for each variable reduces problems caused by these violations (D. M. Shannon, pers. comm.). However, to eliminate problems caused by violations of assumptions, a second factor analysis was conducted in which categorical variables were not used. Many active leks were closest to the same weather station, resulting in pseudoreplication of rainfall data (Hurlbert, 1984). For this reason, rainfall data also was eliminated from the second factor analysis.

RESULTS

Factor analysis using all 12 variables resulted in two factors that together explained 50.1% of variance within the dataset. The first factor, which explained 31.5 % of variance,

loaded heavily for total number of oil wells, number of active oil wells, presence of power lines, length of road, and sound levels (Table 1). This factor was interpreted as effects of petroleum development. The second factor, which explained 18.6% of variance, loaded heavily for *Quercus, Andropogon,* and *Sporobolus*, and was interpreted as grazing effects. Other factors had eigenvalues <1.0, and were not interpreted. Individual scores for each lek on the first two factors were saved and active and abandoned leks were compared using discriminant-function analysis. There was a significant difference between active and abandoned leks for the first factor, effects of petroleum development (Wilks' ? = 0.693, $P < 0.001$). There was no difference between active and abandoned leks for the second factor, grazing effects (Wilks' ? = 1.000, $P = 0.967$).

Results of the second factor analysis were similar to those of the first (Table 1), except that power lines did not load heavily on the first factor because they were not included in the analysis. In the second analysis, the first factor explained 37.4% of variance, and the second explained 33.4% of variance. No other factor had an eigenvalue >1.0. Discriminant-function analyses indicated a difference in active and abandoned leks for the first factor, effects of petroleum development (Wilks' ? = 0.801, $P < 0.001$), and no difference for the second factor, grazing effects (Wilks' ? = 0.993, $P = 0.528$)

DISCUSSION

Populations of lesser prairie-chickens in Lea and Eddy counties, New Mexico, have declined precipitously since breeding populations were first documented in the mid-1980s (Best et al., 2003; Johnson and Smith, 1999*c*). Many reasons for the general population decline of lesser prairie-chickens have been suggested, but some of these are not applicable to populations in the study area. For example, conversion of suitable habitat to agricultural use often is cited as a reason for declines in populations (Crawford and Bolen, 1976; Fuhlendorf et al., 2002;

Johnsgard, 2002), but land-use patterns in the study area have not changed greatly since 1975 (New Mexico Department of Game and Fish, 1999).

Other suggested reasons for decline in populations of lesser prairie-chickens are better supported. Several studies have documented relationships between grazing and lesser prairie-chickens (Davis et al., 1979; Giesen, 1994; Jackson and DeArment, 1963; Merchant 1982). Several vegetative characters symptomatic of overgrazing were associated with abandoned leks in a concurrent study (Chapter 2). Few studies of effects of petroleum development on lesser prairie-chickens have been conducted. Some anecdotal evidence for an effect exists (Smith et al., 1998), and some studies have suggested negative effects of petroleum development on other grouse (Braun et al., 2002; Lyon and Anderson, 2003). A study concurrent with the present study reported correlations between abandoned leks and several aspects of petroleum development, including presence of power lines, number of active oil wells, total number of oil wells, and amount of roads (Chapter 3).

While overgrazing is detrimental to lesser prairie-chickens (Davis et al., 1979; Giesen, 1994; Jackson and DeArment, 1963; Merchant 1982; Chapter 2), southeastern New Mexico has been heavily grazed since the latter half of the 19th Century (Beck, 1962). Conversely, populations of lesser prairie-chickens have coexisted with moderate amounts of petroleum development in some areas, including parts of the current study area. Results of the current study, however, seem to indicate that petroleum development is more important in explaining the decline of lesser prairie-chickens. The greatest amount of variation within the dataset was explained by the factor corresponding to effects of petroleum development, and comparison of factor scores indicated a difference between active and abandoned leks only for this factor.

Results of these analyses should not be interpreted to mean that petroleum development is solely responsible for declines in populations of lesser prairie-chickens, or that overgrazing has not contributed to these declines. Results of concurrent studies indicate strong correlations between declines and both petroleum activities and overgrazing (Chapter 2; Chapter 3). It is likely that declines seen in Eddy and Lea counties are the result of interactions of these factors, along with effects of natural occurrences such as drought. The study area contains some areas with moderate to heavy grazing and little petroleum development (e.g., the Sand Ranch east of Roswell) with seemingly stable populations of lesser prairie-chickens. There also are areas of light and moderate petroleum development with grazing regimes ranging from heavy to none with healthy populations (e.g., prairie-chicken management areas near Milnesand). Areas south and east of Maljamar are overgrazed and heavily developed for petroleum, and contain no breeding populations of lesser prairie-chickens (Best et al., 2003; Chapter 4).

Although an effort was made to include effects of rainfall in this study, such efforts must be considered flawed at best. Rainfall in southeastern New Mexico occurs in spotty patterns, and rainfall amounts may vary widely over short distances. Although inclusion of 5 years of data should help reduce this error, psuedoreplication of values for active leks casts further doubt on the value of inclusion of this variable in this analysis. However, data used are the best available. Removal of these data had little effect on results of analyses. Although drought often is cited as a possible reason for declines in lesser prairie-chickens (Johnsgard, 2002; Merchant, 1982), one study found that although there was a slight correlation between populations of lesser prairie-chickens and rainfall totals from 2 years previously, there was no long-term correlation between rainfall and populations (New Mexico Department of Game and Fish, 1999). Although severe drought has negative effects on survival and reproduction of lesser prairie-chickens (Merchant,

1982), this species evolved and survived for many generations in arid lands (de Juana, 1994; Johnsgard, 2002). However, drought may exacerbate negative effects of other factors (Merchant, 1982).

Results of this study indicate that petroleum development is most important in explaining decline in populations of lesser prairie-chickens in southeastern New Mexico. Future research should focus on specific aspects of petroleum development to determine whether changes in methods of development could make it more compatible with healthy populations of lesser prairie-chickens.

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LITERATURE CITED

Aebischer, N. J., and P. A. Robertson. 1992. Practical aspects of compositional analysis as applied to pheasant habitat utilization. Pp. 285-293 *in* Wildlife telemetry: remote monitoring and tracking of animals (I. G. Pride and S. M. Swift, eds.). Ellis Horwood, New York, 708 pp.

Ahlborn, G. G. 1980. Brood-rearing habitat and fall-winter movements of lesser prairie chickens in eastern New Mexico. M.S. thesis, New Mexico State University, Las Cruces, 73 pp.

Aitchison, J. 1986. The statistical analysis of compositional data. Chapman and Hall, London, United Kingdom, 416 pp.

Beck, W. A. 1962. New Mexico: a history of four centuries. University of Oklahoma Press, Norman, 363 pp.

Best, T. L., K. Geluso, J. L. Hunt, and L. A. McWilliams. 2003. The lesser prairie chicken (*Tympanuchus pallidicinctus*) in southeastern New Mexico: a population survey. The Texas Journal of Science, 55:225-234.

Bidwell, T. B. (ed.). 2002. Ecology and management of the lesser prairie chicken. Oklahoma Cooperative Extension Service, Oklahoma State University, Stillwater, 15 pp.

Bonham, C. D. 1989. Measurements for terrestrial vegetation. John Wiley & Sons, New York, 338 pp.

Braun, C. E., O. O. Oedekoven, and C. L. Aldridge. 2002. Oil and gas development in western North America: effects on sagebrush steppe avifauna with particular emphasis on sage grouse. Transactions of the North American Wildlife and Natural Resources Conference, 67:337-349.

Campbell, H. 1972. A population study of lesser prairie chickens in New Mexico. The Journal of Wildlife Management, 36:689-699.

Chug, J. C., G. W. Anderson, D. L. King, and L. H. Jones. 1971. Soil survey of Eddy area, New Mexico. United States Department of Agriculture, Soil Conservation Service, Washington, D. C., 82 pp.

Clements, F. E. 1920. Plant indicators: the relation of plant communities to process and practice. Carnegie Institution of Washington, Washington, D.C., 388 pp.

Crawford, J. A., and E. G. Bolen. 1976. Effects of land use on lesser prairie chickens in Texas. The Journal of Wildlife Management, 40:96-104.

Davis, C. A., T. Z. Riley, R. A. Smith, H. R. Suminski, and D. M. Wisdom. 1979. Final report: habitat evaluation of lesser prairie-chickens in eastern Chaves County, New Mexico. Department of Fish and Wildlife Sciences, New Mexico Agricultural Experiment Station, Las Cruces, 141 pp.

De Juana, E. 1994. Family Tetraonidae (grouse). Pp. 376-410, *in* Handbook of birds of the World: New World vultures-guineafowl (J. del Hoyo, A. Elliot, and J. Sargatal, eds.). Lynx Edicions, Barcelona, Spain, 2:1-638.

Forman, R. T. T., D. Sperling, J. A. Bissonette, A. P. Clevenger, C.D.Cutshall, V. H. Dale, L. Fahrig, R. France, C. R. Goldman, K. Heanue, J. A. Jones, F. J. Swanson, T. Turrentine, and T. C. Winter. 2003. Road ecology: science and solutions. Island Press, Washington, D.C., 481 pp.

Fuhlendorf, S. D., A. J. W. Woodward, D. M. Leslie, Jr., and J. S. Shackford. 2002. Multi-scale effects of habitat loss and fragmentation on lesser prairie-chicken populations of the US southern Great Plains. Landscape Ecology, 17:617-628.

Giesen, K. M. 1994. Movements and nesting habitat of lesser prairie-chicken hens in Colorado. The Southwestern Naturalist, 39:96-98.

Giesen, K. M. 1998. *Tympanuchus pallidicinctus:* lesser prairie chicken. The Birds of North America, 364:1-19.

Green, S. B., N. J. Salkind, and T. M. Akey. 1997. Using SPSS for Windows. Prentice Hall, Upper Saddle River, New Jersey, 494 pp.

Hair, J. F., R. E. Anderson, R. L. Tatham, and W. C. Black. 1998. Multivariate data analysis. Prentice Hall, Upper Saddle River, New Jersey, 730 pp.

Hurlbert, S. H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs, 54:187-211.

Jackson, A. S., and R. DeArment. 1963. The lesser prairie chicken in the Texas Panhandle. The Journal of Wildlife Management, 27:733-737.

Jamison, B. E. 2000. Lesser prairie-chicken chick survival, adult survival, and habitat selection and movements of males in fragmented rangelands of southwestern Kansas. M.S. thesis, Kansas State University, Manhattan, Kansas, 212 pp.

Johnsgard, P. A. 2002. Grassland grouse and their conservation. Smithsonian Institution Press, Washington, D.C., 157 pp.

Johnson, K., and H. Smith. 1999*a*. Lesser prairie-chicken habitat use on the Sand Ranch and population status in the Caprock Wildlife Habitat Management Area, 1999. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 19 pp.

Johnson, K., and H. Smith. 1999*b*. Lesser prairie-chicken surveys on New Mexico Department of Game and Fish prairie-chicken management areas. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 65 pp.

Johnson, K., and H. Smith. 1999*c*. Survey of the lesser prairie-chicken on Bureau of Land Management lands, Carlsbad Resources Area, NM, 1999. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 44 pp.

Lenfesty, C. D. 1983. Soil survey of Chaves County, New Mexico, Northern Part. United States Department of Agriculture, Soil Conservation Service, Washington, D. C., 224 pp.

Ligon, J. S. 1951. Prairie chickens, highways, and power lines. New Mexico Magazine, 29(5):29.

Lyon, A. G., and S. H. Anderson. 2003. Potential gas development impacts on sage grouse nest initiation and movement. Wildlife Society Bulletin, 31:486-491.

Merchant, S. S. 1982. Habitat-use, reproductive success, and survival of female lesser prairie chickens in two years of contrasting weather. M.S. thesis, New Mexico State University, Las Cruces, 62 pp.

New Mexico Department of Game and Fish. 1999. Status and trend of the lesser prairie-chicken in New Mexico and recommendation to list the species as threatened under the New Mexico Conservation Act. New Mexico Department of Game and Fish, Santa Fe, 32 pp.

NOAA. 1980-2003. Climatological data (monthly temperature and precipitation data for New Mexico). United States Department of Commerce, National Oceanic and Atmospheric Administration Environmental Data Service, National Climatic Center, Asheville, North Carolina, volumes 84-107.

Peterson, R. S., and C. S. Boyd. 1998. Ecology and management of sand shinnery communities: a literature review. United States Department of Agriculture Forest Service, Rocky Mountain Research Station, General Technical Report, RMRS-GTR-16:1-44.

Riley, T. Z., C. A. Davis, M. Ortiz, and M. J. Wisdom. 1992. Vegetative characteristics of successful and unsuccessful nests of lesser prairie chickens. The Journal of Wildlife Management, 56:383-387.

Ross, W. J., and O. F. Bailey. 1967. Soil survey of Roosevelt County, New Mexico. United States Department of Agriculture, Soil Conservation Service, Washington, D. C., 74 pp.

Schroeder, M. A., and R, K. Baydack. 2001. Predation and the management of prairie grouse. Wildlife Society Bulletin, 29:24-32.

Shannon, D. M., and M. A. Davenport. 2001. Using SPSS to solve statistical problems. Merrill Prentice Hall, Upper Saddle River, New Jersey, 374 pp.

Smith, H., K. Johnson, and L. DeLay. 1998. Survey of lesser prairie chicken on Bureau of Land Management lands, Carlsbad Resource Area, NM 1998. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, 12 pp.

Stubbendieck, J., S. L. Hatch, and C. H. Butterfield. 1997. North American range plants. 5th edition. University of Nebraska Press, Lincoln, 501 pp.

Taylor, M. A., and F. S. Guthery. 1980. Status, ecology, and management of the lesser prairie chicken. United States Department of Agriculture Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report, RM-77:1-15.

Turner, M. T., D. N. Cox, B. C. Mickelson, A. J. Roath, and C. D. Wilson. 1974. Soil survey of Lea County, New Mexico. United States Department of Agriculture, Soil Conservation Service, Washington, D.C., 89 pp.

Table 1.—Rotated factor-matrix loadings for factor analysis using all variables and analysis using no categorical variables or rainfall data for leks of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in southeastern New Mexico, 2003.

Variable	Factor 1	Factor 2
All variables		
Presence of honey mesquite	0.289	-0.104
Type of soil	0.127	-0.159
Sound level	0.619	0.165
Andropogon	-0.365	0.578
Sporobolus	0.314	0.770
Quercus	0.111	0.999
Precipitation 5 years in past	0.348	0.016
Length of road within 1.6 km	0.714	0.050
Presence of power lines	-0.747	-0.021
Number of active wells	0.892	-0.189
Total number of wells	0.865	-0.156
Without categorical variables or rainfall data		
Sound level	0.575	0.199
Andropogon	-0.326	0.524
Sporobolus	0.249	0.801
Quercus	0.051	1.007
Length of roads within 1.6 km	0.714	0.078
Number of active wells	0.923	-0.136
Number of total wells	0.942	-0.114

CHAPTER 6

RELATIONSHIP BETWEEN LEVELS OF NOISE AND LEKS OF LESSER PRAIRIE-CHICKEN (*Tympanuchus pallidicinctus*) IN SOUTHEASTERN NEW MEXICO

ABSTRACT

Populations of lesser prairie-chickens (*Tympanuchus pallidicinctus*) have declined sharply across the geographic range of the species, including southeastern New Mexico. Several possible causes for this decline have been suggested, including noise caused by petroleum development. To test this hypothesis, ambient sound levels were measured at 33 active leks, 39 abandoned leks, and 60 control points. Sound levels at leks and control points were not significantly different. Sound levels were about 4 decibels greater at abandoned leks than at active leks. This difference, while statistically significant, is probably not great enough to explain abandonment of leks. Instead, difference in noise levels is symptomatic of high levels of petroleum development, which contributes to abandonment through increased destruction and fragmentation of habitat and greater amounts of human-caused disturbance.

INTRODUCTION

Range-wide declines in populations of lesser prairie-chickens (*Tympanuchus pallidicinctus*) have been well documented. Populations have declined 97% since the 1800s (Taylor and Guthery, 1980). A similar decline in populations has occurred in southeastern New Mexico. Surveys in the 1980s and 1990s suggested that the lesser prairie-chicken had nearly disappeared from central Eddy and Lea counties, New Mexico (Johnson and Smith, 1999*c*). Reasons for declines in populations are not well understood. Suggested causes include drought, conversion of habitat to agricultural use, improper grazing management, chemical control of

shinnery oak, hunting, and disturbance caused by petroleum development (Giesen, 1998; Johnson and Smith, 1999*c*; New Mexico Department of Game and Fish, 1999; Peterson and Boyd, 1998).

Lesser prairie-chickens use a breeding system in which males display at leks for females. A lek is an area where males set up and defend territories on which they perform elaborate mating displays accompanied by a variety of vocalizations (Johnsgard, 2002). Smith et al. (1998) suggested that noise caused by petroleum development interfered with lekking activities of lesser prairie-chickens. There is some anecdotal support for this hypothesis; one group of researchers noted that several abandoned leks were near new oil-drilling operations (Johnson and Smith, 1999*c*; Smith et al., 1998). However, no study has been conducted to determine whether there is a correlation between noise caused by petroleum development and decline in populations of lesser prairie-chickens.

Most studies of effects of noise on wildlife focus on effects of sonic booms and low-flying aircraft (Manci et al., 1988). Few studies have investigated effects of noise on breeding birds (Bowles, 1995; Forman and Alexander, 1998; Manci et al., 1988). Increased levels of stress, interruption of brooding, and accelerated hatching of birds exposed to noise have been documented (Bowles, 1995; Manci et al., 1998). A series of studies in The Netherlands revealed that noise caused by road traffic was correlated with reduction in density of population of breeding birds (Foppen and Reijnen, 1994; Reijnen and Foppen, 1994; Reijnen et al., 1995). Some forest birds had difficulty keeping and attracting mates. It was hypothesized that noise from vehicle traffic interfered with communication related to reproduction (Reijnen and Foppen, 1994). No study has investigated effects of noise on behavior of lekking birds (Bowles, 1995). This study compares ambient noise levels at active and abandoned leks of lesser prairie-chickens.

MATERIALS AND METHODS

The study site is located in Eddy, Lea, Chaves, and Roosevelt counties in southeastern New Mexico, and contains about 304,000 ha (750,000 acres) of shinnery oak, which is a primary habitat component of the lesser prairie-chicken (Peterson and Boyd, 1998). Petroleum development is scattered throughout the shinnery oak community, with some areas of high concentration of development. The study area contains areas where lesser prairie-chickens have remained present with some fluctuation in size of populations, and other areas in which populations have disappeared (Best, 2001; Best et al., 2003; Johnson and Smith, 1999*a*, 1999*b*, 1999*c*; Smith et al., 1998; Chapter 4).

In 2003, 33 active and 39 abandoned leks were selected and located with assistance of personnel from the Bureau of Land Management and New Mexico Department of Game and Fish. Status of leks as active or abandoned was determined through extensive surveys (Chapter 4). A control point was established 300 m (1,000 feet) from the center of 60 of the leks. At each lek and each control, sound levels were measured with a CEL-231 Digital Sound Survey Meter (CEL Instruments Limited, Kempston, United Kingdom). Levels were compared statistically using Student's *t*-tests (Green et al., 1997) to determine whether there were differences in ambient sound levels of abandoned leks, currently active leks, and control points. Measurements of sound levels were made at times when lesser prairie-chickens were not present on the leks. Sound levels at drilling rigs and various types of production areas, and of various types of oil-field traffic were measured for comparison.

RESULTS AND DISCUSSION

No significant difference was found between ambient sound levels at leks and those at control points ($t = 0.028$, $P = 0.978$). Average ambient sound level at active leks was 30.4

decibels, while that of inactive leks was 34.8 decibels; this difference is statistically significant ($t = 4.308$, $P < 0.001$). Sound levels at leks, controls, at various types of petroleum production facilities, and for oil field traffic are reported in Table 1.

Acoustic communication is an important part of the breeding cycle of many animals, especially birds (Gill, 1995). Male lesser prairie-chickens use vocalizations to establish and defend territories, and to attract females (Giesen, 1998; Hjorth, 1970; Johnsgard 2002). Loud noise could interfere with this communication and disrupt breeding behavior. Abandoned leks in this study had a significantly higher ambient noise level than active leks. However, average difference was only about 4 decibels. This difference probably is not enough to explain the abandonment of leks. Instead, higher levels of noise are symptomatic of increased human activity from petroleum development. Factor analysis conducted concurrently with this study (Chapter 5) indicated that greater ambient noise levels were associated with several aspects of petroleum development, including greater number of active and inactive wells, presence of power lines, and greater density of roads.

While ambient noise levels are greater at abandoned leks than at active leks, it seems unlikely that the difference is great enough to explain abandonment of leks. However, some birds are sensitive to aspects of vocalizations such as frequency and structure (Dooling, 1982). It is possible that noise generated by petroleum development mimics some aspect of vocalizations of lesser prairie-chickens and interferes with communication in a way other than simple loudness. Further research is needed to determine whether this is a possibility.

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LITERATURE CITED

Best, T. L. 2001. Status of the lesser prairie chicken (*Tympanuchus pallidicinctus*) on lands administered by the Bureau of Land Management in Southeastern New Mexico. Oil and Gas Consortium, Artesia, New Mexico, 517 pp.

Best, T. L., K. Geluso, J. L. Hunt, and L. A. McWilliams. 2003. The lesser prairie chicken (*Tympanuchus pallidicinctus*) in southeastern New Mexico: a population survey. The Texas Journal of Science, 55:225-234.

Bowles, A. E. 1995. Responses of wildlife to noise. Pp. 109-156 *in* Wildlife and recreationists: coexistence through management and research (R. L. Knight and K. J. Gutzwiller, eds.). Island Press, Washington, D.C., 372 pp.

Dooling, R. J. 1982. Auditory perception in birds. Pp. 95-130 *in* Acoustic communication in birds: production, perception, and design features of sounds (D. E. Kroodsma and E. H. Miller, eds.). Academic Press, New York, 1:1-371.

Foppen, R., and R. Reijnen. 1994. The effects of car traffic on breeding bird populations in woodland. II. Breeding dispersal of male willow warblers (*Phylloscopus trochilus*) in relation to the proximity of a highway. The Journal of Applied Ecology, 31:95-101.

Forman, R. T. T., and L. E. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics, 29:207-231.

Giesen, K. M. 1998. *Tympanuchus pallidicinctus:* lesser prairie chicken. The Birds of North America, 364:1-19.

Gill, F. B. 1995. Ornithology. 2nd edition. W. H. Freeman and Company, New York, 763 pp.

Green, S. B., N. J. Salkind, and T. M. Akey. 1997. Using SPSS for Windows. Prentice Hall, Upper Saddle River, New Jersey, 494 pp.

Hjorth, I. 1970. Reproductive behavior in Tetraonidae, with special reference to males. Viltrevy, Swedish Wildlife, 7:183-596.

Johnsgard, P. A. 2002. Grassland grouse and their conservation. Smithsonian Institution Press, Washington, D.C.,157 pp.

Johnson, K., and H. Smith. 1999*a*. Lesser prairie-chicken habitat use on the Sand Ranch and population status in the Caprock Wildlife Habitat Management Area, 1999. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 19 pp.

Johnson, K., and H. Smith. 1999*b*. Lesser prairie-chicken surveys on New Mexico Department of Game and Fish prairie-chicken management areas. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 65 pp.

Johnson, K., and H. Smith. 1999*c*. Survey of the lesser prairie-chicken on Bureau of Land Management lands, Carlsbad Resources Area, NM, 1999. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 44 pp.

Manci, K. M., D. N. Gladwin, R. Villella, and M. G. Cavendish. 1988. Effects of aircraft noise and sonic booms on domestic animals and wildlife: a literature synthesis. United States Fish and Wildlife Service, National Ecology Research Center, Fort Collins, Colorado, NERC-88/29:1-88.

New Mexico Department of Game and Fish. 1999. Status and trend of the lesser prairie-chicken in New Mexico and recommendation to list the species as threatened under the New Mexico Conservation Act. New Mexico Department of Game and Fish, Santa Fe, 32 pp.

Peterson, R. S., and C. S. Boyd. 1998. Ecology and management of sand shinnery communities: a literature review. United States Department of Agriculture Forest Service, Rocky Mountain Research Station, General Technical Report, RMRS-GTR-16:1-44.

Reijnen, R., and R. Foppen. 1994. The effects of car traffic on breeding bird populations in woodland. I. Evidence of reduced habitat quality for willow warblers (*Phylloscopus trochilus*) breeding close to a highway. The Journal of Applied Ecology, 31:85-94.

Reijnen, R., R. Foppen, C. ter Braak, and J. Thissen. 1995. The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads. The Journal of Applied Ecology, 32:187-202.

Smith, H., K. Johnson, and L. DeLay. 1998. Survey of lesser prairie chicken on Bureau of Land Management lands, Carlsbad Resource Area, NM 1998. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, 12 pp.

Taylor, M. A., and F. S. Guthery. 1980. Status, ecology, and management of the lesser prairie chicken. United States Department of Agriculture Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report, RM-77:1-15.

Table 1.—Sources of sound in habitat of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in southeastern New Mexico.

Location	Average sound level (decibels)
Active leks of lesser prairie-chickens (n = 33)	30.4
Inactive leks of lesser prairie-chickens (n = 39)	34.8
Control points (n = 60)	32.2
Lekking prairie-chickens (5 displaying males, Lek 45N, 20 m from center of lek)	52.5
Oil drilling rig	
Distance of 20 m (n = 10)	74.7
Distance of 160 m (n = 10)	61.1
Distance of 320 m (n = 10)	54.7
Distance of 480 m (n = 10)	48.6
Distance of 640 m (n = 10)	45.9
Distance of 800 m (n = 10)	43.9
Distance of 960 m (n = 10)	41.7
Distance of 1,120 m (n = 10)	40.6
Distance of 1,280 m (n = 10)	39.5
Distance of 1,440 m (n = 10)	38.3
Distance of 1,600 m (n = 10)	37.9
Propane-powered pumpjacks	
Distance of 20 m (n = 10)	86.5
Distance of 160 m (n = 10)	52.0
Distance of 320 m (n = 10)	44.4
Distance of 480 m (n = 10)	39.7
Distance of 640 m (n = 10)	38.0
Distance of 800 m (n = 10)	36.4
Distance of 960 m (n = 10)	36.5
Distance of 1,120 m (n = 10)	36.1
Distance of 1,280 m (n = 10)	36.2
Distance of 1,440 m (n = 10)	35.9
Distance of 1,600 m (n = 10)	35.3
Electric pumpjacks	
Distance of 20 m (n = 10)	66.1
Distance of 160 m (n = 10)	37.3
Distance of 320 m (n = 10)	36.3

Distance of 480 m (n = 10)	35.3
Distance of 640 m (n = 10)	35.5
Distance of 800 m (n = 10)	35.1
Distance of 960 m (n = 10)	35.5
Distance of 1,120 m (n = 10)	35.4
Distance of 1,280 m (n = 10)	35.4
Distance of 1,440 m (n = 10)	34.9
Distance of 1,600 m (n = 10)	35.1
Compressor stations	
Distance of 20 m (n = 10)	76.8
Distance of 160 m (n = 10)	58.3
Distance of 320 m (n = 10)	49.9
Distance of 480 m (n = 10)	46.5
Distance of 640 m (n = 10)	43.2
Distance of 800 m (n = 10)	40.7
Distance of 960 m (n = 10)	39.0
Distance of 1,120 m (n = 10)	38.4
Distance of 1,280 m (n = 10)	37.5
Distance of 1,440 m (n = 10)	36.5
Distance of 1,600 m (n = 10)	36.0
Vehicles on paved road, about 110 km/h, from 8 m	
Tanker trucks (n = 10)	90.0
Eighteen-wheelers (n = 10)	87.2
Motorcycles (n = 2)	85.6
Work trucks/welding trucks (n = 10)	85.5
Pickup trucks with trailers (n = 10)	85.1
Bus (n = 1)	81.6
Automobiles (n = 10)	81.3
Pickup trucks (n = 10)	80.8

CHAPTER 7

MANAGEMENT RECOMMENDATIONS

INTRODUCTION

Range-wide declines in populations of lesser prairie-chickens (*Tympanuchus pallidicinctus*) have been well documented. Populations may have declined 97% since the 1800s (Taylor and Guthery, 1980). A similar decline in populations has occurred in southeastern New Mexico. Surveys in the 1980s and 1990s suggest that the lesser prairie-chicken has nearly disappeared from breeding leks first documented in Eddy and Lea counties, New Mexico, in the mid-1980s. These leks persisted into the mid-1990s (Johnson and Smith, 1999). Reasons for decline in populations are not well understood. Suggested causes include drought, conversion of habitat to agricultural use, improper grazing management, chemical control of shinnery oak (*Quercus havardii*), hunting, mortality caused by collisions with power lines, and noise and fragmentation of habitat caused by petroleum development (Bevanger, 1995, 1998; Faanes, 1987; Fuhlendorf et al., 2002; Giesen, 1998; Johnson and Smith, 1999; Ligon, 1951; New Mexico Department of Game and Fish, 1999; Peterson and Boyd, 1998).

In 1998, the United States Fish and Wildlife Service listed the lesser prairie-chicken as a candidate for threatened status (Walsh, 1998). Federal agencies, such as the Bureau of Land Management, which administer public lands that include habitat of lesser prairie-chickens, are required to manage for the conservation of the species and to ensure that their actions do not contribute to the further need to list the species as threatened or endangered (Reinke and Swartz, 2001). As a partial response to this requirement, the Bureau of Land Management authorized and provided support for the study documented herein. This study found that breeding

populations of lesser prairie-chickens were extirpated from the Carlsbad Field Office except for an area in the extreme northern part of Lea County and another area near Eunice (Chapter 4). Abandoned leks were associated with overgrazing (Chapter 2), and petroleum development (Chapter 3, Chapter 6). Petroleum development probably is more important than overgrazing in causing declines (Chapter 5). Following are management recommendations made based on results of this study.

MANAGEMENT RECOMMENDATIONS

Shift of emphasis.—To this point, research and management decisions made by personnel of the Carlsbad Field Office regarding lesser prairie-chickens have centered on geographic areas in which active leks formerly occurred. For example, although breeding populations no longer exist in the Querecho Plains area of Lea and Eddy counties (Best, 2001; Best et al., 2003; Chapter 4), much management and research effort of the Bureau of Land Management has been focused there. This area has been heavily developed for petroleum extraction. It is unlikely lesser prairie-chickens will move into the area, and equally unlikely that populations could be reestablished even if birds returned. Fragmentation of habitat, high density of roads and power lines, and noise and disturbance associated with petroleum development combined with chronic overgrazing of the area would likely make this a population sink—an area in which more mortality than production occurs—if lesser prairie-chickens move into the area or are reintroduced (Meffe and Carroll, 1994). Focus of management and research should shift away from this geographic area, and toward areas in the northern part of the Carlsbad Field Office and around Eunice where breeding populations still exist. Methodical surveys to detect leks should be continued through all suitable habitat. Such surveys also need to be conducted in areas with

petroleum development, in the unlikely event that birds return to these areas, but more effort should be concentrated away from such development.

Petroleum development.—Extensive petroleum development is not compatible with healthy populations of lesser prairie-chickens (Chapter 3, Chapter 5). Although populations exist in areas with low levels of petroleum development, current economic and political forces and methods of petroleum extraction tend to push development to high levels once it has entered an area (Conaway, 1999; Energy Information Administration, 2004; Karliner, 1997). Therefore, no new petroleum development should be allowed in areas where populations of lesser prairie-chickens exist. Specifically, development should not be allowed on the Sand Ranch administered by the Roswell Field Office or Prairie Chicken Areas administered by the New Mexico Department of Game and Fish. As active leks are identified in the northern part of the Carlsbad Field Office, areas that contain them should be protected from new petroleum development.

The Bureau of Land Management has taken the precautionary step of restricting oil-field activities in suitable habitat during the breeding season of lesser prairie-chickens in the Carlsbad Field Office. These restrictions include maintenance of noise levels <75 decibels on existing oil and gas production equipment, no drilling of new wells between 15 March and 15 June in areas that have not been surveyed for lesser prairie-chickens or in areas that contain known active leks, and no maintenance of wells or construction activities commencing before 0900 h. These restrictions seem unnecessary in areas where there are no remaining populations of lesser prairie-chickens, and inadequate where populations occur. Much time and resources are spent by biologists of the Bureau of Land Management researching and processing possible exclusions to these restrictions, most of which are granted (J. S. Sherman, pers. comm.). These restrictions

may have become more of a hindrance to biologists than to petroleum developers. Consideration should be given to modifying these restrictions.

If no oil or gas are present, or when available oil has been removed from a well, the drill pad should be reclaimed and the road leading to the drill pad should be destroyed. This has been done at some wells (for example, BB-1—Appendix I). Drill pads and roads often are destroyed by plowing them over without first removing the caliche surface. If this is done, years may elapse before native plants become reestablished. Caliche should be removed from abandoned drill pads and roads before they are destroyed. In the past, if seeding was done, non-native grasses such as Lehmann lovegrass (*Eragrostris lehmanniana*) sometimes were used. Reseeding reclaimed areas is desirable, but native grasses, especially sand bluestem (*Andropogon halli*), should be used.

Overgrazing.—Lesser prairie-chickens have coexisted with grazing animals such as bison (*Bison bison*) and pronghorns (*Antilocapra americana*) for their entire evolutionary history, and this fact often is used as justification for allowing grazing in areas important to lesser prairie-chickens (Brown and McDonald, 1995; Owen-Smith, 1988). However, bison probably were never present in New Mexico in numbers in which cattle now occur, and they were not confined to fenced pastures. Representatives of the cattle industry claim that more research is necessary to establish that overgrazing is harmful (Arritt, 1998). However, it is well established that overgrazing is detrimental to reproduction of lesser prairie-chickens (Ahlborn, 1980; Davis et al., 1979; Giesen, 1994; Jackson and DeArment, 1963).

This study found that abandoned leks were associated with effects of overgrazing (Chapter 2). Even in areas where residual grasses existed in some years, relative amounts of species of grass indicated that areas surrounding abandoned leks had been subject to long-term

overgrazing. This overgrazing resulted in greater incidence of sand dropseed (*Sporobolus cryptandrus*), which replaces *Andropogon* under heavy grazing regimes. *Andropogon* is necessary for concealment of nests. Previous studies have reported that much of the historic range of lesser prairie-chickens in New Mexico is overgrazed (Bailey et al., 2000). This study supports that claim. If populations of lesser prairie-chickens are to be preserved and reestablished in the Carlsbad Field Office, grazing must be reduced. Lower grazing allotments should be imposed, especially in areas with petroleum development. Height of residual grasses in each pasture that contains leks should be monitored using the Robel method (Robel et al., 1970).

Reestablishment of populations of lesser prairie-chickens.—Efforts should be made to identify areas with low levels of petroleum development where populations might become reestablished if grazing pressure is relaxed. Suggested areas include the Bilbrey Basin in Lea County, the San Simon Swale west of Eunice in Lea County, and some areas in the eastern Querecho Plains in Lea County. The Sand Ranch in the Roswell Field Office may be a good example of proper management of grazing. To protect populations from stochastic events such as drought, some parts of these areas should be kept free of grazing. These areas could be maintained with prescribed fires if necessary (Boyd and Bidwell, 2001).

Reduction or elimination of grazing would eventually result in return of *Andropogon* (Ross and Bailey, 1967). This process could be aided by planting seed of *Andropogon* in desired areas. Because it may be detrimental to populations of lesser prairie-chickens (Chapter 2), it may be necessary to remove honey mesquite (*Prosopis glandulosa*), either by mechanical or selective chemical means.

Removal of shinnery oak often is suggested as a way of improving habitat by increasing grass cover. However, research indicates that removal of shinnery oak may be detrimental to lesser prairie-chickens (Johnsgard, 2002; Olawsky, 1987). The present study found no relationship between amount of shinnery oak and abandonment of leks (Chapter 2). Because shinnery oak is important to lesser prairie-chickens as food and cover (Davis et al., 1979; Johnsgard, 2002), it is recommended that treatment of shinnery oak with tebuthiuron be avoided. In the event that removal of shinnery oak is deemed essential, temporary removal may be accomplished with prescribed fire (Peterson and Boyd, 1998).

Once suitable habitat is reestablished, it is possible that lesser prairie-chickens will return naturally. Individuals move during winter to find food sources (Sharpe, 1968); such individuals have been observed on several occasions within the Carlsbad Field Office (Best, 2001; Best et al., 2003; S. Belinda and T. L. Best, pers. comm.). Female grouse may remain in new areas if suitable habitat is present (Bergerud and Gratson, 1988). However, remaining populations near Eunice and in nearby Texas probably are very small (Best et al., 2003; Sullivan et al., 2000). It may be necessary to reintroduce lesser prairie-chickens.

Off-road vehicles.—Off-road vehicles have gained in popularity for recreational use, and for use by resource managers and researchers. Off-road vehicles can cause damage to habitat of desert birds by destroying residual grasses needed for nesting and cover (Luckenbach, 1978). For example, on 1 February 2003, we observed an off-road vehicle being used to track a radio-equipped lesser prairie-chicken at lek NB-1 east of Milnesand (Appendix I). The pasture, which also contained another active lek (NB-2—Appendix I), was criss-crossed with tracks from the off-road vehicle. A great deal of residual vegetation had been destroyed by the vehicle. We continued to observe the vehicle as we conducted plant transects. It was finally loaded into a

pickup truck that was clearly marked with insignia of a research organization conducting research on lesser prairie-chickens in the area. The New Mexico Department of Game and Fish later closed the area to off-road use. It is recommended that off-road vehicles are prohibited in areas occupied by lesser prairie-chickens.

Power lines.—Numerous abandoned drill pads were observed that still had standing electrical poles with attached power lines. For example, the abandoned drill pad nearest to lek QP-23 (Appendix I) had a power line that ran nearly 2 km from the nearest operational pumpjack. Many birds, including lesser prairie-chickens, suffer mortality due to collisions with power lines (Bevanger, 1995; Ligon, 1951; Jamison, 2000). Unused power lines should be removed. In addition, petroleum developers should be encouraged to place power lines underground when possible.

Cooperative arrangements for access to private lands.—It seems probable that breeding leks of lesser prairie-chickens occur on private lands. For example, conversations with local residents indicate that populations occur on private ranches north of Eunice (J. L. Hunt, pers. obs.). It is desirable to determine the status of lesser prairie-chickens on these lands. It may be necessary to institute a program similar to that used by the Texas Parks and Wildlife Department. In this program, personnel of the Department are allowed access to private lands to determine status of populations, but agree to keep the status private (H. A. Whitlaw, pers. comm.). This helps allay fears of landowners that data gathered may be used to place restrictions on use of their land. Such a program also would help build trust and goodwill between personnel of the Bureau of Land Management and private ranchers, and could be used as a starting point to encourage landowners to manage their lands for lesser prairie-chickens.

Future research.—Surveys for leks of lesser prairie-chickens should be continued throughout suitable habitat within the Carlsbad Field Office, with emphasis in areas near where populations are known to occur. These areas include habitat near Eunice, areas in the northern part of Lea County, and areas north of heavy petroleum development near Loco Hills. Surveys should be conducted at least three times during the breeding season (Chapter 4).

Studies of feasibility of reintroduction of lesser prairie-chickens should be conducted. Such studies have been conducted for sharp-tailed grouse and greater prairie-chickens (Rodgers, 1992). This would serve as a starting point for reintroduction of lesser prairie-chickens, once suitable habitat is identified and protected.

The present study suggests that an interaction between grazing and presence of roads may contribute to decline in populations of lesser prairie-chickens (Chapter 3). Research into this relationship could be conducted by performing surveys of plant species near roads in ungrazed areas and in moderately and heavily grazed areas.

Much effort has been expended to place watering devices into habitat formerly and currently occupied by lesser prairie-chickens. However, little research has been conducted to determine effects of waterers on wildlife, and results of research that has been conducted is equivocal and controversial (Broyles, 1995; Rosenstock et al., 1999). It is recommended that a study be undertaken to determine effects of wildlife waterers on lesser prairie-chickens. Until such studies are complete, it is recommended that no further waterers are constructed in areas where the species occurs. Lesser prairie-chickens may use open water if it is available (Crawford and Bolen, 1973), but it is unlikely that it is necessary for survival or reproduction (Giesen, 1998; Schmidt-Nielsen, 1964). Therefore, artificial waterers may have only negative effects on populations by attracting predators and facilitating spread of disease (Broyles, 1995).

The recommendations within this report will require much in the way of manpower and resources. Interaction with biologists of the Bureau of Land Management has made plain their enthusiasm for protection and reestablishment of lesser prairie-chickens and their dedication to balancing the many uses of the land and resources entrusted to them. We encourage further support of, and cooperation with, these biologists, both from within the Bureau and from state and federal agencies.

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LITERATURE CITED

Ahlborn, G. G. 1980. Brood-rearing habitat and fall-winter movements of lesser prairie chickens in eastern New Mexico. M.S. thesis, New Mexico State University, Las Cruces, 73 pp.

Arritt, S. 1998. Reversing the decline of lesser prairie-chickens. New Mexico Wildlife, 43(4):14-16.

Bailey, J. A., J. Klingel, and C. A. Davis. 2000. Status of nesting habitat for lesser prairie-chicken in New Mexico. The Prairie Naturalist, 32:149-156.

Bergerud, A. T., and M. W. Gratson. 1988. Survival and breeding strategies of grouse. Pp. 473-577 *in* Adaptive strategies and population ecology of northern grouse (A. T. Bergerud and M. T. Gratson, eds.). University of Minnesota Press, Minneapolis, 2 vols., 809 pp.

Best, T. L. 2001. Status of the lesser prairie chicken (*Tympanuchus pallidicinctus*) on lands administered by the Bureau of Land Management in Southeastern New Mexico. Oil and Gas Consortium, Artesia, New Mexico, 517 pp.

Best, T. L., K. Geluso, J. L. Hunt, and L. A. McWilliams. 2003. The lesser prairie chicken (*Tympanuchus pallidicinctus*) in southeastern New Mexico: a population survey. The Texas Journal of Science, 55:225-234.

Bevanger, K. 1995. Estimates and population consequences of tetraonid mortality caused by collisions with high tension power lines in Norway. The Journal of Applied Ecology, 32:745-753.

Bevanger, K. 1998. Biological and conservation aspects of bird mortality caused by electricity power lines: a review. Biological Conservation, 86:67-76.

Boyd, C. S., and T. G. Bidwell. 2001. Influence of prescribed fire on lesser prairie-chicken habitat in shinnery oak communities in western Oklahoma. Wildlife Society Bulletin, 29:938-947.

Brown, J. H., and W. McDonald. 1995. Livestock grazing and conservation on southwestern rangelands. Conservation Biology, 9:1644-1647.

Broyles, B. 1995. Desert wildlife water developments: questioning use in the Southwest. Wildlife Society Bulletin, 23:663-675.

Conaway, C. F. 1999. The petroleum industry: a nontechnical guide. PennWell Publishing, Tulsa, Oklahoma, 289 pp.

Crawford, J. A., and E. G. Bolen. 1973. Spring use of stock ponds by lesser prairie chickens. The Wilson Bulletin, 85:471-472.

Davis, C. A., T. Z. Riley, R. A. Smith, H. R. Suminski, and D. M. Wisdom. 1979. Final report: habitat evaluation of lesser prairie-chickens in eastern Chaves County, New Mexico. Department of Fish and Wildlife Sciences, New Mexico Agricultural Experiment Station, Las Cruces, 141 pp.

Energy Information Administration. 2004. Country analysis briefs: United States of America. United States Department of Energy, Washington, D.C., 22 pp.

Faanes, C. A. 1987. Bird behavior and mortality in relation to power lines in prairie habitats. United States Department of the Interior, Fish and Wildlife Service, Fish and Wildlife Technical Report, 7:1-24.

Fuhlendorf, S. D., A. J. W. Woodward, D. M. Leslie, Jr., and J. S. Shackford. 2002. Multi-scale effects of habitat loss and fragmentation on lesser prairie-chicken populations of the US southern Great Plains. Landscape Ecology, 17:617-628.

Giesen, K. M. 1994. Movements and nesting habitat of lesser prairie-chicken hens in Colorado. The Southwestern Naturalist, 39:96-98.

Giesen, K. M. 1998. *Tympanuchus pallidicinctus:* lesser prairie chicken. The Birds of North America, 364:1-19.

Jackson, A. S., and R. DeArment. 1963. The lesser prairie chicken in the Texas Panhandle. The Journal of Wildlife Management, 27:733-737.

Jamison, B. E. 2000. Lesser prairie chicken chick survival, adult survival, and habitat selection and movements of males in fragmented rangelands of southwestern Kansas. M.S. thesis, Kansas State University, Manhattan, 197 pp.

Johnsgard, P. A. 2002. Grassland grouse and their conservation. Smithsonian Institution Press, Washington, D.C.,157 pp.

Johnson, K., and H. Smith. 1999. Survey of the lesser prairie-chicken on Bureau of Land Management lands, Carlsbad Resources Area, NM, 1999. New Mexico Natural Heritage Program, Department of Biology, University of New Mexico, Albuquerque, 44 pp.

Karliner, J. 1997. The corporate planet. Sierra Club Books, San Francisco, California, 298 pp.

Ligon, J. S. 1951. Prairie chickens, highways, and power lines. New Mexico Magazine, 29(5):29.

Meffe, G. K., and C. R. Carroll. 1994. Principles of conservation biology. Sinauer Associates, Inc., Sunderland, Massachusetts, 600 pp.

New Mexico Department of Game and Fish. 1999. Status and trend of the lesser prairie-chicken in New Mexico and recommendation to list the species as threatened under the New Mexico Conservation Act. New Mexico Department of Game and Fish, Santa Fe, 32 pp.

Olawsky, C. D. 1987. Effects of shinnery oak control with tebuthiuron on lesser prairie-chicken populations. M.S. thesis, Texas Tech University, Lubbock, 83 pp.

Owen-Smith, R. N. 1988. Megaherbivores: the influence of very large body size of ecology. Cambridge University Press, Cambridge, United Kingdom, 369 pp.

Peterson, R. S., and C. S. Boyd. 1998. Ecology and management of sand shinnery communities: a literature review. United States Department of Agriculture Forest Service, Rocky Mountain Research Station, General Technical Report, RMRS-GTR-16:1-44.

Reinke, D. C., and L. L. Swartz. 2001. Endangered species: legal requirements and policy guidance. Batelle Press, Columbus, Ohio, 469 pp.

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

Rodgers, R. D. 1992. A technique for establishing sharp-tailed grouse in unoccupied range. Wildlife Society Bulletin, 20:101-106.

Rosenstock, S. S., W. B. Ballard, and J. C. DeVos, Jr. 1999. Viewpoint: benefits and impacts of wildlife water developments. Journal of Range Management, 52:302-311.

Ross, W. J., and O. F. Bailey. 1967. Soil survey of Roosevelt County, New Mexico. United States Department of Agriculture, Soil Conservation Service, Washington, D. C., 74 pp.

Schmidt-Nielsen, K. 1964. Desert animals: physiological problems of heat and water. Oxford University Press, London, United Kingdom, 277 pp.

Sharpe, R. S. 1968. The evolutionary relationships and comparative behavior of prairie chickens. Ph.D. dissertation, University of Nebraska, Lincoln, 188 pp.

Sullivan, R. M., J. P. Hughes, and J. E. Lionberger. 2000. Review of the historical and present status of the lesser prairie-chicken (*Tympanuchus pallidicinctus*) in Texas. Prairie Naturalist, 32:177-178.

Taylor, M. A., and F. S. Guthery. 1980. Status, ecology, and management of the lesser prairie chicken. United States Department of Agriculture Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report, RM-77:1-15.

Walsh, N. E. 1998. Endangered and threatened wildlife and plants; 12-month finding for a petition to list the lesser prairie chicken as threatened and designate critical habitat. The Federal Register, 63:31400-31406.