Lesser Prairie-chicken (*Tympanuchus pallidicinctus*): A Technical Conservation Assessment

Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project

March 31, 2005

Leslie A. Robb[1] and Michael A. Schroeder[2]
[1]P.O. Box 1077, Bridgeport, WA 98813
[2]Washington Department of Fish and Wildlife
P.O. Box 1077, Bridgeport, WA 98813

Peer Review Administered by
Society for Conservation Biology

Robb, L.A. and M.A. Schroeder. (2005, March 31). Lesser Prairie-chicken (*Tympanuchus pallidicinctus*): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/lesserprairiechicken.pdf [date of access].

ACKNOWLEDGMENTS

The authors would like to thank the Species Assessment Core Team for Region 2 of the USDA Forest Service for guidance during this project. K. Giesen kindly provided an extensive bibliography of lesser prairie-chicken literature and was helpful answering inquiries about lesser prairie-chickens in Colorado. The manuscript benefited greatly from comments by anonymous reviewers.

AUTHORS' BIOGRAPHIES

Leslie A. Robb earned degrees from Acadia University (1983, B.Sc. Honors) and the University of Alberta (1987, M.Sc. Zoology), where she worked with W. A. Samuel on lungworm parasites of bighorn sheep. She has since conducted fieldwork on greater prairie-chickens and white-tailed ptarmigan in Colorado working with M. A. Schroeder, C. E. Braun, and K. Martin. She is an author of the white-tailed ptarmigan and the greater prairie-chicken species accounts for the Birds of North America (American Ornithologists' Union).

Michael A. Schroeder earned degrees from Texas A&M University (1980, B.Sc., Wildlife Ecology), the University of Alberta (1984, M.Sc., Zoology), and Colorado State University (1989, Ph.D., Wildlife Biology). He currently works for the Washington Department of Fish and Wildlife as the Upland Bird Research Biologist. He has been conducting research on the behavior, population dynamics, and management of grouse since 1982 and has publications on greater and lesser prairie-chickens, spruce grouse, sharp-tailed grouse, and greater sage-grouse.

COVER PHOTO CREDIT

The lesser prairie-chicken photo was provided with permission by Christian A. Hagen from research he conducted in Kansas.

Summary of Key Components for Conservation of Lesser Prairie-chicken

Status

The overall distribution of the lesser prairie-chicken (*Tympanuchus pallidicinctus*) has declined an estimated 92 percent since settlement by people of European descent and an estimated 78 percent since the early 1960s. Concurrent with this decrease in occupied range, numbers of lesser prairie-chickens have declined at least 90 percent since European settlement, resulting in smaller, more isolated populations. As a consequence of these declines, the lesser prairie-chicken is a candidate for federal listing as a threatened or endangered species.

Primary Threats

The major threats to the lesser prairie-chicken in USDA Forest Service Region 2 are the loss, fragmentation, and degradation of habitat on both private and public lands. Conversion of native prairie habitat increasingly isolates populations, elevating the risk of localized extirpations and leading to an erosion of metapopulation viability. Populations throughout the species' range are vulnerable to land use practices that degrade or eliminate nesting and brood-rearing areas. Some of the fundamental threats to this species include:

- inappropriate timing and intensity of livestock grazing
- conversion of native prairie for development and crop production
- fragmentation of habitat with roads, utility corridors, fences, towers, turbines, and energy developments
- introduction and expansion of noxious weeds
- alteration of fire regimes
- planting of trees.

Primary Conservation Elements, Management Implications, and Considerations

In managing for the conservation of this species, land managers must consider practices associated with grazing, farming, burning, and mowing of potential and occupied habitat, as well as the impacts of urban development, roads, power lines, fences, oil and gas development, tree planting/encroachment, and off- road vehicles. The inappropriate timing and intensity of livestock grazing, in particular, can cause widespread degradation of habitat for lesser prairie-chickens by homogenizing the essential heterogeneous grassland landscape created by the native ungulate grazing fauna prior to European settlement. Features associated with human development (e.g., communities, roads, land use changes, herbicides) also contribute to habitat fragmentation, alter predation dynamics, and introduce disturbance and mortality factors.

TABLE OF CONTENTS

EDITORS: John Sidle and Gary Patton, USDA Forest Service, Rocky Mountain Region

LIST OF TABLES AND FIGURES

Tables:

Figures:

INTRODUCTION

This conservation assessment is one of many being produced to support the Species Conservation Project of the Rocky Mountain Region (Region 2), USDA Forest Service (USFS). The lesser prairie-chicken (*Tympanuchus pallidicinctus*) is the focus of an assessment because it has been designated a sensitive species by USFS Region 2 and petitioned for listing under the Endangered Species Act of 1973. Review of the listing petition by the U.S. Fish and Wildlife Service (USFWS) concluded that listing is warranted but currently precluded due to listing actions of higher priority. Threats to this species are considered by the USFWS to be moderate and imminent.

While this assessment addresses the biology of the lesser prairie-chicken throughout its range, it focuses on Region 2. However, because the overall range of the lesser prairie-chicken is relatively small, its biology, ecology, and management in Oklahoma, Texas, and New Mexico (outside Region 2) are relevant within Colorado and Kansas (within Region 2).

Goal of Assessment

Species conservation assessments produced as part of the Species Conservation Project are designed to provide land managers, biologists, and the public with a thorough discussion of the biology, ecology, conservation, and management of certain species based on existing scientific knowledge. The assessment goals limit the scope of the work to summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific prescriptions for management of populations and habitats. Rather, it provides the ecological background upon which management should be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, this assessment cites previously published management recommendations and examines the success of those recommendations that have been implemented.

Scope of Assessment

The assessment examines the biology, ecology, conservation, and management of lesser prairie-chickens with specific reference to the geographic and ecological characteristics of the USFS Region 2. Although a majority of the literature on the species originates from field investigations and planning outside the region, this document places that literature in the ecological and social context of Region 2. For example, lesser prairie-chickens are found outside Region 2 in Oklahoma, Texas, and New Mexico. Nevertheless, some of these areas have habitats and population characteristics comparable to areas in Region 2. In fact, some populations are shared between states. This assessment also is concerned with reproductive behavior, population dynamics, and other characteristics of lesser prairie-chickens in the context of the current environment. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

Data Used to Produce this Assessment

In producing this assessment, most attention was focused on peer-reviewed sources such as journal publications, theses and dissertations, and agency and university technical reports. The numerous references that were not peer-reviewed were not considered, except in situations where peer-reviewed information was not available. In these situations, the nature of the information was clearly acknowledged. In addition, the strength of evidence for particular ideas is noted and alternative explanations are described when appropriate.

Treatment of Uncertainty

Most of the available research on lesser prairie-chickens is based on correlative information. Controlled experiments at the appropriate scale are extremely difficult to conduct on species that occupy broad home ranges where there is minimal management control. Consequently, we attempt to provide details of the referenced research (such as sample sizes) so that the reader can understand some of the strengths and weaknesses of the inferences. We also attempted to avoid references that were not peer-reviewed such as magazine and newspaper articles and some agency reports. Although peer-review does not eliminate uncertainty or the possibility of error, it at least assures that the research has undergone review by other scientists.

Publication of Assessment on the World Wide Web

To facilitate use of these conservation assessments, they are being published on the USFS Region 2 World Wide Web site. Placing the documents on the web makes them available to agency biologists and managers, other agencies, and the public more rapidly than publication

as a book or report. More importantly, future revision of the assessments will be facilitated. Revision will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the Web. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment. Peer review of this assessment was administered by the Society for Conservation Biology, using two experts on the subject or related species.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

The lesser prairie-chicken was petitioned for listing under the federal Endangered Species Act in 1995. The 12-month finding was "warranted but precluded" with threats considered to be moderate and imminent (U.S. Fish and Wildlife Service 1998). Lesser prairie-chickens are currently a candidate for listing with an assigned listing priority of 8 (scale of 1 to 12, with 1 being the most urgent; U.S. Fish and Wildlife Service 2004). Since 1973 the lesser prairie-chicken has been listed as state threatened in Colorado under the Nongame and Endangered or Threatened Species Conservation Act (closed hunting season). It is considered a game species in Kansas, with an annual limited harvest, and a gamebird in New Mexico (closed hunting season), Oklahoma (closed hunting season), and Texas (open hunting season). The lesser prairie-chicken is listed as a sensitive species by USFS Region 2 and a Management Indicator Species on the Comanche and Cimarron national grasslands (**Figure 1**). The Bureau of Land Management considers the lesser prairie-chicken in its regional management plans, primarily eastern New Mexico (Bureau of Land Management 2005). Partners in Flight has placed the lesser prairie-chicken on their Watch List with multiple causes for concern across its entire range, and has assigned it a combined vulnerability assessment score of 20 out of a maximum possible of 20 (Rich et al. 2004). The lesser prairie-chicken is on the International Union for Conservation of Nature and Natural Resources" (IUCN) Red List as a threatened species (Storch 2000).

Existing Regulatory Mechanisms and Management/Conservation Strategies

The USFS Region 2 considers the lesser prairie-chicken a sensitive species based on several characteristics including distribution, population abundance and trend, habitat vulnerability and trend, dispersal capability, and demographics. The official USFS policy on "Wildlife, Fish, and Sensitive Plant Habitat Management" (Amendment number 2600-95-7; June 23, 1995) lists numerous issues that apply to the lesser prairie-chicken. In the U.S. Code (Title 16, Chapter 35, § 1534), the Secretary of Agriculture is designated with the responsibility to "establish and implement a program to conserve fish, wildlife, and plants, including those which are listed as endangered species or threatened species…" The U.S. Code (Title 16, Chapter 35, § 1536) adds to this responsibility by mandating conference with the appropriate Secretary whenever an action is likely to jeopardize the continued existence of any species proposed for listing as threatened or endangered, or whenever an action might result in destruction or adverse modification of critical habitat proposed for listing.

FSM 2670.12 (Amendment number 2600-95-7; June 23, 1995) clarifies the authority of the USFS to deal with threatened and endangered species:

1. Manage "habitats for all existing native and desired nonnative plants, fish, and wildlife species in order to maintain at least viable populations of such species."

2. Conduct activities and programs "to assist in the identification and recovery of threatened and endangered plant and animal species."

3. Avoid actions "which may cause a species to become threatened or endangered."

FSM 2670.22 (Amendment number 2600-95-7; June 23, 1995) lists the objectives of the USFS with regard to sensitive species:

1. Develop and implement management practices to ensure that species do not become threatened or endangered because of USFS actions.

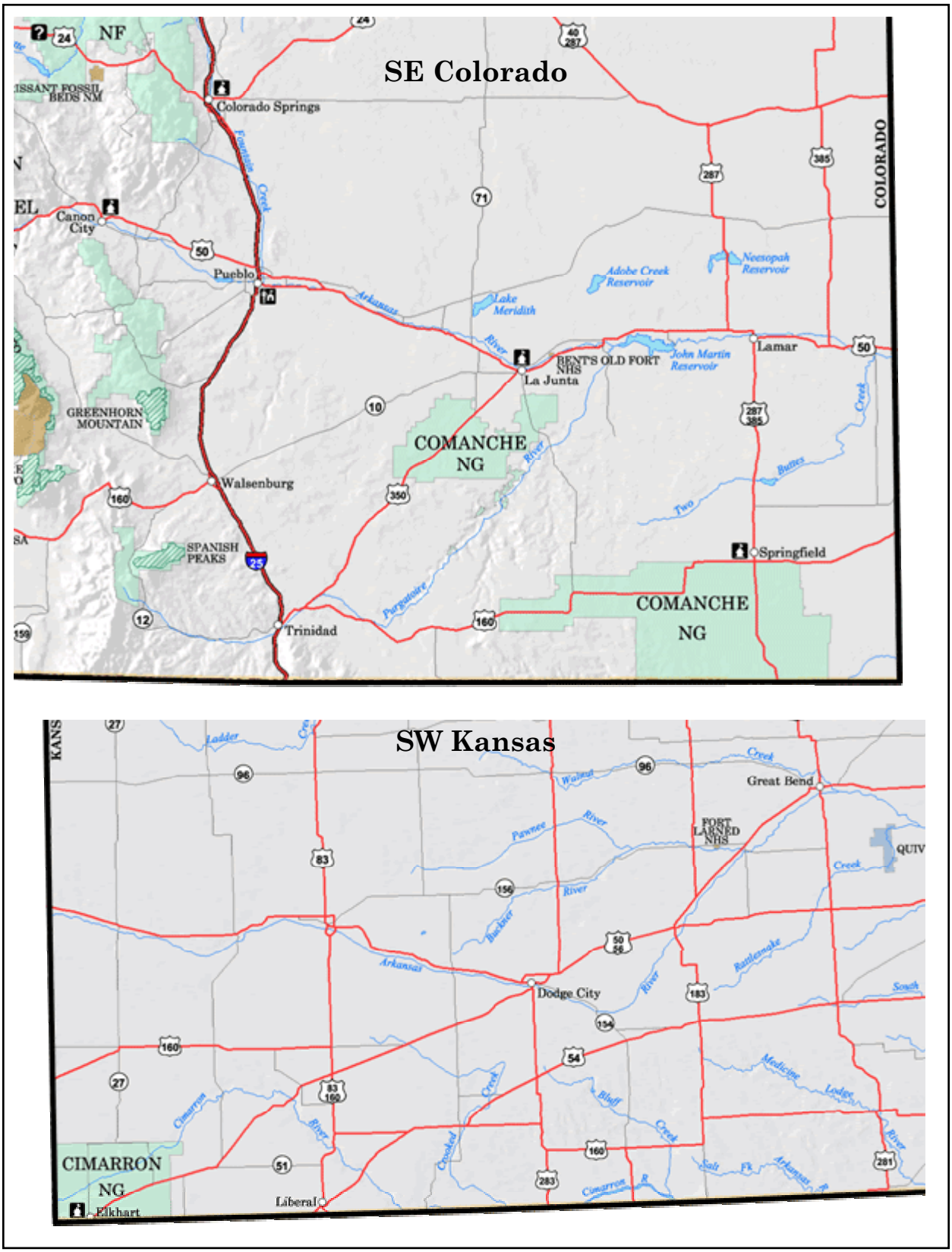

Figure 1. Location of national grasslands in southeastern Colorado and southwestern Kansas within the Rocky Mountain Region of the USDA Forest Service.

2. Maintain viable populations of all native and desired nonnative wildlife, fish, and plant species in habitats distributed throughout their geographic range on National Forest System lands.

3. Develop and implement management objectives for populations and/or habitat of sensitive species.

FSM 2670.32 (Amendment number 2600-95-7; June 23, 1995) lists the official policy of the USFS with regard to sensitive species:

1. Assist States in achieving their goals for conservation of endemic species.

2. As part of the National Environmental Policy Act process, review programs and activities, through a biological evaluation, to determine their potential effect on sensitive species.

3. Avoid or minimize impacts to species whose viability has been identified as a concern.

4. If impacts cannot be avoided, analyze the significance of potential adverse effects on the population or its habitat within the area of concern and on the species as a whole. (The line officer, with project approval authority, makes the decision to allow or disallow impact, but the decision must not result in loss of species viability or create significant trends toward Federal listing.)

5. Establish management objectives in cooperation with the States when projects on National Forest System lands may have a significant effect on sensitive species population numbers or distributions. Establish objectives for Federal candidate species, in cooperation with the USFWS or the National Marine Fisheries Service and the States.

In contrast to sensitive species, Management Indicator Species (MIS) are chosen as indicators of particular management strategies. The lesser prairie-chicken has been designated as a MIS on the Comanche and Cimarron national grasslands (USDA Forest Service, **Figure 1**). The Resource Management Plan contains guidelines for management of lesser prairie-chicken habitat (U.S. Fish and Wildlife Service 2002). There also is a detailed management plan for lesser prairie-chickens in New Mexico (Massey 2001).

Most currently occupied habitat occurs on private lands in Region 2, where state and federal agencies have little regulatory authority to protect this species or its habitat (U.S. Fish and Wildlife Service 2002). Consequently, addressing the problems associated with conservation of lesser prairie-chickens will necessitate cooperation and coordination of efforts among federal and state agencies, non-governmental organizations, and private landowners (Massey 2001). The Wildlife Habitat Management Institute (1999) published habitat management guidelines for lesser prairie-chickens that emphasize cooperation and coordination between public agencies and private landowners. The Lesser Prairie-chicken Interstate Working Group (LPCIWG), comprised of the five state wildlife agencies within the current range of lesser prairie-chickens, in addition to other state, federal, and private organizations, has prepared a range-wide conservation strategy for lesser prairie-chickens (Mote et al. 1998). The IUCN also has produced a status survey and conservation action plan for grouse species worldwide, including the lesser prairie-chicken (Storch 2000).

Biology and Ecology

Systematics and general species description

The lesser prairie-chicken belongs to the Order Galliformes, Family Phasianidae, and subfamily Tetraoninae. The first description of the lesser prairie-chicken was published in 1873 by Ridgway, who considered it a race of the greater prairie-chicken (*Tympanuchus cupido*) (Baird and Ridgway 1873). In 1885 Ridgway amended his original description and assigned the lesser prairie-chicken specific status; at that time the scientific name was changed from *Cupidonia cupido* var. *pallidicincta* to the present designation *T. pallidicinctus* (Ridgway 1885).

The lesser prairie-chicken is a medium-sized grouse, similar to, but slightly smaller than, the greater prairie-chicken; total body length is 38 to 41 cm (Johnsgard 1983, Giesen 1998). Body mass averages 752 g for males and 712 g for females; however, considerable variation occurs among seasons, age and sex classes, and regions (Giesen 1998). Plumage is similar for males and females and typically is barred with alternating brown and buffy-white bands; the upper body is somewhat darker than the belly (Giesen 1998). The body is oval in shape, and the tail is short

and rounded in appearance. On the sides of the neck, males possess long tufts of feathers (pinnae) that they hold erect during courtship displays; females have smaller, less prominent, pinnae feathers. Males also exhibit bright yellow eyecombs above the eye, and dull red esophogeal air sacs on the sides of the neck during courtship behavior. The outer rectrices of males also have less horizontal barring than the outer rectrices of females (Pitman et al. 2005).

Currently, lesser prairie-chickens and greater prairie-chickens are recognized as distinct species (American Ornithologists' Union 1957, 1983). However relatively minor differences in appearance, habitat, and behavior between the two species have generated debate regarding the specific classification of the lesser prairie-chicken. In general, greater prairie-chickens are slightly larger and darker than lesser prairie-chickens, and the males have orange scarlet-edged air sacs (Schroeder and Robb 1993, Giesen 1998). Aldrich and Duvall (1955:8) believed that "... no characters [of the lesser prairie-chicken] differ from those of the other prairie chickens, except in degree; thus, only a racial difference is indicated". But Aldrich (1963:537) later stated that "... the lesser prairie-chicken appears to have sufficiently separated morphological characters to be considered a distinct species by most ornithologists." Short (1967) and Johnsgard (1983) considered lesser and greater prairie-chickens allopatric subspecies while Sharpe (1968) suggested that they were allospecies of one superspecies. However, Jones (1964a) examined the behavioral and morphological characteristics of both the lesser and greater prairie-chicken and concluded that specific status of the lesser prairie-chicken was warranted. In a comprehensive review of the reproductive behavior of Tetraonidae, Hjorth (1970) also treated the lesser prairie-chicken as a separate species. Examination of genetic variation among members of the genus *Tympanuchus* indicates low levels of interspecific divergence, suggesting recent speciation among the North American prairie-grouse (Ellsworth et al. 1994, Ellsworth et al. 1995, Gutiérrez et al. 2000, Drovetski 2002, Drovetski 2003). Ellsworth et al. (1994) postulated that morphological and behavioral differences observed within the genus *Tympanuchus* may result from sexual selection.

Reports of hybridization between the lesser prairie-chicken and other species in the genus *Tympanuchus* are rare (U.S. Fish and Wildlife Service 2002). In captivity, crosses between lesser prairie-chickens and greater prairie-chickens (*T. cupido pinnatus*) have produced fertile offspring (Crawford 1978). In recent years, traditional display sites (leks) with both lesser and greater prairie-chicken males have been observed north of the Arkansas River in western Kansas during the breeding season. Behavioral observations indicate that some males exhibit courtship behaviors and vocalizations intermediate between the two species, and recent hybridization has been confirmed (U.S. Fish and Wildlife Service 2002). Lesser prairie-chickens may be confused with greater prairie-chickens in areas where the two species overlap (primarily in Wallace, Logan, Gove, Trego, Scott, Lane, and Ness counties in western Kansas).

Distribution and abundance

Historical and current global distribution and abundance

The lesser prairie-chicken is endemic to the xeric grasslands of the southern Great Plains of North America (**Figure 2**; Giesen 1994a, Giesen 1998, Mote et al. 1998, Hagen et al. 2004). Few records exist to verify the historical distribution of lesser prairie-chickens prior to European settlement because the geographic region that is generally regarded as historical range (southeastern Colorado, southwestern Kansas, western Oklahoma, northern Texas, and eastern New Mexico) was largely unexplored during the 1800s (Aldrich and Duvall 1955, Sharpe 1968). The first expeditions to explore Colorado tended to bypass the southeastern part of the state (Rockwell 1908), and it was not until 1914 that lesser prairie-chickens were recorded officially from Baca County (Lincoln 1918). In Kansas and Oklahoma, the area south of the Arkansas River was considered "Indian Territory" or "No Man's Land" and was not officially opened for settlement until the late 1890s (Copelin 1959). At that time, settlement occurred rapidly, and the landscape changed "... almost before the species [lesser prairie-chicken] was described" (Sharpe 1968:40). Early records from Texas indicate that the historical range of the lesser prairie-chicken included the High and Rolling Plains in the panhandle part of the state (Jackson and DeArment 1963, Litton 1978). However, it has been suggested that "... even during the time of wide distribution, the lesser prairie-chicken may have been only a winter migrant in the southernmost part of its range in Texas." (Jackson and DeArment 1963:733). In eastern New Mexico, the lesser prairie-chicken is believed to have inhabited the area from Union County south to the New Mexico-Texas border (Bailey 1928, Sands 1968). Lesser prairie-chickens were reported in New Mexico first in 1854 when Capt. Chas L. Taplin mentioned in his notes that "prairie chickens" were numerous in the area northeast of the confluence of the Delaware and Pecos rivers in present

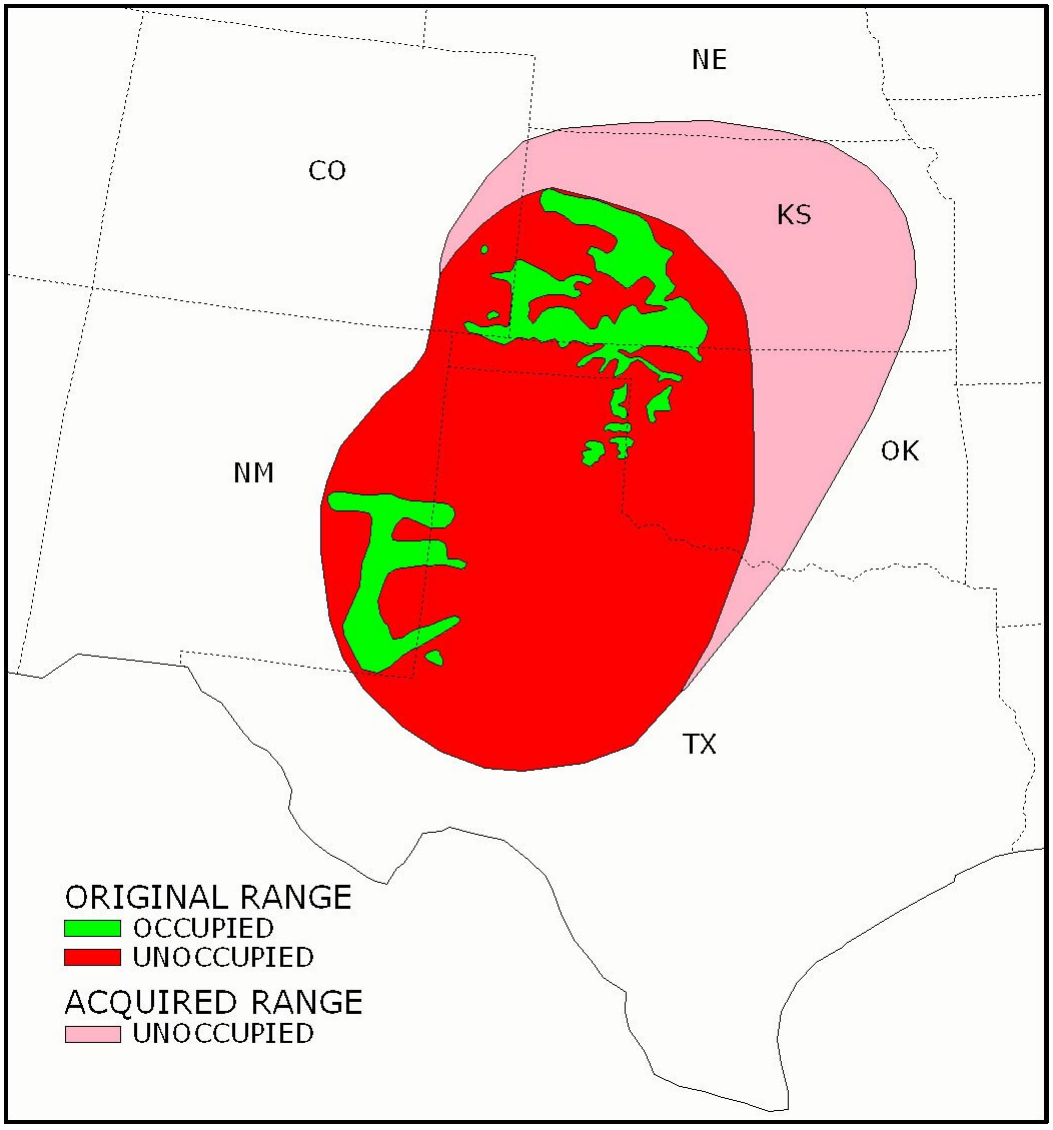

Figure 2. Original (pre-European settlement), acquired, and current distribution of lesser prairie-chickens in North America (based on Mote et al. 1998, Silvy and Hagen 2004).

day southeastern Eddy County (Bailey 1928). The type specimens for the lesser prairie-chicken were collected during this same expedition from the Staked Plains region by Capt. John Pope in 1854 near the Clear Fork of the Brazos River (Bailey 1928, citing Pope's diary).

Several references document the presence of lesser prairie-chickens in areas generally considered outside their historical range (Sharpe 1968). Bendire (1892, quoting William Lloyd) mentions birds observed in Concho County, and along the Middle Concho River in Tom Green County, Texas, and Bent (1932) noted winter flocks near Carlsbad, New Mexico. The eastern-most record of lesser prairie-chickens comes from Lawrence (1877:52), who identified specimens of lesser prairie-chickens that had been shipped from Pierce City, southwestern Missouri for sale in the Fulton Market, New York City: "... I got two in good condition. On examination they agreed accurately with Mr. Ridgway's description ... All I talked with said they had not noticed them before this winter." Although Lawrence likely identified these specimens correctly, it is not known if they were harvested in Missouri or brought in from elsewhere and simply shipped out of Pierce City (Sharpe 1968, Giesen 1998).

In Kansas, reports of lesser prairie-chickens outside their historical range also tend to occur during winter (Baker 1953). For instance, lesser prairie-chickens were shot as far east as Neosho County during December 1878 and January 1879, in Anderson County during January 1894, and in northern Logan County during January 1921 (Bent 1932, Baker 1953). Bent (1932) mentions anecdotal reports of lesser prairie-chickens in Nebraska, and Sharpe (1968) describes specimens of lesser prairie-chickens that were collected near Danbury, Red Willow County, Nebraska during the 1920s. Although Bailey and Niedrach (1965) considered the lesser prairie-chicken a former resident of the grassland areas of Nebraska, Sharpe (1968) believed that the occurrence of lesser prairie-chickens in that state represented a short-lived range expansion following settlement and the introduction of agriculture.

The distribution of lesser prairie-chickens during the 1800s is difficult to estimate because most observers at that time did not differentiate between the lesser prairie-chicken and the greater prairie-chicken, in part, because the two species are similar in appearance and the lesser prairie-chicken was not recognized as a distinct species until 1885 (Baker 1953, Sharpe 1968). It is accepted generally that during the late 1800s and early 1900s lesser prairie-chickens were abundant throughout their historical five-state range (Bent 1932, Sands 1968, Crawford 1980). Bent (1932: 280) describes the lesser prairie-chicken as "... still to be found in fair numbers in its restricted range, where it is protected, or not disturbed." Although there is no documented evidence of lesser prairie-chickens in Colorado prior to the 1900s (Giesen 2000), Bailey and Niedrach (1965:268) state that they were "... once fairly common in southeastern Colorado." In Kansas, they were reportedly abundant throughout their range until the dust bowl years of the 1930s (Baker 1953). Litton (1978) estimated that the population of lesser prairie-chickens in Texas may have been as high as two million birds prior to the 1900s. Judd (1905:20) mentions that "... one man shipped 20,000 of them from [Wheeler County, Texas] in a single season." Precise estimates of the historical abundance of lesser prairie-chickens in New Mexico and Oklahoma are unknown (Bailey and Williams 2000, Horton 2000).

The geographic distribution of the lesser prairie-chicken during the 1800s is estimated to have encompassed 358,000 km^2 (Taylor and Guthery 1980a, based on Aldrich 1963). By 1969 this area had been reduced to 125,000 km^2, and by 1980 27,300 km^2 of occupied habitat remained, representing a 78 percent decrease in the distribution of the lesser prairie-chicken since 1963, and a 92 percent decrease since historical times (**Figure 2**; Taylor and Guthery 1980a). Throughout their geographic distribution, lesser prairie-chicken numbers have declined an estimated 97 percent since the 1800s (Giesen 1998, Mote et al. 1998, Hagen et al. 2004).

Historical records of population numbers are rare but suggest that during the early decades of the twentieth century lesser prairie-chickens were relatively common within their five-state range (Sands 1968, Crawford 1980). However, as early as 1909 there was concern in Oklahoma regarding decreasing numbers of birds in the western part of the state (non peer-reviewed report, Duck and Fletcher 1944). During the 1930s, populations were nearly extirpated in Colorado, Kansas, and New Mexico, and markedly declined in Oklahoma and Texas (Baker 1953, Crawford 1980). Although accurate estimates are lacking, populations are believed to have fluctuated range-wide through the 1940s and 1950s. Populations modestly increased through the 1980s but appeared to decline again during the 1990s (based on total number of leks and number of males/lek; Mote et al. 1998). Survey data collected during the past four decades indicate that populations have declined in Oklahoma, New Mexico, and Texas, remained somewhat stable in Colorado (since the 1980s), and possibly have increased in Kansas in recent years (U.S. Fish and Wildlife Service 2002).

Conversion of native grassland for production of row crops is believed to be largely responsible for the range-wide decrease in occupied habitat. The current geographic range of the lesser prairie-chicken includes the extreme southeastern part of Colorado including Baca, Prowers, Kiowa, and Cheyenne counties (Giesen 2000); southwestern Kansas from the Oklahoma border north to Wallace and Ellis counties, and east to Ellis, Stafford, and Barber counties (Jensen et al. 2000); the panhandle and western Oklahoma including isolated parts of Cimarron, Texas, Beaver, Harper, Ellis, Roger Mills, Woods, and Woodward counties (Horton 2000); southeastern New Mexico including parts of Curry, Roosevelt, De Baca, Chaves, and Lea counties (Bailey and Williams 2000, Massey 2001); and the panhandle of Texas in parts of Lipscomb, Hemphill, Wheeler, Gray, Donley, Collingsworth, Bailey, Cochran, Yokum, and Terry counties (Sullivan et al. 2000). Because of the infrequent observations of birds and the small number of regular surveys, no accurate distribution maps are available based on Breeding Bird Surveys or Audubon Christmas Bird Counts.

Concurrent with the decrease in occupied range, numbers of lesser prairie-chickens have declined at least 90 percent since the 1800s (Mote et al 1998, Hagen et al. 2004). In 1980, the range-wide population was estimated to be between 44,000 and 53,000 birds (U.S. Fish and Wildlife Service 1998). Recent population estimates for the lesser prairie-chicken are 800 to 1,000 in Colorado and 20,000 to 31,000 in Kansas (U.S. Fish and Wildlife Service 2002). Rich et al. (2004) estimated the range-wide population to be 32,000. Current density estimates indicate that the number of leks per area is variable: 0.1 to 0.2 leks per km^2 in Colorado (Giesen 2000); 1.8 to 2.1 leks per km^2 in Kansas; <0.1 to 0.1 leks per km^2 in Oklahoma; and 0.1 leks per km^2 in New Mexico (U.S. Fish and Wildlife Service 2002). Although actual numbers of the overall breeding population are unknown, most individual populations are believed to be less than 1,000 individuals (Storch 2000).

Historical and current distribution and abundance in Colorado

Documentation of the historical distribution and abundance of lesser prairie-chickens prior to 1900 is lacking, but it is possible that suitable habitat in southeastern Colorado supported populations before settlement by people of European descent (Giesen 2000). Bailey and Niedrach (1965:268) reported that lesser prairie-chickens were common in southeastern Colorado "... when the unbroken grasslands stretched from horizon to horizon…". Populations are believed to have been greatest within occupied range south of the Arkansas River (Hoffman 1963). Nevertheless, Cooke (1897) did not include the lesser prairie-chicken in his review of the bird species in Colorado. However, at this time only two ornithologists had explored the eastern part of Colorado from Pueblo to the Kansas border. One of these men, Captain P. M. Thorne, lived in Fort Lyon, Colorado along the Arkansas River, well within the established historic distribution of the lesser prairie-chicken (Aldrich and Duvall 1955). Although he shot and recorded approximately 160 bird species during a 5-year period, none were the lesser prairie-chicken (Cooke 1897). The first recorded lesser prairie-chicken in Colorado was collected in 1914 in Baca County by Frederick C. Lincoln, who also collected specimens during 1916 near Holly in neighboring Prowers County (Lincoln 1918). Bailey (Bailey and Niedrach 1965: 268) collected lesser prairie-chickens in 1923 in Baca County. At that time he described the countryside as "... rolling, unbroken land, with waving bluestem grass [*Andropogon* spp.] waist high in the swales, and yucca [*Yucca* spp.] and wormwood [*Artemisia* spp.] on knolls..." Bailey went on to write that "...soon after, extensive cultivation and successive seasons of drouth caused the destruction of the grasslands, resulting in the virtual extirpation of the species [lesser prairie-chicken] from the state."

Early reports suggest that lesser prairie-chickens occurred in suitable sand sagebrush (*Artemisia filifolia*) and mixed grass habitats in southeastern Colorado including Baca, Prowers, Bent, Kiowa, Lincoln, and Cheyenne counties (Hoffman 1963, Giesen 2000). Giesen (2000) suggested that the drought of the 1930s, heavy grazing of rangeland, and conversion of native habitat for production of row crops resulted in a significant reduction and fragmentation of the lesser prairie-chicken distribution in the state. Many of the mixed-grass plant communities were converted to shortgrass prairie (mixed prairie maintained by grazing as a shortgrass disclimax) and farmland, which provided less favorable cover for lesser prairie-chickens (Hoffman 1963).

Little was known about the status of lesser prairie-chicken populations until 1959, when the Colorado Division of Wildlife located a small resident population in Baca and Prowers counties and began surveys of historic and active lek sites (Hoffman 1963). During the 1960s lesser prairie-chickens were considered rare in the state (Hoffman 1963), and in 1973 they were officially listed as threatened (Giesen 1998).

Although some lek sites were monitored during the 1960s and 1970s, systematic surveys of lesser prairie-chicken populations throughout the state were not begun by the Colorado Division of Wildlife until 1980 (Giesen 2000). The total autumn population in 1979 was an estimated 400 to 500 individuals (Crawford 1980). In 1980, two populations of lesser prairie-chickens were known to reside in Prowers (2 leks) and Baca (20 leks) counties (Taylor and Guthery 1980a). Survey efforts by the Colorado Division of Wildlife were intensified during the 1980s, when the breeding population is believed to have peaked at 1,000 to 2,000 birds (Giesen 2000). By the late 1980s, the breeding population was known to be distributed in Baca, Prowers, and Kiowa counties (Giesen 1994a). Fewer than 50 leks were known to exist during the early 1990s (Andrews and Righter 1992). By the mid-1990s, the known distribution of lesser prairie-chickens included small populations in southeastern Baca County (primarily on the Comanche National Grasslands), in Baca County southeast of Springfield, and in Prowers and Kiowa counties (Giesen 1994a). The Colorado Division of Wildlife estimated a total population of 800 to 1,000 lesser prairie-chickens in the state in 1997

(U.S. Fish and Wildlife Service 2002). A small isolated population of birds was discovered on private land in Cheyenne County in 1998.

The total population was still estimated to be less than 1,500 breeding individuals in 2000 (Giesen 2000). Survey data collected during 2000 indicated the presence of 317 birds on 27 lek sites (U.S. Fish and Wildlife Service 2001). During 2001, 298 lesser prairie-chickens were counted on a total of 30 leks, a decrease of 6 percent from the previous year (U.S. Fish and Wildlife Service 2002). In general, survey data collected by the Colorado Division of Wildlife from the 1950s to present suggest that the abundance of lesser prairie-chickens in the state has remained relatively stable, or has increased slightly, in recent decades (Giesen 2000). Currently, isolated populations of lesser prairie-chickens occur on private and public land in Baca, Prowers, Kiowa, and Cheyenne counties (Giesen 2000). The core population of lesser prairie-chickens in the state occurs east of Campo on the Comanche National Grassland (Giesen 1994a). In recent years there has been a downward trend for lesser prairie-chicken populations on the Comanche National Grassland (USDA Forest Service 2003).

Historical and current distribution and abundance in Kansas

The historical distribution of the lesser prairie-chicken in Kansas is difficult to determine due to the fact that early observers often confused it with the greater prairie-chicken (Baker 1953). Schwilling (1955) examined available records and estimated that the original range included 39 counties in the southwestern quarter of the state, from the Oklahoma border, north to the Smoky Hill River, and east to Harper and Kingman counties. Colvin (non peer-reviewed report in 1914) describes 15,000 to 20,000 lesser prairie-chickens feeding in grain fields in Seward County during the autumn of 1904, and in neighboring Meade County residents were known to harvest lesser prairie-chickens in place of domestic poultry (Baker 1953). Schwilling (1955:5) believed they were found originally in "... moderate numbers", and Baker (1953:8) reported that birds were "abundant" prior to the 1930s. Populations declined, and lesser prairie-chickens were nearly extirpated from Kansas during the dust bowl years of the 1930s as heavy grazing of rangeland, coupled with several years of drought, reduced available food and cover (Baker 1953). During this time, many of the tallgrass prairie communities were eliminated and replaced with shortgrass prairie (Baker 1953). Additionally, conversion of native grasslands for production of row crops reduced much of the available habitat (Crawford 1980). Although lesser prairie-chickens reportedly nested in Graham County sometime prior to the 1950s, verified documentation is lacking (Baker 1953, Schwilling 1955). A survey by the Kansas Forestry, Fish, and Game Commission in 1950 determined that lesser prairie-chickens were resident in 14 counties in the southwestern part of the state, primarily south of the Arkansas and Cimarron rivers, from Morton County north to extreme southwestern Greeley County, east to southern Pawnee County, and south to southwestern Comanche County (Baker 1953). By 1963 the distribution was largely restricted to areas near the Cimarron and Arkansas rivers, and populations were most abundant in Morton, Kearny, and Finney counties (Taylor and Guthery 1980a, Horak 1985).

The lesser prairie-chicken population in Kansas was estimated at 10,000 to 15,000 individuals during the late 1960s (Sands 1968). During the 1970s the range of lesser prairie-chickens in the state extended from Hamilton, Stanton, and Morton counties east to Reno, Kingman, and Harper counties (Taylor and Guthery 1980a). The population was estimated at 17,000 to 18,000 individuals during the autumn of 1979 (Crawford 1980, Taylor and Guthery 1980a). In some Kansas counties, significant population declines occurred in concert with the conversion of native habitat to center-pivot irrigated cropland (Jamison 2000). Lek survey data (number of leks per survey route and number of males per lek) examined for 1964 through 1998 indicate a general downward trend in lesser prairie-chicken numbers throughout their statewide distribution (Applegate and Riley 1998, Jensen et al. 2000). Similarly, in recent years there has been a downward trend in lesser prairie-chicken populations on the Cimarron National Grassland (USDA Forest Service 2003).

The Conservation Reserve Program (CRP) is a federal program initiated in the mid-1980s to conserve water, soil, and wildlife resources by paying farmers to plant and maintain perennial cover crops of grasses, forbs, and shrubs. CRP is believed to have provided increased residual cover for lesser prairie-chickens in recent years, and 165 "new" lek sites have been located in 16 counties north of the Arkansas River since 1997 (U.S. Fish and Wildlife Service 2002). CRP in Kansas is noteworthy because of special efforts to plant native grasses and to inter-seed with forbs. Survey efforts by the Kansas Department of Wildlife and Parks indicate that lesser prairie-chickens currently occupy 31 of the original 39 counties assumed to comprise its historical distribution; the previous estimate of occupation was

only 19 of 39 counties (Jensen et al. 2000). The latest population estimate is 20,000 to 31,000 birds (U.S. Fish and Wildlife Service 2002). Although Jensen et al. (2000) hypothesized that population increases observed on a local scale may reflect use of shrinking habitat patches, the apparent expansion in occupied habitat suggests that these trend observations are real.

Discontinuities in regional distribution

Several sources of information can be used to evaluate discontinuities in the distribution of lesser prairie-chickens. For instance, surveys of lesser prairie-chickens in Region 2 have helped identify where birds occur (Applegate 2000). Additionally, research on lesser prairie-chicken behavior suggests that most dispersal/seasonal movements are <10 km (Copelin 1963, Giesen 1998), but perhaps up to 44 km in a fragmented landscape (Jamison 2000). Information on habitat use by lesser prairie-chickens (Taylor and Guthery 1980a, Giesen 1998, Mote et al. 1998) and the distribution of suitable habitats throughout Region 2 may be used to evaluate populations that are isolated and/or if movement corridors are limited. Our understanding of the current distribution pattern of lesser prairie-chickens (**Figure 2**) suggests that lesser prairie-chickens may be relatively continuously distributed within Kansas while populations in Colorado (Kiowa and Cheyenne counties) are relatively small, fragmented, and isolated. Although the distribution of lesser prairie-chickens in Prowers and Baca counties is believed to be continuous with lesser prairie-chicken range in Kansas and Oklahoma respectively, populations in this portion of Kansas have themselves become fragmented. Thus connectivity with populations outside of Colorado may be an important factor in developing long-term conservation strategies.

In Kansas, lesser prairie-chickens have recently expanded their distribution north of the Arkansas River, but the CRP lands believed responsible for the increased range and number of birds are inherently ephemeral, suggesting that populations in the expanded range may be unstable. Continuity of populations of lesser prairie-chickens may be over-estimated in Kansas, in part because large populations tend to be sub-sampled while small populations tend to be completely counted. Hence, it is possible that the populations in Kansas may not be as continuous as they are represented. Improvements in the quality of distribution data, as well as dispersal/movement data are needed to highlight areas where population isolation may be a problem in Region 2. Understanding factors that influence habitat use (quality, configuration, juxtaposition, fragmentation, patch size) also are important.

Activity patterns and movements

Circadian

Lesser prairie-chickens roost at night and feed during the day. Jones (1964a) reported two main feeding periods, morning and evening. Broods are more variable and may forage throughout the day, but feeding is most common in the morning and evening (Giesen 1998). Crawford and Bolen (1973) recorded male lesser prairie-chickens regularly making short visits to stock ponds during March and April, usually 1 to 3 hours after sunrise and 1 to 3 hours before sunset. Courtship activity primarily occurs during morning and evening hours (Hjorth 1970). During relatively warm weather in the middle of the day, birds often rest or loaf; during the spring males may loaf on leks (Hjorth 1970) and during summer birds may loaf in the shade of oak (*Quercus* spp.) motts or clumps of bunchgrass (Schwilling 1955, Copelin 1963, Jackson and DeArment 1963, Donaldson 1969).

Like other species of prairie grouse, lesser prairie-chickens spend most of their time on the ground but commonly fly when disturbed, and between foraging, breeding, loafing/roosting areas, and water sources (Giesen 1998). Most flights are <1 km although birds are capable of flying further (Giesen 1998). Copelin (1963: 43) observed that birds flushed by a raptor generally flew "... a fourth to a half mile or more away".

Winter season

Lesser prairie-chickens tend to form flocks during winter (Giesen 1998), but little is known about flock stability or behavior. Schwilling (1955) reported the occurrence of winter flocks in southwestern Kansas from early October to February. He observed small flocks of 10 to 15 birds but noted that flock size tended to increase with snow and cold temperatures. During the relatively mild winter of 1954-55, flocks were usually less than 50 individuals. In contrast, the winter of 1951-52 was particularly severe, and flocks of up to 500 lesser prairie-chickens were observed. Similarly, Copelin (1963) working in Oklahoma noted that as the weather became colder, the number of birds in flocks increased. Flocks of 15 to 80 individuals have been recorded in New Mexico during autumn/early winter (Ahlborn 1980).

Daily movements of lesser prairie-chickens tend to increase through autumn and winter and decrease in late winter/early spring (Taylor and Guthery 1980b, Jamison 2000). The increase in daily movements

by birds in Texas coincided with the cessation of the autumn display period and the increased use of sunflower fields as foraging areas. Juvenile males moved the farthest (from the lek where captured), especially during November and December (Taylor and Guthery 1980b). Similarly, Campbell (1972) examined hunter recoveries of banded male lesser prairie-chickens from October through December in New Mexico and found that juvenile males moved an average 8.8 km (n = 9, range 0.4 to 21.0 km) from their lek of capture while adult males moved 3.4 km (n = 4, range 0.5 to 4 km). In general, most birds remain relatively close to lek sites during winter. In Texas 79 to 100 percent of locations of 19 radio-marked individuals were within 3.2 km of their lek of capture (Taylor and Guthery 1980b). In Oklahoma, Copelin (1963) observed 114 banded lesser prairie-chickens, 79 percent of which were within 3.2 km of their capture location and 97 percent of which were within 6.4 km. However, in New Mexico, Ahlborn (1980) monitored 15 radio-marked lesser prairie-chickens, and by early winter 11 birds had moved on average 11.0 km (range 1.6 to 21.1 km) to grain fields; distances moved were similar for adult (average = 11.6 km, n = 6) and juvenile birds (average = 10.2 km, n = 5).

Home range size of adult males in Texas averaged 365 ha (n = 4) during November and decreased to 50 ha (n = 1) by February (Taylor and Guthery 1980b). Home range size of one adult female was 308 ha during January and then decreased to 62 ha in February. The autumn/winter home range size of four lesser prairie-chickens monitored in New Mexico averaged 298 ha (Candelaria 1979). Home range size of male lesser prairie-chickens (age classes combined) in Kansas was largest during October (average = 433 ha, n = 23; Jamison 2000).

Spring season

During early spring, male lesser prairie-chickens begin to congregate on breeding areas termed leks (Giesen 1998). Median home range of males ranged from 12 to 140 ha during April and May in southwestern Kansas (Jamison 2000).

In New Mexico, pre-nesting home range (measured from time of capture on lek to nest initiation) averaged 63 – 231 ha (n = 66; Merchant 1982, Riley et al. 1994) and was noted to increase during drought conditions (average = 122 ha during drought conditions [n = 18] vs. average = 63 ha at other times [n = 8]); Merchant 1982). Daily movements of 40 female lesser prairie-chickens during the pre-nesting period averaged 390 m per day in New Mexico (Riley et al. 1994) and home range averaged 231 ha (Candelaria 1979). Haukos (1988) recorded daily movements of 0.1 to >6 km (n = 55) by females during the breeding and pre-incubation periods; he attributed the larger distances to inter-lek movements.

Females initiate laying their first clutch 1 to 2 weeks after copulation and usually lay one egg per day with occasional skips of 1 day. Incubation of the clutch begins when the last egg is laid and usually lasts for 24 to 26 days (Giesen 1998). When females commence incubation, daily movements decrease and are restricted to feeding forays, often <30 minutes duration and usually 0.3 km from the nest site (Sell 1979, Giesen 1998). Incubation recesses typically occur during early morning and evening hours (Sell 1979, Giesen 1998). Females are able to initiate a second nest following destruction or abandonment of their first clutch, and replacement clutches usually are laid within 2 weeks of nest loss (Giesen 1998). In New Mexico, home range size of nesting females ranged from 9 to 92 ha (n = 33; Merchant 1982, Riley et al. 1994); daily movements averaged 250 m per day (n = 12; Riley et al. 1994).

Summer season

Home range size and daily movements tend to be less during the summer than at other times of year. Spring/summer home range size in Colorado was smaller for males (211 ha, n = 19) than females (596 ha, n = 14) primarily because males remained close to their leks (Giesen 1998). Males often loaf and/or rest near leks during summer, and although occasional courtship behavior is observed, no breeding activity takes place (Jones 1964a, Giesen 1998). During late summer, birds may make daily trips to obtain water (Jones 1964a), but the necessity of this activity is unclear. Home range size may increase in years of drought, possibly because of reduced cover and availability of insect food. The average home range size of female lesser prairie-chickens was 174 ha (n = 7) during a year of normal precipitation, compared to 464 ha (n = 8) in a drought year (Merchant 1982). Home range size of broods averaged 47 ha in New Mexico during a year of normal precipitation (Ahlborn 1980). Copelin (1963) recorded a home range size of at least 104 ha for one brood in Oklahoma during a dry summer.

Females with broods tend to have larger home ranges and more extensive daily movements than unsuccessful females without broods (Riley et al. 1994). Home range size averaged 119 ha (n = 3), and daily movements averaged 280 m per day (n = 3) for

brood females; home range size averaged 73 ha (n = 19) and daily movements 220 m per day (n = 19) for unsuccessful females (Riley et al. 1994). Broods tend to feed most in the morning and evening, and during hot weather they may loaf in the shade of oak motts or clumps of bunchgrass in midday (Schwilling 1955, Copelin 1963, Jackson and DeArment 1963, Donaldson 1969). Daily brood movements may increase as the chicks age; in southwestern Kansas, movements averaged 248 m per day (n = 14, range 195 - 434 m) for broods less than 14 days of age and 320 m per day (n = 8, range 186 - 658 m) for broods 14 to 60 days of age (Jamison 2000). Broods of different ages sometimes combine during late summer (Copelin 1963).

Autumn season

Chicks are able to fly short distances at 2 weeks of age and are independent at 12 to 15 weeks of age (Giesen 1998). Little published information is available regarding aspects of brood break-up or the autumn phase of dispersal. Taylor and Guthery (1980c) had one of four radio-tagged juvenile males move 12.8 km in 5 days during early December; they suggested that this movement represented a dispersal movement. Copelin (1963) observed three juveniles on lek sites during autumn approximately 0.9, 1.1, and 3.2 km, respectively, from their place of capture (assumed brood territory).

Males sometimes visit lek sites in autumn and exhibit courtship behavior, but the display is less frequent and less intense than during spring and no breeding occurs (Copelin 1963). In Oklahoma, small flocks of juveniles visited lek sites in late September (suggesting that brood break up had begun at this time), and females occasionally visited lek sites during October and November (Copelin 1963).

Broad-scale movement patterns

Bent (1932:280) believed that the lesser prairie-chicken was a migratory species, breeding in the northern part of its historical distribution and wintering in the south, primarily central Texas. He did not have any information regarding the seasonal movement of birds between these areas but noted "... comparatively little seems to be known and still less has been published on the habits and distribution of the small, light-colored, lesser prairie chicken ...". Sharpe (1968) noted that many observations outside the normal range occurred during winter months, and he suggested they may have represented individuals searching for a winter food source. Jackson and DeArment (1963) considered the lesser prairie-chicken a winter migrant in the southernmost part of its historical range in Texas, but Taylor and Guthery (1980a) argued that the distribution of suitable habitat in these areas suggested that these birds most likely were residents.

In general, there is little documentation of historical movement patterns of lesser prairie-chickens, and it is unknown if large-scale migration movements occurred. Existing lesser prairie-chicken populations are not known to migrate between breeding and winter areas (Giesen 1998). However, individuals are capable of, and do make, long distance movements; one female captured in Kansas and released in Colorado traveled approximately 300 km that same year back to Kansas (Giesen 1998). Lesser prairie-chickens make seasonal movements between breeding and wintering areas, but most movements are restricted to suitable habitat within a radius of 3 - 4 km from the lek they use (Taylor and Guthery 1980a, Giesen 1998). Many aspects of seasonal patterns of movement are not understood clearly.

Population connectivity

There are no natural barriers impeding the connectivity of lesser prairie-chicken populations throughout most of their range. However, alteration of habitat through loss, fragmentation, and degradation (**Figure 3** and **Figure 4**) clearly has created large areas uninhabited by lesser prairie-chickens (**Figure 2**). Many of these ecological barriers appear to be large enough to prohibit or slow the frequency of movements by lesser prairie-chickens between patches of habitat and between populations. For instance, populations in Kiowa and Cheyenne counties, Colorado are small, with <100 birds each, and they are isolated by at least 20 km from other populations within and outside the state (Giesen 2000). Although lesser prairie-chickens in Prowers and Baca counties are believed to be contiguous with populations in Oklahoma and Kansas, respectively, the populations in these states also have become fragmented (Giesen 1994a). The lesser prairie-chickens in southwestern Kansas may have a more contiguous distribution, but the habitat in the border areas with Colorado is fragmented. It is not currently known how fragmentation influences the demographics of lesser prairie-chicken populations (Jensen et al. 2000).

Habitat

Regional habitat

The geographic distribution of the lesser prairie-chicken in Region 2 includes two main ecoregions.

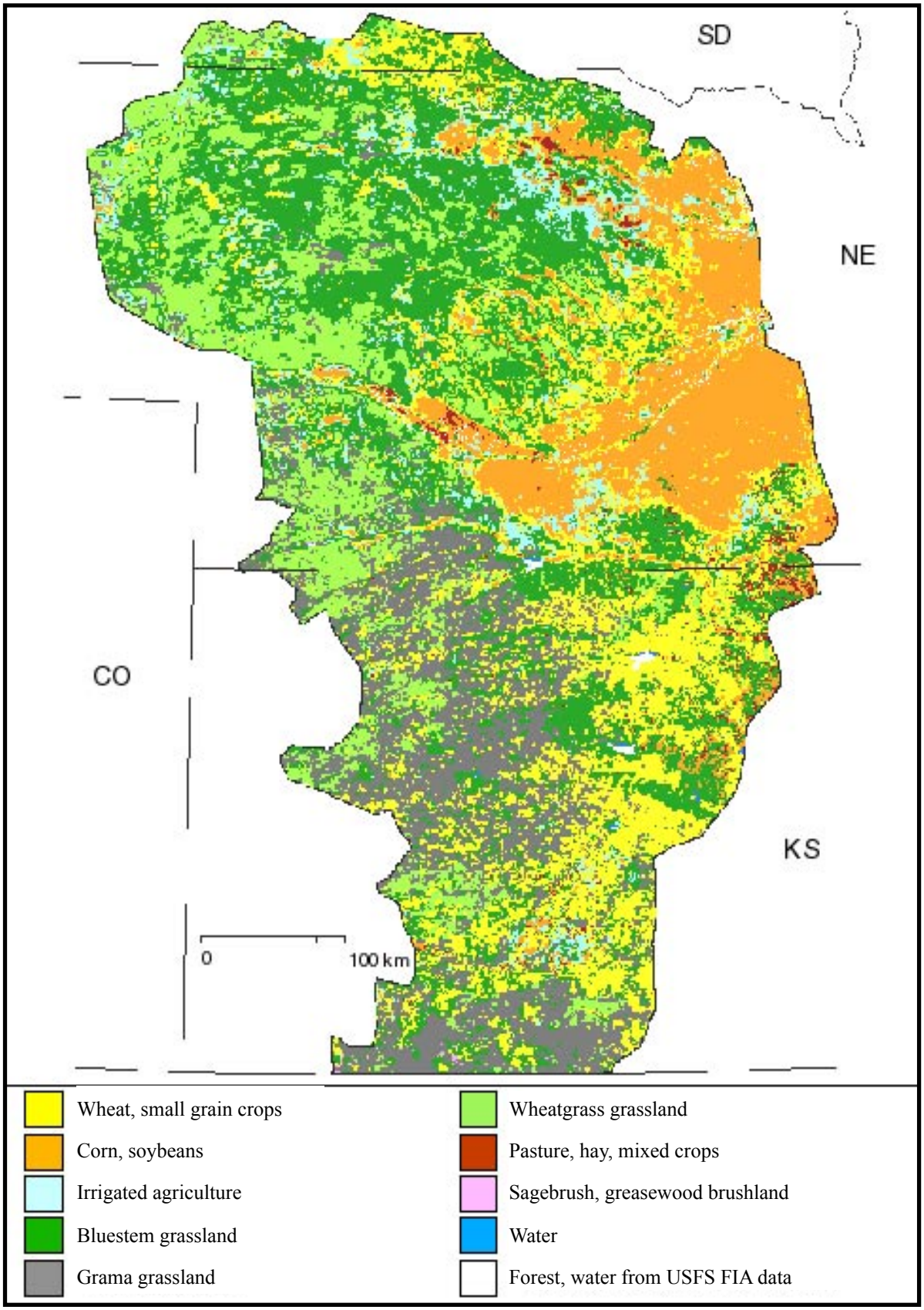

Figure 3. Distribution of major cover types in the Central Mixed Grass Prairie physiographic area as estimated mostly with 1990 U.S. Geological Survey data and provided by Partners in Flight (http://www.cast.uark.edu/pif/gif/34.nfor.gif, December 1, 2004).

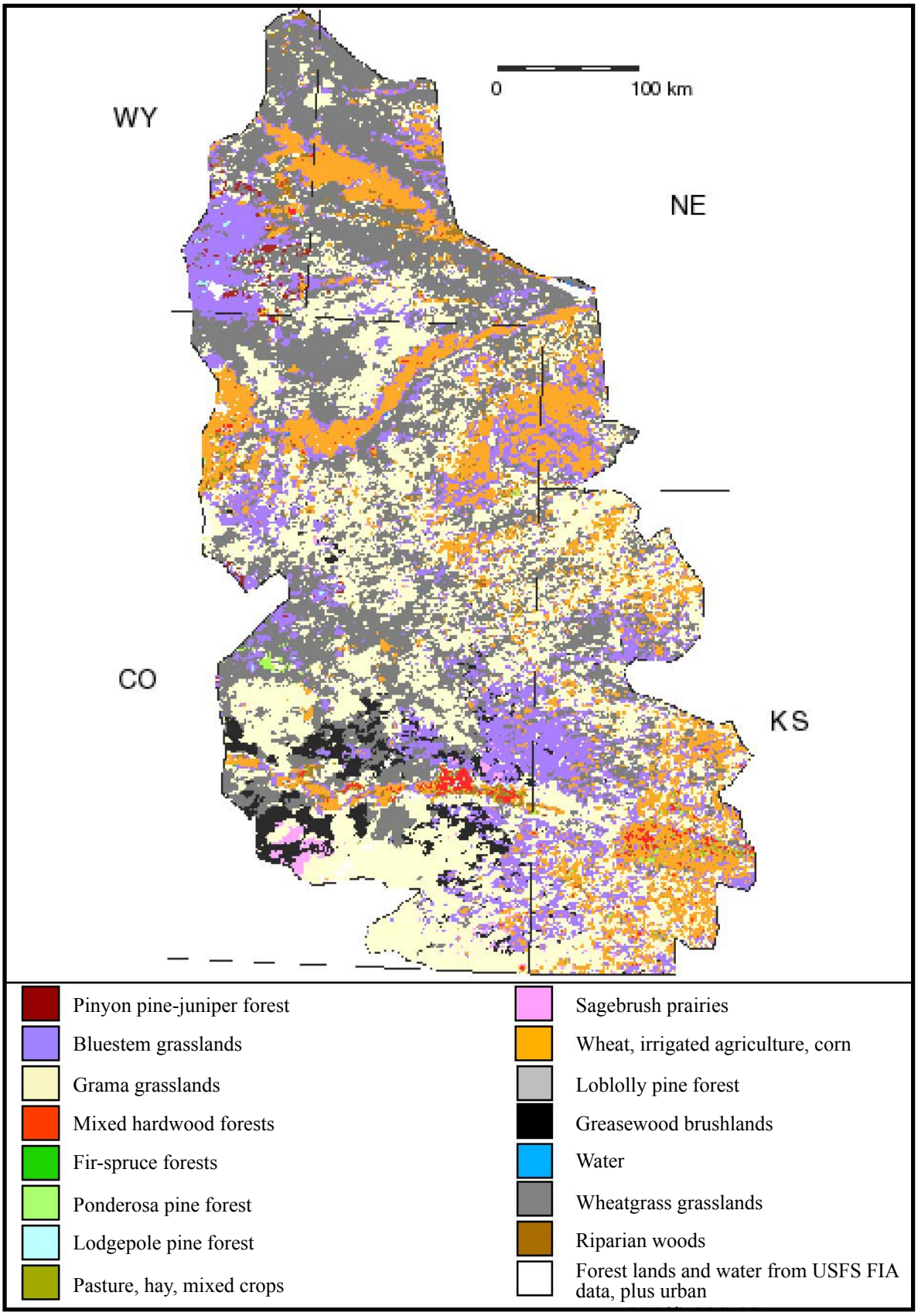

Figure 4. Distribution of major cover types in the Central Short Grass Prairie physiographic area as estimated mostly with 1990 U.S. Geological Survey data and provided by Partners in Flight (http://www.cast.uark.edu/pif/gif/36.nfor.gif, December 1, 2004).

The Great Plains-Dry Steppe Province Ecoregion of southeastern Colorado and southwestern Kansas is characterized by rolling plains and tablelands, shortgrass prairie, and Mollisol soils with a high level of precipitated calcium carbonate and low humus content (http://www.fs.fed.us/r2/nebraska/gpng/matrix/ecoregions.html). Most precipitation occurs during the summer months, but evaporation often exceeds precipitation, resulting in low moisture levels. Average annual temperature is 7 °C but may reach 16 °C in the southern reaches. The Great Plains Steppe Province Ecoregion of southwestern and south-central Kansas is characterized by flat and rolling plains, mixed-grass steppe vegetation, and, generally, Mollisol soils. Annual precipitation levels range from 51 to 64 cm, and average annual temperature is 15 °C. The western boundary of this ecoregion shifts with changes in precipitation. Dry periods favor the dominance of short grasses, resulting in a boundary shift to the east; during wet years tall grasses are favored, and the boundary shifts west.

The regional distribution of current suitable habitat can be illustrated for major portions of the lesser prairie-chicken range in Region 2 using the physiographic areas as defined by the U.S. Geological Survey for Partners in Flight. Although these physiographic regions were defined, in part, from data provided by Breeding Bird Surveys, they illustrate the distribution of major habitat types that are relevant to lesser prairie-chickens. The two primary physiographic areas in Region 2 include the Central Mixed-grass Prairie (**Figure 3**) and the Central Shortgrass Prairie (**Figure 4**.); only small portion of the New Mexico Mesa and Plains is in Colorado. General habitat categories are quantified in **Table 1**.

Lesser prairie-chickens are endemic to the xeric grasslands of the southwestern Great Plains. Historical habitat of the lesser prairie-chicken is poorly documented but is believed to have coincided with the sand sagebrush-bluestem and shinnery oak (*Quercus havardii*)-bluestem vegetation associations described by Kuchler (1964) and Taylor and Guthery (1980a). Currently, throughout their range lesser prairie-chickens occur in mixed-grass dwarf-shrub vegetation associations, usually found on sandy soils. Two main habitat associations are used: 1) sand sagebrush dominated rangelands in Colorado, Kansas, and parts of Oklahoma (**Figure 5**), and 2) shinnery oak-bluestem plant communities in Oklahoma, Texas, and New Mexico (**Figure 6**; Taylor and Guthery 1980a, Giesen 1998, Mote et al. 1998). Bidwell et al. (1995) describes lesser prairie-chicken habitat as savanna-type vegetation created by the interspersion of shrub and grass cover.

In Region 2, outside of CRP-dominated areas, lesser prairie-chickens use sand sagebrush communities with mixed bunchgrasses, primarily sand dropseed (*Sporobolus cryptandrus*), red threeawn (*Aristida longiseta*), and sideoats grama (*Bouteloua curtipendula*) (Giesen 1998). An interspersed pattern of cover types is believed to be important for supporting the different life history stages of lesser prairie-chickens (Cannon and Knopf 1981a, Bidwell et al. 1995). Jamison (2000) examined habitat selection by males in an area of fragmented sand sagebrush habitat in southwestern Kansas. At the broad scale (approximately 588,452 ha of habitat), lesser prairie-chickens selected sand sagebrush prairie in all months studied, despite the fact that this habitat type comprised only 10 percent of available habitat. At the local scale (home range), males generally selected sand sagebrush prairie throughout the year; at this scale sand sagebrush comprised 57 percent of the available habitat. The presence of Acrididae and total invertebrate biomass also were higher in use than non-use areas during summer (Jamison et al. 2002a). Invertebrate biomass was, in turn, positively associated with abundance of native forbs, leading Jamison et al. (2002a) to suggest that native forbs are important components of habitat quality. In other portions of Region 2, populations of lesser prairie-chickens have been documented in landscapes dominated by crops, short grasses, and CRP lands generally planted to native tall grasses (Jamison 2000).

In Oklahoma, Texas, and New Mexico lesser prairie-chickens often use shinnery oak habitats dominated by mid-tall grasses such as sand bluestem (*Andropogon hallii*), little bluestem (*A. scoparium*), sand dropseed, threeawn, and blue grama (*Bouteloua gracilis*) (Cannon and Knopf 1981a, Giesen 1998). Taylor and Guthery (1980b) monitored 19 radio-marked birds during autumn and winter and concluded

Table 1. Quantity of habitat types in USDA Forest Service Region 2 physiographic regions, as estimated with 1990 U.S. Geological Survey data, and provided by Partners in Flight (http://www.cast.uark.edu/pif/, December 1, 2004).

Physiographic region	Grassland	Shrubland	Cropland	Pasture/hay	Forest	Other	Area (ha)
Central Shortgrass Prairie	77.9%	3.7%	14.5%	0.3%	3.2%	0.4%	17,055,668
Central-mixed Grass Prairie	57.9%	0.0%	40.3%	1.1%	0.5%	0.2%	22,107,300

Figure 5. Example of sand sagebrush landscape on the Comanche National Grassland in southeastern Colorado. Photograph by Michael A. Schroeder.

Figure 6. Example of shinnery oak landscape in western Oklahoma. Photograph by Michael A. Schroeder.

that shinnery oak-sand sagebrush, shinnery oak-little bluestem, and sunflower (*Bouteloua* spp.) vegetation types were used more than expected, given their availability on the Texas study area. Winter foraging and roosting sites of eight radio-marked males in New Mexico were almost entirely in High Plains Bluestem Subtype (HPBS) vegetation that was dominated by grasses, 59 to 66 percent (basal composition), especially threeawn (Riley et al. 1993a). Females nested in specific subclasses of HPBS vegetation; nine of 37 (24 percent) nests were located in HPBS-1 that was dominated by sand bluestem (12 percent of the study area), 21 (57 percent) of nests were located in HPBS-2 that was dominated by little bluestem (44 percent of the study area), and seven nests (19 percent) were located in HPBS-3, where grasses and shinnery oak were present in similar amounts (33 percent of the study area) (Riley et al. 1992). Wisdom (1980) noted that 78 percent of nest sites in New Mexico were located in clumps of bluestem grasses, even though these grasses comprised 32 percent of the vegetation. Ahlborn (1980) recorded observations of five radio-marked females with broods and found higher use of sandhill and shinnery oak-midgrass vegetation types than shinnery oak-bluestem, reverted cropland, and shortgrass-snakeweed (*Gutierrezia sarothrae*) habitats in New Mexico.

Habitat in Colorado

The original mixed-grass plant communities within the historical distribution of the lesser prairie-chicken have been replaced with shortgrass communities as a consequence of the replacement of native grazers with domestic cattle, combined with the drought of the 1930s (Hoffman 1963). As a consequence of the replacement of native grazers (especially bison) with domestic cattle, combined with the drought of the 1930s (Hoffman 1963). These shortgrass rangelands are dominated by sand sagebrush and mixed bunchgrasses, primarily sand dropseed, red threeawn, and sideoats grama (Giesen 1994b). Other common plants include small soapweed (*Yucca glauca*), broom snakeweed, western ragweed (*Ambrosia psilostachya*), and Russian thistle (*Salsola kali*) (Giesen 1994b). Average annual precipitation is approximately 40 cm, but because rainfall often comes in the form of thunderstorms, precipitation levels are highly variable throughout the area (Giesen 2000). Grazed rangeland interspersed with occasional cropland is the dominant land use (Giesen 1994b).

Habitat in Kansas

Similar to Colorado, the original habitats that supported lesser prairie-chicken populations in Kansas changed after the drought of the 1930s. Baker (1953: 9) stated "... the residents of southwestern Kansas report that these sandy lands supported stands of tall grasses before the drought of the 1930 - 1940 decade. These grasses were eliminated over wide areas during the drought, and were replaced by sagebrush; to date the grasses have not completely recovered." Currently, lesser prairie-chickens occur in sandy, mixed and shortgrass prairies and occasionally sand prairie habitat in the southwestern part of the state (Mote et al. 1998, Jensen et al. 2000). Populations have also expanded into areas dominated by CRP (Fields 2004). Dominant vegetation in native habitats includes sand sagebrush, blue grama, sideoats grama, paspalum (*Paspalum* spp.), bluestem grasses, western ragweed, sunflowers, and Russian thistle. Other common plants include prickly pear cactus (*Opuntia* spp.) and small soapweed; buffalo-gourd (*Cucurbita foetidissima*) and purple poppy mallow (*Callirhoe* spp.) occur in disturbed areas (Jamison 2000). Soils are generally classed as Tivoli-Vona and are in the choppy sands category. Average annual precipitation is 50 cm. Dominant land use practices include center-pivot irrigated cropland and livestock grazing of rangeland (Jensen et al. 2000).

Lek habitat

Physiognomic features and aspects of plant structure are more important than plant species composition *per se* when evaluating lek site characteristics (Jamison et al. 2002b, Hagen et al. 2004). Lek sites typically are located on ridge tops in open areas, with good visibility, where the vegetation is short or sparse (Davison 1940, Copelin 1963, Jones 1963, Jones 1964a, Sharpe 1968, Donaldson 1969, Ahlborn 1980, Taylor and Guthery 1980a, Applegate and Riley 1998, Giesen 1998). Hjorth (1970:390) observed leks in sand dune fields in Kansas and suggested that "smooth ground" may be relatively more important than elevation. Near agriculture areas, leks may be situated in wheat, bare corn, cut hay, and cultivated fields (Copelin 1963, Crawford and Bolen 1976a, Applegate and Riley 1998). Swales are used occasionally in Oklahoma (Donaldson 1969), and Copelin (1963) noted leks on shortgrass meadows in valleys when sand sagebrush vegetation on nearby ridges was tall and dense. Disturbed areas such as ground-level roads, abandoned oil pads, herbicide

treatment plots, and windmill sites also have been used by lesser prairie-chickens as lek sites (Crawford and Bolen 1976a, Sell 1979, Taylor 1980, Locke 1992).

Vegetation height at lek sites in sand sagebrush grassland in Oklahoma averaged 10 cm (Jones 1963). In Colorado, density of sand sagebrush on nine lek sites averaged 310 plants per ha, with a mean height of 41 cm. Plant species composition included buffalograss (*Buchloe dactyloides*, 20 percent), blue grama (19 percent), red threeawn (17 percent), and sideoats grama (16 percent) (non peer-reviewed report, Giesen 1991). In western Oklahoma, medium-tall grass sites were only used if the vegetation had been mowed or grazed (Donaldson 1969), and in Colorado the taller grasses present on lek sites were kept short by grazing (non peer-reviewed report, Giesen 1991). Donaldson (1969) noted that lek sites where vegetation growth was rapid tended to be abandoned earlier than those with shorter vegetation.

Nest habitat

Female lesser prairie-chickens construct nests that are shallow, bowl-shaped depressions in the substrate that they line with dried leaves, grasses, and feathers (Bailey 1928, Bent 1932, Copelin 1963, Donaldson 1969, Giesen 1998). Nest bowl dimensions average 20 cm wide by 7 to 10 cm deep (Copelin 1963, Sell 1979, Haukos 1988).

Females typically nest in shinnery oak and sand sagebrush dominated grasslands (Giesen 1998, Mote et al. 1998), but in some cases CRP habitats (Fields 2004). Nests tend to be located in areas with high canopy cover, moderate vertical/horizontal cover, and residual vegetation (**Table 2**, **Figure 7**; Haukos and Smith 1989, Giesen 1998, Mote et al. 1998, Pitman 2003). In Colorado, nests often are situated beneath shrubs (69 percent of 29 nests) or in bunchgrasses (31 percent of 29 nests; Giesen 1994b). In shinnery oak grasslands, nests usually are located in areas dominated by tall bunchgrasses, especially bluestems; 30 of 37 nests (81 percent) in New Mexico were located in the High Plains Bluestem Subtype vegetation where sand bluestem and little bluestem were the dominant grasses (Riley et al. 1992). In areas where grasses are reduced by grazing and/or drought, nests may be located in shrub cover (Riley 1978, Merchant 1982).

The mean height and density of vegetation at the nest site typically is greater than the surrounding habitat (Giesen 1998): 43 cm above nest vs. 18 cm within 9 m (n = 37, Wisdom 1980); 42 to 52 cm above nest vs. 29 to 31 cm within 3 m (n = 24, Wilson 1982); 61 cm above nest vs. 29 cm within 9 m (n = 18, Riley 1978). Haukos and Smith (1989) monitored 13 nests in Texas, all of which were situated in cover provided by residual grasses, primarily purple three-awn (*Aristida purpurea*); percent overhead cover and plant height averaged 43 percent and 45 cm. In southeastern Colorado, the average height of the tallest vegetation measured at 29 nest sites was 51 cm (range 29 - 81 cm; non peer-review report, Giesen 1991). Wilson (1982) located nests in shinnery oak grassland and noted that areas with greater vegetation height (average = 34 cm), percent litter (average = 39 percent), and canopy cover (average = 37 percent) were used most commonly. Sell (1979) found increased sand sagebrush structural density and canopy cover at nest sites located in shinnery oak/sand sagebrush grasslands.

Table 2. General habitat characteristics at nesting and brooding-rearing sites for lesser prairie-chickens (adapted from Jamison et al 2002b, Hagen et al. 2004). Region 2 states are in bold.

Location	Nesting habitat			Brood-rearing habitat			Reference
	Shrub	Grass	Forb	Shrub	Grass	Forb	
Colorado	7%	29%	1%				Giesen 1994
Kansas	15%	37%	8%				Pitman 2003
Kansas				17%	26%	11%	Hagen et al. 2004
Oklahoma				23%	8%	16%	Jones 1963
Oklahoma				14%	51%	35%	Donaldson 1969
Texas					42%		Haukos and Smith 1989
Texas	25%	8%	2%				Wilson 1982
New Mexico	46%	46%	8%				Riley et al. 1992
New Mexico				30%	50%	20%	Ahlborn 1980
New Mexico				43%	43%	15%	Riley and Davis 1993

Figure 7. Lesser prairie-chicken nest in southwestern Kansas (Hagen et al. 2004). Photograph by Christian A. Hagen.

Grasses were found to be taller at successful nests (average height = 67 cm, *n* = 10), than unsuccessful nests (average height = 35 cm, *n* = 26; Riley et al. 1992). In shinnery oak grasslands, nest success was highest for nests located in sand bluestem cover. Riley et al. (1992) suggested that the large dense clumps formed by this grass species provide effective concealment from predators, as predation accounted for nearly 81 percent of nest loss in their study. Davis et al. (1979) noted more litter and less bare ground at successful than unsuccessful nest sites. Applegate and Riley (1998) considered good nest habitat a mix of 65 percent tallgrasses, 30 percent shrubs (shinnery oak or sand sagebrush), and some forbs. Riley et al. (1992) suggested that high quality nest cover not only offers concealment from predators but also mitigates adverse effects of high temperatures, winds, low relative humidity, and solar radiation. Wisdom (1980) noted that 34 of 37 nests (92 percent) in his study were situated on north-facing or northeast-facing slopes or in relatively small depressions, and high dunes usually were located to the south and west of the nest site offering protection from prevailing winds.

Giesen (1994b) found that nests on the Comanche National Grassland in Colorado were located in shrub cover (69 percent of 29 nests), primarily sand sagebrush (12 of 29 nests), while bunchgrasses provided cover for nine nest sites. Pitman (2003) observed similar tendencies in southwestern Kansas. Nest habitat had greater height of shrubs, forbs, and grasses than the adjacent rangeland, and the height of the tallest vegetation over the nest averaged 51 cm (measurements taken after hatch or nest loss). Density of sand sagebrush cover averaged 3471 plants per ha (range 0 – 12,667). Height-density of nest site vegetation averaged 3.2 dm (range 1.0 – 6.5 dm) vs. 2.0 dm (range 1.0 – 3.4 dm) for adjacent areas. Canopy cover at nest sites averaged 7 percent (range 0 – 36 percent) sand sagebrush, 29 percent (range 9 to 62 percent) grass species, and 1 percent (range 0 – 7 percent) forbs. Vegetation tended to be sparsely distributed; data from intercept transects indicated 70 percent (range 38 to 88 percent) bare ground.

Summer habitat

Most research on greater prairie-chicken broods has determined that brood habitat must be structured so that chicks can travel easily, broods are adequately protected from predators and weather, and the chicks and brood female are provided with the necessary

nutritional requirements (**Table 2**). Similar criteria likely are important for evaluating lesser prairie-chicken brood habitat. Jones (1963) concluded that broods in western Oklahoma used areas dominated by shrub and half-shrub life-forms. Percentage of forbs, especially western ragweed, usually was higher in brood-use areas than habitats used by males and unsuccessful females. In his study, vegetation with a high percentage of forbs consistently had more insects per unit area than other vegetation types; insects are important diet items for chicks and adult birds (see Food Habits section; Jones 1963). Similarly, Jamison et al. (2002a) determined that broods selected areas with high invertebrate biomass, and these areas also had high abundance of native forbs. Donaldson (1969:44) noted that brood foraging areas were "... low in stature and of a rather open aspect...". Brood foraging sites in New Mexico were vegetated sparsely and dominated by shinnery oak and three awn grass species (Riley and Davis 1993). In general, brood sites had less grass and shorter vegetation than nest sites located in the same area. During hot weather, broods loaf in shade provided by moderate to tall vegetation, such as shinnery oak motts, little bluestem, or sand bluestem (Copelin 1963, Jones 1964b). In New Mexico, Ahlborn (1980) found that broods used areas with an open canopy (25 percent coverage), an average vegetation height of 30 cm, a relatively high basal composition of shrubs and forbs, and sparse basal plant cover.

Several studies report lesser prairie-chickens loafing in the shade of small trees or shrubs during hot weather (Copelin 1963, Jones 1964b). Jones (1964b) reported that birds in western Oklahoma often loaf in dwarf half-shrub vegetation (63 percent of observations) such as those dominated by skunkbrush sumac *(Rhus aromatica*). They are also known to take dust-baths in loose dry soil (Giesen 1998). Small patches of short vegetation, surrounded by taller vegetation, were common sites for night roosts in Oklahoma (Jones 1963). Copelin (1963) located roosting sites in grassed ravines, draws, and on ridges, where the vegetation height did not exceed 1 m; heavily grazed pastures were not used for roosting. Jamison (2000) mentions lesser prairie-chickens roosting in crop fields. Birds roost singly or in small flocks; individual night roosts are spaced from <1 to 6 m apart (Copelin 1963, Jones 1964a).

Autumn and winter habitat

Jones (1963) noted that 59 percent of winter feeding observations were in tallgrass habitat types. In Texas, lesser prairie-chickens increasingly used shinnery oak-sand sagebrush habitat through the winter (Taylor and Guthery 1980b). Various studies report the use of crop fields for feeding areas. Birds used sunflower fields in Texas during December and January (Taylor and Guthery 1980b), sorghum fields during autumn/winter in New Mexico, Oklahoma, and west Texas (Jones 1964b, Crawford and Bolen 1976a, Ahlborn 1980), and corn fields in southwestern Kansas (Jamison 2000). Lesser prairie-chickens may move relatively long distances to agriculture fields. For instance, Ahlborn (1980) recorded 11 of 15 radio-marked birds moving to grain fields (sorghum) in November, with an average distance moved of 10.9 km (range 1.6 - 21.1 km). Some populations, however, demonstrate little to no use of agricultural crops for forage (Riley et al. 1993b).

Jones (1964b) reported that birds in western Oklahoma loaf in sand sagebrush through the winter. They roosted in areas of tall vegetation or in drifts of snow (Jones 1963). Copelin (1963) observed winter flocks flying 2.4 km between grain fields and roosting areas during morning and evening.

Landscape configuration

Jones (1963) concluded that lesser prairie-chicken habitat generally consists of small patches of short grass interspersed with large patches of shrub or half-shrub vegetation. Lesser prairie-chickens use a variety of life-form vegetation types, such as tallgrass, midgrass, dwarf half-shrub, and midforbs, for breeding, foraging, and roosting activities throughout the year (Jones 1963). Consequently, they require a diversity of life-forms within their home range (Taylor and Guthery 1980a). Because lesser prairie-chickens have relatively small home ranges (Riley et al. 1994, Jamison 2000) and most nesting and brood rearing activity occurs within 3 km of lek sites (Giesen 1998), diversity of plant succession and species composition are important at the local scale.

At the broad scale, landscape-level configuration of rangeland and cropland may influence population density and trends. For example, Crawford and Bolen (1976a) recorded lek density and average number of males per lek in west Texas, and they found the largest populations where native rangeland comprised 63 to 95 percent of the landscape and cultivated fields (primarily minimum tillage sorghum) the rest. Lek sites generally did not occur in areas where cultivation exceeded 37 percent. Cannon et al. (1982) examined Landsat data of shinnery oak rangeland in western Oklahoma and found a positive correlation between percentage of grassland habitat and density of displaying males (based on spring lek surveys). Woodward et al. (2001) examined the

relationship between number of displaying males per lek and vegetation change within 4.8 km of the lek, for historical lek sites in Oklahoma, Texas, and New Mexico during the period 1959 to 1996. Landscapes where the number of males per lek declined typically had higher rates of landscape change (11 percent per decade) and loss of shrubland cover types (3.8 percent per decade) than landscapes associated with leks that did not decline (2 percent and 1 percent per decade, respectively; Woodward et al. 2001). Average decline in total shrubland cover was almost four times greater in landscapes where numbers of males per lek declined (Woodward et al. 2001).

Throughout the geographic range of lesser prairie-chickens, there is a correlation between lek locations and nest sites. Females usually nest 1.2 to 3.4 km from the lek where they were captured (Giesen 1998). In southeastern Colorado, the distance from the lek of capture to a female's nest averaged 1.8 km (range 0.2 – 4.8 km, n = 31) and was greater than the mean distance between the nest site and the closest lek (average = 1.0 km, range 0.2 – 2.5 km; Giesen 1994b). Distance between the nest site and the nearest lek does not differ between successful and unsuccessful nests, but successful nests exhibit less variation in distance from lek sites (Phillips 1990).

Females move their broods soon after hatch. Because young broods are unable to fly, suitable brood habitat for foraging and concealment has to be within walking distance of the nest. Daily movement of broods are usually <300 m (Giesen 1998), and movements tend to be greater for broods 14 to 60 days of age (average = 320 m, n = 8) than younger broods (average = 248 m, n = 14; Jamison 2000). Ahlborn (1980) recorded movements of five radio-marked broods for approximately 7 weeks post hatch; average maximum distance moved by broods was 1148 m, and all recorded locations were within 1.5 km of a lek site.

Occupied versus unoccupied habitat

Lesser prairie-chickens typically use contiguous grassland habitat containing a mosaic of seral stages (Bidwell et al. 1995, Applegate and Riley 1998). Adequate nesting cover and brood-rearing habitat are believed to be critical habitat components for prairie grouse (Kirsch 1974, Bidwell et al. 1995, Hagen et al. 2004). For example, lack of nesting/brood-rearing habitat has been suggested to be the primary factor limiting the greater prairie-chicken (Westemeier et al. 1998). Habitat that could be used by lesser prairie-chickens is made unavailable when range management practices do not leave adequate cover for nesting or brood rearing (Mote et al. 1998). Additionally, grasslands occupied by lesser prairie-chickens may be sensitive to heavy grazing during drought conditions (U.S. Fish and Wildlife Service 2002); significant population declines of lesser prairie-chickens have been recorded during drought years (Mote et al. 1998). In Kansas, Hagen (2003) found a negative correlation between site occupancy and anthropogenic features. Many grouse species are relatively poor dispersers (Braun et al. 1994); thus habitat suitable for lesser prairie-chickens may be unoccupied because of isolation from viable populations.

Food habits

Diet items

Studies of lesser prairie-chicken diets have focused on populations inhabiting shinnery oak rangelands. There are few studies of lesser prairie-chicken food habits in sand sagebrush-dominated grasslands such as those found in Region 2. Lesser prairie-chickens typically forage on the ground on a wide array of items including insects, seeds, leaves, buds, and cultivated grains (Jones 1963, Giesen 1998). Water is also used in many areas, but its necessity has not been determined (Copelin 1963, Crawford and Bolen 1973, Candelaria 1979, Davis et al. 1979, Sell 1979).

Vegetative composition of the diet varies among regions, seasons, and age classes (Jones 1963, Crawford and Bolen 1976a, Davis et al. 1980, Riley et al. 1993b). In part, these differences result from variation in food availability and habitats. For instance, in shinnery oak-grassland habitats in eastern New Mexico, shinnery oak (acorns, leaves, and galls) comprised 49 percent of the spring diet, 21 percent of the summer diet, and 69 percent of the winter diet of adult birds (Davis et al. 1980, Riley et al. 1993b). Shinnery oak comprised 23 percent of the autumn diet of birds (age unknown) in western Texas (Crawford and Bolen 1976a). In western Oklahoma, buds and fruits of skunkbush sumac and six-week fescue (*Festuca octoflora*) were the highest ranked diet items throughout the year (Jones 1963). In some areas, cultivated grains are important food sources; sorghum comprised 43 percent of the autumn diet of lesser prairie-chickens in western Texas (Crawford and Bolen 1976a). Other grains commonly eaten by lesser prairie-chickens (if available) include corn and wheat (Schwilling 1955, Crawford and Bolen 1976a, Ahlborn 1980, Jamison 2000). In southwestern Kansas, lesser prairie-chickens are known to use alfalfa fields as foraging areas (Jamison 2000).

A striking aspect of the lesser prairie-chicken diet is the relatively high proportion of insects consumed by adult birds; percent volume insect matter in the summer diet of adult lesser prairie-chickens was as high as 23 percent in Oklahoma (Jones 1963) and 55 percent in eastern New Mexico (Davis et al. 1980). Important insect prey items for adults include short-horned grasshoppers (Acrididae; Schwilling 1955, Davis et al. 1980, Riley et al. 1993b) and darkling beetles (Tenebrionidae; Crawford and Bolen 1976a).

Insects are the primary diet items of chicks (Jones 1963, Davis et al. 1980). The diet of chicks less than four weeks of age was 100 percent insects, predominately short-horned grasshoppers (Acrididae, 50 percent), treehoppers (Membracidae, 26 percent), and long-horned grasshoppers (Tettigoniidae, 12 percent) (n = 10; Davis et al. 1980). When chicks are less than two weeks of age, treehoppers (Membracidae) may comprise as much as 80 percent of the diet (Davis et al. 1980). Jones (1963) examined seven droppings and one crop from chicks approximately one month old and concluded that insects comprised 85 percent of the diet; Carabidae (27 percent) and Orthoptera (42 percent). Davis et al. (1980) examined crop contents of chicks 5 to 10 weeks of age, and although chicks had begun to consume mast, seeds, and other vegetative material, insects constituted 99 percent of the diet. During this period, short-horned grasshoppers were the most common prey item (approximately 80 percent of all insects consumed). Captive greater sage-grouse (*Centrocercus urophasianus*) chicks require insects in their diet for survival, especially during the first three weeks of age; for older chicks, survival and growth rates increased as the proportion of insects in the diet increased (Johnson and Boyce 1990).

Diet and behavior

Little information exists regarding foraging behavior, daily intake, and nutritional requirements of lesser prairie-chicken chicks. However, the most critical time for the young of most grouse is the first 20 days after hatch, when chicks have a rapid growth rate (Dobson et al. 1988). Merchant (1982) monitored nesting behavior of radio-marked females in two years of contrasting weather, a year of average precipitation vs. drought. During the drought year, females nested on average 11 days later, had smaller first clutches, and were less likely to renest than did females during the year when precipitation levels were normal. He suggested that the lower reproductive effort observed during the drought year resulted from a lack of food resources important to females for reproduction. These behavioral observations appear to explain the positive correlation between precipitation and harvest levels in New Mexico (Brown 1978). A relationship between productivity and weather has also been observed with sharp-tailed grouse (*Tympanuchus phasianellus*; Flanders-Wanner et al. 2004).

Most feeding activity occurs during the early morning and late afternoon (Giesen 1998). Taylor and Guthery (1980b) noted increased daily movements of radio-marked birds during autumn coinciding with cessation of the autumn display period and increased use of sunflower fields as foraging areas. Crawford and Bolen (1973) recorded male lesser prairie-chickens regularly making short visits to stock ponds during March and April. Copelin (1963) observed lesser prairie-chickens visiting free water (stock ponds) daily, or twice daily, from October through March, and Jones (1964a) noted birds visiting water sources during late summer and autumn.

Food abundance and distribution

Insects are important diet items for all age classes, but especially chicks. Although insect abundance may be high in habitats with a high proportion of forbs (Jones 1963, Jamison 2000), relatively little is known about insect/plant associations important to lesser prairie-chickens. Forb diversity and abundance on rangelands are influenced by grazing practices (Fuhlendorf and Engle 2001), as well as burning, mowing, and chemical spraying. Additionally, drought conditions may decrease species richness of eastern grasslands by contributing to the loss of annual species, woody species, and perennial grasses, forbs, and legumes (Tilman and Haddi 1992). Recolonization of grasslands by native annual species may take several years even when precipitation levels return to normal (Tilman and Haddi 1992).

Grain crops are used as a food resource by some populations of lesser prairie-chickens (Crawford and Bolen 1976a). Availability of grain crops may vary both annually and regionally as it is determined largely by agriculture practices (crop rotation, tilling, harvest) and policies (such as those associate with the CRP).

Breeding biology

Breeding behavior

Lesser prairie-chickens are one of several species of Tetraoninae that have a lek mating system: 1) males provide no parental care; 2) females come to an arena or lek where most males aggregate for mating; 3) display

sites used by males do not contain specific resources required by females except the males themselves; and 4) females can choose a mate at the lek (Bradbury 1981). Lekking species typically exhibit elaborate courtship behaviors and displays (Bradbury 1981, Höglund and Alatalo 1995).

The primary display performed by male lesser prairie-chickens during the lekking period in spring is referred to as "gobbling" (Davison 1940, Sharpe 1968). The gobbling display (Sharpe 1968, Hjorth 1970, Johnsgard 1983, Giesen 1998) consists of the following behaviors:

- the tail is raised to its highest extent and is slightly fanned
- the pinnae are raised and positioned forward, almost parallel with the ground
- the wings are drooped and the primaries are spread
- the head and neck are extended forward
- the yellow-orange superciliary eye-combs are enlarged
- stamping of the feet moves the body in a forward motion
- the esophageal air sacs are inflated producing a "booming" vocalization.

The vocalization produced by males during this display is of relatively low frequency and high intensity and has been referred to as a "gobbling" (Sharpe 1968), "bubbling" (Grange 1940), or "yodelling" (Hjorth 1970) sound. Grange (1940:129) phonetically described this sound as "*quoodle-oook, quoodle oook*". The gobbling display functions in both territory defense and courtship, and performed collectively, it may advertise the presence of a lek to females in the vicinity. Male lesser prairie-chickens also perform antiphonal "gobbling" whereby males in adjacent territories display jointly by alternating gobbling displays in a duet fashion (Hjorth 1970). Antiphonal "gobbling" gradually increases in frequency; up to 10 "gobbles" may be produced in rapid succession during one bout of antiphonal "gobbling" (Sharpe 1968). In addition to the gobbling display, males perform a flutter jump, or wing beat, display, especially when females are on or near the lek (Sharpe 1968, Hjorth 1970, Haukos 1988). Males use short wing bursts to leap 2 or 3 m into the air, sometimes landing 180° from their take-off orientation (Hjorth 1970). A cackle vocalization usually accompanies the flutter jump display (Hjorth 1970); cackle vocalizations were heard for 16 of 20 flutter jump displays (Sharpe 1968).

Males commence visiting lek sites during March in Colorado (Hoffman 1963), February in Kansas, Texas, and Oklahoma (Davison 1940, Schwilling 1955, Copelin 1963, Sell 1979), and as early as January in New Mexico (Merchant 1982). The spring display period usually lasts until mid-May or mid-June (Copelin 1963, Hoffman 1963). However, Jones (1964a) found lesser prairie-chickens attending lek sites in Oklahoma during all months of the year except August and December. An autumn display period may occur (Crawford and Bolen 1976a, Taylor and Guthery 1980a, Jamison 2000), but male attendance is less regular and the displays are less intense than during the spring breeding period (Copelin 1963). A decline and eventual cessation of lek activity occurs through autumn as temperatures become colder (Copelin 1963).

Males visit a lek during morning and evening hours; evening attendance is more common during spring (Crawford and Bolen 1975, Giesen 1998). Males usually arrive on leks 30 to 60 minutes prior to sunrise and remain for 3 to 4 hours (Giesen 1998). Factors such as weather, season, and temperature may influence male attendance and/or display activity at the lek (Davison 1940, Schwilling 1955, Copelin 1963, Hoffman 1963, Merchant 1982). During spring, the number of males attending a lek peaks from sunrise to 105 minutes later (Crawford and Bolen 1975); courtship displays may be most intense around sunrise (Copelin 1963). During calm conditions displaying males may be heard by a human observer from a distance of >3 km (Schwilling 1955). Because leks, and hence individuals, can be located during the spring display period, surveys for lesser prairie-chickens typically are conducted at this time.

On lek sites, male lesser prairie-chickens establish territories that they actively defend against other males (Copelin 1963, Sharpe 1968, Hjorth 1970, Campbell 1972, Haukos 1988). These territories generally consist of a core area, in which neighboring males are seldom encountered, and peripheral or boundary areas where aggressive encounters with other males occur (Sharpe 1968, Robel 1970). The area of the territory may vary with the dominance rank of the male; centrally located territories of dominant males tend to be smaller than those of peripheral males (Giesen 1998). Territory sizes in Oklahoma ranged from 3.6 to 4.5 m in diameter (Copelin 1963) and were all >7 m in diameter in a study

in Kansas (Hjorth 1970). Territory boundaries often follow natural features of the landscape (Giesen 1998) but may shift if the substrate is such that boundaries are poorly defined (Haukos 1988). Territorial boundaries are not rigidly observed as a dominant male will follow a female into the territory of an adjacent male, and in some cases males have been observed leaving the lek to follow a departing female (Sharpe 1968). Haukos (1988) described small subgroups of males on a lek and a dominance hierarchy among males in these subgroups rather than a linear hierarchy of dominance among all males attending a lek. Territories also have been observed to change between morning and evening display periods (Haukos 1988).

Similar to other species of prairie grouse, a dominant male on a lek is responsible for the majority of copulations; of 13 successful copulations 85 percent were by the socially dominant male (Sharpe 1968). The number of males observed at leks increases early in the spring. By the peak of the breeding season, the number of males attending leks tends to be relatively stable then rapidly drops off as female visitation declines (Giesen 1998).

The peak of female attendance on leks varies regionally and with weather. Peaks occur during late April-early May in Oklahoma (Copelin 1963), early-mid April in Texas (Crawford and Bolen 1975, Haukos 1988), early-mid April in New Mexico (Merchant 1982), early April in Colorado (Giesen 2000), and early-mid April in Kansas (Schwilling 1955). Drought conditions may delay the peak in female attendance by 7 to 10 days in Texas (Haukos 1988) and as much as two weeks in New Mexico (Merchant 1982). During the peak of mating activity, females may visit the lek singly (Davison 1940) or in small flocks (Sharpe 1968, Haukos 1988). Social dominance interactions have been observed within these flocks whereby the socially dominant female may prevent subordinate females from mating (Sharpe 1968, Haukos 1988).

The peak period for females to lay and incubate eggs is during April to June, and the peak brood season is during May to July (Giesen 1998). Little is known about the timing of brood break-up and dispersal, but the former appears to be common when the chicks are 12 to 15 weeks of age (Giesen 1998).

Breeding site fidelity

Lek sites generally are considered traditional because they are frequently used by lesser prairie-chickens year after year (Copelin 1963, Hoffman 1963, Campbell 1972, Giesen 1998). Males, in particular, exhibit high fidelity to their lek site among years (Davison 1940, Copelin 1963, Giesen 1998). Although many lek sites of prairie grouse are permanent, several temporary or satellite leks may also be established within a region during the breeding season (Robel et al. 1970b, Hamerstrom and Hamerstrom 1973, Schroeder and Braun 1992). The presence of satellite leks may reflect population fluctuations, becoming more common when the population increases (Hamerstrom and Hamerstrom 1973, Schroeder and Braun 1992). Attendance of males at satellite leks may coincide with decreased attendance by males at neighboring leks (Haukos and Smith 1999). Although the proportion of birds that establish territories on leks is unknown, in a study conducted in Kansas, 100 percent of 76 radio-marked male lesser prairie-chickens attended a lek (Jamison 2000). This estimate is, however, potentially biased, as the males in this study were initially captured at lek sites.

Once males establish a breeding site, they typically display fidelity to that lek in subsequent years (Campbell 1972). In New Mexico, four of 114 (3.5%) recaptures of banded males were located on leks different from where they were banded (Campbell 1972). These four recaptures represented three birds, two yearlings, and one adult. Similarly, Haukos and Smith (1999) recaptured 35 banded males within the same season; only one adult and one yearling were captured at a lek other than where they were banded. Mobility of males among leks was higher in a fragmented landscape in Kansas (Jamison 2000). Of 48 banded males, 21 percent (n = 10) were recaptured at leks other than where they were banded; distances moved between lek of capture and new lek ranged from 0.4 to 4.4 km (Jamison 2000). However, three of the 10 males in Jamison's study were initially captured at what he termed "unstable" or "satellite" leks, and four of the 10 males were yearlings. Haukos and Smith (1999) noted that satellite leks generally formed later in the season and coincided with decreased attendance on permanent leks. They hypothesized that satellite leks consisted of individuals, primarily yearling birds, that were unable to establish territories on permanent leks. The yearling:adult ratio of males attending leks was 3.8:1 for leks active 2 years and 1.0:1.0 for leks active >6 years (Haukos and Smith 1999). Yearling males also have been observed on more than one lek during a single breeding season (Campbell 1972). This is comparable to greater prairie-chickens where yearling males have been observed on as many as six different leks in a single breeding season, and occasionally on two different leks during the same morning (Bowman and Robel 1977, Schroeder and Braun 1992).

Variation in the stability of leks can reflect population changes or the relocation of leks among years (Crawford and Bolen 1976a, Jamison 2000). Similar lek dynamics have been observed for greater prairie-chickens, whereby localized habitat changes resulted in the formation of a new lek near a previously established lek site (Schroeder and Braun 1992). Giesen (1998) reported an annual lek turnover rate of 14 percent for all permanent and satellite lesser prairie-chicken leks on his study area in Colorado.

There is little published information regarding lek visitation by female lesser prairie-chickens. Haukos and Smith (1999) recaptured one banded female on two different leks, three days apart. However, female greater prairie-chickens commonly visit more than one lek during a breeding season, and visits to as many as six different leks have been documented (Schroeder 1991). The distance between a female's nest and the nearest lek averaged 1.0 km and was less than the distance between a female's nest site and the lek where she was captured (average = 1.8 km, n = 31; Giesen 1994b). In general, females nest within 3.4 km of the lek where they were captured (Giesen 1998).

Parental care, brood break-up, and dispersal

Parental care is provided by females; the males play no role in incubating eggs or rearing chicks (Giesen 1998). Females incubate their clutches for 24 to 26 days; complete hatching of the clutch may take one or two days. The chicks are precocial. They generally leave the nest within 24 hours following hatch and travel to insect-rich habitats. Females regularly brood their chicks throughout the day, especially when the chicks are young. Broods are relatively mobile, but little is known regarding factors that influence brood behavior and movements.

Scant information is published regarding aspects of brood break-up and juvenile dispersal, especially movements by females. Brood break-up tends to occur when the chicks are 12 to 15 weeks of age, after which they form mixed flocks with adult birds (Giesen 1998). Copelin (1963) banded juvenile lesser prairie-chickens during summer, and in autumn he recaptured 14 individuals (unknown sex) on lek sites. All 14 were within 4.7 km of their respective brood ranges, and six were less than 1.6 km. Taylor and Guthery (1980b) followed 19 radio-marked lesser prairie-chickens from October through February. One juvenile male moved 12.8 km in a 4-day period during the second week of December. Jamison (2000) monitored lesser prairie-chickens in a fragmented landscape and recorded two of 76 radio-marked males making relatively long distance movements during the latter part of March and early April. One adult male moved 13.5 km; the other bird, a yearling, moved 44.0 km. The number of days to complete these movements and whether they ever returned to the study area are unknown. Additionally, two males banded as chicks were later recaptured at lek sites. One male was located that autumn on a lek approximately 2.2 km from its hatch site and 2.9 km from its brood range; the other was recaptured the following spring on a lek approximately 2.3 km from its hatch site and 1.1 km from its brood range.

There is a tendency for juvenile females to move farther than juvenile males between their autumn/winter range and first breeding area; 17 of 27 males moved 0.0 to 0.7 km to their first breeding area while three of five females moved greater than 3.2 km (Copelin 1963). This is consistent with evidence from studies with other species of prairie grouse (Hamerstom and Hamerstrom 1973 for greater prairie-chickens; Connelly et al. 1998 for sharp-tailed grouse; Schroeder et al. 1999 for sage-grouse), indicating that females tend to disperse farther than males. Thus, in a given population, males are far more localized than females. Consequently, dispersal movements by females may be particularly important in maintaining gene flow.

Demography

Genetic characteristics and concerns

Generally, a population is defined as the individuals of a specific species in a particular group or area. In most instances, a population is an assemblage of groups distributed over a large area (Soulé 1987). Fundamental to population genetics is the fact that small or isolated populations (with few individuals and no immigration) lose genetic variation over time, thereby increasing the probability of extinction and decreasing the probability of future adaptive change (Lande and Barrowclough 1987). The genetic structure of a population is determined by mutation, random genetic drift, natural selection, and gene flow; as gene flow is decreased, genetic variation is lost due to random genetic drift (Ewens et al. 1987, Slatkin 1987). Genetic variation is believed to be important for a population's long-term persistence because it prevents the deleterious effects of inbreeding and the random loss of alleles through genetic drift. The amount of genetic variation in a population is, in part, a function of what is termed "effective population size", or the "... number of individuals in an ideal population that would have the same genetic properties (in terms of random genetic

drift) as an actual population with its own complicated pattern of demographics, sex ratio, etc." (Lande and Barrowclough 1987:99).

As an example, greater prairie-chickens in Illinois declined from an estimated several million birds distributed over 60 percent of the state during the mid-1800s, to an estimated 2000 individuals in 179 subpopulations in 1962, to a low of 46 birds in two populations by 1994. The decline in numbers between 1962 and 1994 occurred despite extensive management efforts to improve habitat, control nest parasites (ring-necked pheasants [*Phasianus colchicus*]), and control predators (Westemeier et al. 1998). Declines in reproductive parameters such as egg fertility (fertile incubated eggs per total eggs) and hatching rate (hatched eggs per total eggs in fully incubated clutches) were associated with a contraction and decline of the population (Westemeier et al. 1998). Genetic studies indicated significantly lower levels of genetic diversity in the Illinois population than in larger, more contiguous populations (Bouzat et al. 1997). The introduction of greater prairie-chickens from relatively continuous populations in Minnesota, Kansas, and Nebraska resulted in significant increases in egg fertility and hatching rates in the Illinois population (Westemeier et al. 1998). Westemeier et al. (1998) concluded that the Illinois population would have inevitably gone extinct without this intervention, as it would have been unable to recover the genetic variation necessary to offset environmental effects.

Genetic issues are important considerations for management of lesser prairie-chickens as the broad-scale loss and fragmentation of the species' historical range have isolated some populations and/or reduced or eliminated others (Bouzat and Johnson 2004). Moreover, because lesser prairie-chickens have a lek mating system and potentially limited dispersal, calculations of effective population size may underestimate the ideal population needed to maintain genetic diversity (Bouzat et al. 1997, Johnson et al. 2004). Although genetic viability of lesser prairie-chicken populations is a recognized concern, research has not shown a relationship in genetic heterogeneity between Oklahoma (relatively fragmented) and New Mexico (relatively unfragmented; Van Den Bussche et al. 2003). However, a similar examination of relatively small and fragmented populations of greater prairie-chickens in Wisconsin showed substantial effects (Johnson et al. 2003, Johnson et al. 2004). The Wisconsin findings appeared related to the length of time the population had been isolated and fragmented. A comparison of genetic samples collected in 1951 with samples collected in the late 1990s illustrated a dramatic loss of genetic heterogeneity (Bellinger et al. 2003).

In Colorado, the lesser prairie-chicken is limited mostly to a few small populations in the southeastern corner of the state. Genetic viability is a concern for the isolated populations in Kiowa and Cheyenne counties as these populations each number less than 100 individuals (Giesen 2000). Kansas has the largest estimated number of lesser prairie-chickens in the five-state range. However, while this population is believed to be contiguous, landscape configuration in the southwestern border areas is characterized by isolated grassland fragments (Jensen et al. 2000). It is possible that this fragmentation influences demographic processes such as dispersal, and consequently genetic interchange (Bellinger et al. 2003, Johnson et al. 2003, Bouzat and Johnson 2004, Johnson et al. 2004).

Lesser prairie-chickens have expanded their range in Kansas in recent years (U.S. Fish and Wildlife Service 2002). Greater prairie-chicken populations also have responded positively to CRP. In some areas both species overlap, and mixed leks are becoming common. Although the rate of hybridization during pre-settlement times cannot be determined, it is probable that differences in habitat use served as an isolating mechanism between the two species (Jones 1963, Sharpe 1968). Hybrid birds have been observed in Kansas, but the frequency of hybridization, the fertility of hybrids, and the potential long-term impact of hybridization are unknown (U.S. Fish and Wildlife Service 2002). Lesser prairie-chicken populations north of the Arkansas River are low density, and consequently they may be particularly susceptible to the negative effects of hybridization (U.S. Fish and Wildlife Service 2002). Similarly, hybridization has been recorded between greater prairie-chickens and sharp-tailed grouse in areas where populations are sympatric (Ammann 1957, Sparling 1980). In these cases, hybrid birds are fertile, and it has been suggested that sharp-tailed grouse eventually become the dominant species, as F1 females appear to show a preference for sharp-tailed males (Sparling 1981, Toepfer et al. 1990).

Life history characteristics

Although yearling males (0.5 to 1.5 years of age) are physiologically able to breed, adult males are believed to do most of the breeding (Giesen 1998). Most females are believed to breed the first year following hatch and usually lay one completed clutch *per se*ason. Clutch size averages 10.9 eggs (range 8 – 14, $n = 95$ nests from eight studies; review by Giesen

1998, Hagen 2003, Fields 2004). Females may renest if their first clutch is depredated, but renest clutches tend to be smaller (Merchant 1982, Giesen 1998, Hagen 2003, Fields 2004). Hagen (2003) and Fields (2004) found that average clutch sizes in Kansas were four to six eggs larger for first nests than for renests. Hatching success of eggs (proportion of eggs that hatch in fully incubated clutches) was 100 percent in Oklahoma (n = 47 eggs from four clutches; Copelin 1963) and >90 percent in Colorado (Giesen 1998). No information is available regarding fertility of eggs.

Nest success (proportion of nests that hatch at least one egg) varies among studies: 15 percent in Texas (n = 13, Haukos 1988), 37 percent in Texas (n = 8, Sell 1979), 67 percent in Oklahoma (n = 6, Copelin 1963), 47 percent in New Mexico (n = 17, Riley 1978), 36 percent in New Mexico (n = 14, Ahlborn 1980), 28 percent in New Mexico (n = 36, Riley et al. 1992), 26 percent in Kansas (n = 74, Jamison 2000), 26 percent in Kansas (n = 172, Hagen 2003), and 54 percent in Kansas (n = 35, Fields 2004). Nest success was 54 percent (7 of 13 nests hatched) in New Mexico during a year of average precipitation, but it was 0 percent (0 of 11 nests hatched) during a year of severe drought (Merchant 1982). Average nest success throughout the range, including unpublished data from Colorado, is 30 percent for 12 studies (Giesen 1998, Hagen 2003, Fields 2004). Hagen (2003) found that first nests tended to be more successful (28.9 percent, n = 142) than renests (13.3 percent, n = 30) in southwestern Kansas. Annual variation in nest success may occur because of differences in weather, age structure of nesting females, and predation rates (Bergerud 1988b, Fields 2004), as well as availability of suitable nesting cover (Riley et al. 1992).

Few studies have examined survival of chicks from hatching to independence (Hagen 2003). Based on observations recorded from July through September, Davison (1940) reported an average brood size of 5.2 to 7.5 chicks per brood in Oklahoma over a 4-year period. Copelin (1963) reported an average brood size of 6.2 to 7.3 chicks per brood over four years. Merchant (1982) reported an average brood size of 7.8 chicks per brood (n = 17 observations) during a year of average precipitation and 3.5 chicks per brood (n = 4 observations) during a dry year. However, brood sizes reported in these studies may be over-estimated as counts tend to decrease later in the season. Young broods typically have more chicks than older broods, as chick survival averages only 24 percent during the first 35 days following hatch (Hagen 2003). Survival for chicks between 35 days of age and the following spring was estimated to be 53.9 percent in southwestern Kansas (Hagen 2003). Inaccurate counts also may occur because broods occasionally mix later in the season (Copelin 1963). Jamison (2000) examined brood survival of lesser prairie-chickens and the pattern of attrition from hatch to independence for individually identifiable chicks. The daily survival of chicks was 94.1 percent/day during the first 14 days and 98.3 percent/day from 14 to 60 days after hatch. The estimated overall survival rate of chicks for the 60-day period after hatch was 19 percent. Jamison (2000) concluded that average brood size, calculated from flush count data, tended to overestimate the survival rate of chicks, as factors such as total brood loss and brood-mixing were not considered. For instance, in Jamison's (2000) study nearly half of the females monitored suffered total brood loss within two weeks of hatch.

Annual survival was estimated as 35 percent for 67 males banded in New Mexico, using capture-recapture techniques (Campbell 1972). Campbell indicated that these estimated survival rates may be low by as much as 5 to 10 percent because of the possibility that some birds could not be recaptured. Campbell (1972) reported a complete turnover of banded male lesser prairie-chickens in a 5-year period. Annual survival estimates for lesser prairie-chickens in Kansas were 45 percent for 311 males (Hagen et al. 2005) and 43 percent for 227 females (Hagen 2003). Survival was estimated to be 60 percent for yearling males and 43 percent for adult males (Hagen et al. 2005). Survival also tended to be higher for yearling females than for adults (**Table 3**; Hagen 2003, Hagen et al. 2004). Female survival tended to be lowest during the nesting period during May (Hagen 2003). Survival rate for radio-marked females was estimated to be 59 percent during mid-March to mid-May in Texas (n = 46, Haukos 1988) and 41 percent during April to August in New Mexico (n = 41, Merchant 1982).

We adapted a population model (Caswell 2001) to evaluate the finite rate of population change (λ) for a well-studied lesser prairie-chicken population in southwestern Kansas (**Figure 8**, **Table 3**; Hagen 2003). Although data for other portions of the lesser prairie-chicken range exist, the data sets are not as complete. The rate of growth for this population was estimated to be 0.689. This value was extremely low, well below the 1.0 rate necessary for a stable population. In the original research upon which this analysis was based, the study had been divided into two portions with growth rates of 0.544 and 0.754, respectively (Hagen 2003). Explanations for the low rate include habitat alteration and support of the population with immigration from surrounding areas (Hagen 2003).

Table 3. Parameter values for productivity and survival for female lesser prairie-chickens in southwestern Kansas (Hagen 2003). Although Hagen separated some of the parameters by age and study area, many of the values were combined (weighted means) for the table below.

Parameter	Estimate	n
Likelihood of nesting at least once	100%	-[a]
Clutch size for first nests	12.1 eggs	151 nests
Success rate for first nests	28.9%	142 nests
Likelihood of renesting following failure of first nest	30.3	99
Clutch size for renests	7.7	29
Success rate for renests	13.3	30
Assumed sex ratio of eggs	1:1	-[b]
Hatchability for eggs in a successful nest	100%	-[c]
Survival of hatched chicks to 34 days of age (fledging)	23.6	38
Average number of female fledglings produced (F in Figure 8)	0.44	-[d]
Survival of juveniles from fledging to the next spring (S_J in Figure 8)	53.9	32
Annual survival of yearlings (S_Y in Figure 8)	52.1	57
Annual survival of adults (S_A in Figure 8)	36.9	98

[a]This data was not provided by Hagen (2003), but assumed to be close to 100%.

[b]Sex ratio data varies substantially (Geisen 1998), so a ratio of 1:1 was assumed.

[c]This data was not provided by Hagen (2003), but was likely close to 100% based on the summary of data in Geisen (1998).

[d]The average number of female fledglings produced combines nesting and renesting likelihood, success, and clutch size, as well as chick survival throughout 34 days of age.

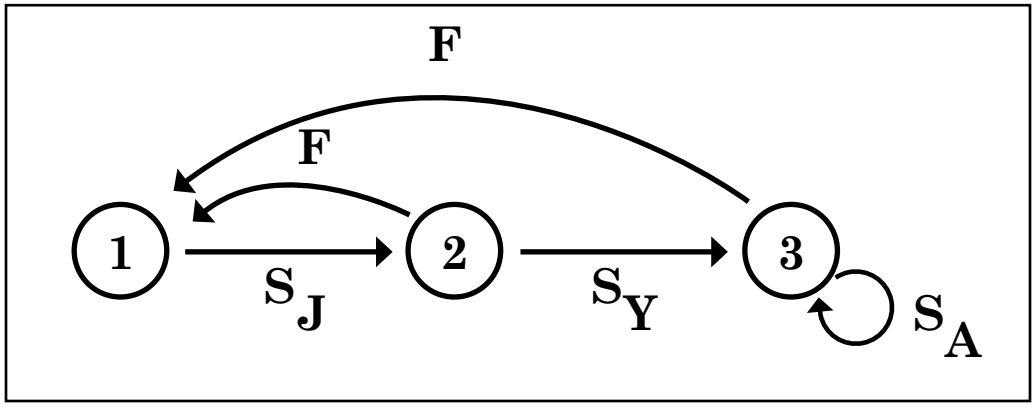

Figure 8. Life cycle diagram for the lesser prairie-chicken (based on techniques in Caswell 2001). Data for the parameters is provided in **Table 3**.

Hagen (2003) conducted sensitivity and elasticity analyses on the effect of vital rates on the estimation of λ. Because the elasticity analysis differs from the sensitivity analysis, in that the results are scaled for comparison, Hagen focused on the elasticity analysis. Hagen's analysis showed that survival of chicks between hatch and 34 days had the largest impact on λ. The next most important parameters included the survival and productivity of adults, respectively.

The knowledge of which demographic components (life stages) exert the greatest effect on population growth is important for managers to consider (Caswell 1989). Nest success and chick survival are generally considered the most significant features influencing population dynamics of prairie grouse (Bergerud 1988b, Peterson and Silvy 1996, Wisdom and Mills 1997, Schroeder and Baydack 2001). Sensitivity analysis of vital rates for lesser prairie-chicken populations indicates that nest success and chick survival have the greatest effect on population growth (Hagen 2003). Hagen (2003) also noted that the populations of lesser prairie-chickens he studied in Kansas would not have maintained themselves without immigration from outside the population.

Population regulation

Numerous intrinsic factors (e.g., spacing behavior) and extrinsic factors (e.g., weather, predation, habitat, disease) have been suggested to influence survival and reproduction in various grouse species (Angelstam 1988, Hannon 1988); however, the relative importance of the various factors and how they interact often is unclear (Boag and Schroeder 1992, Zwickel 1992, Braun et al. 1993, Schroeder and Robb 1993). Lesser prairie-chickens are highly social throughout the year; even during the breeding season. Males form flocks with other males from the same lek, and females often visit leks in small groups (Sharpe 1968, Haukos 1988, Giesen 1998). Although females select nesting areas, whether or not these areas are defended is unclear; in some cases, individuals have been found nesting 14 m apart (Copelin 1963). Dominant females also have been observed to drive off other females on leks (Sharpe 1968, Haukos 1988). This has also been noted in greater prairie-chickens (Robel 1970). This type of behavior has been considered to significantly impact populations in other species of grouse (Hannon 1988). However, the importance of this type of behavior on lesser prairie-chicken demography is unknown.

In contrast to intrinsic factors, extrinsic factors (e.g., weather, predation, habitat degradation, disease) have been well documented. The most common threats to grouse populations are habitat loss, fragmentation, and degradation and the interaction of these processes to create increasingly isolated populations that are more susceptible to predation, disease, declines in genetic diversity, and increases in vulnerability to extinction through stochastic events (Fritz 1979, Davies 1992, Bergmann and Klaus 1994, Mote et al. 1998, Storch 2000). In the case of lesser prairie-chickens, the conversion of native rangeland directly eliminates critical nesting habitat (Mote et al. 1998, Hagen et al. 2004) and results in fragmentation of remaining areas. Although low levels of cultivated cropland (specifically grain crops) have not been detrimental to some populations (Crawford and Bolen 1976a), in many cases, crops (e.g., cotton grown in Texas) do not provide the cover and food resources required by lesser prairie-chickens (Sullivan et al. 2000). Habitat quality, composition, and structure of rangeland vegetation are factors limiting the distribution and numbers of lesser prairie-chickens in some areas, as evidenced by the 92 percent reduction in range (Taylor and Guthery 1980a, Davies 1992, Giesen 1994b).

The lack of suitable nesting cover is considered a limiting factor for greater prairie-chickens throughout their range (Kirsch 1974). Residual vegetation is a critical habitat component for lesser prairie-chickens as nest success has been positively correlated with increased height and density of grasses at nest sites (Riley et al. 1992). For instance in east-central and southeastern New Mexico, 4 percent of the available nesting habitat is considered "good", 16 percent is rated fair, and 80 percent is considered unsuitable-poor (Bailey et al. 2000). Habitat degradation caused by heavy grazing may adversely impact nest success (Hagen et al 2004), as relatively dense cover is believed to provide greater concealment of nests from predators for most species of grouse (Bergerud 1988a, Bergerud 1988b). This effect may be exacerbated by drought (Merchant 1982). Predation is a significant cause of failed nests; 85 percent (n = 55) of nest loss was attributed to predation in Kansas (Jamison 2000), and 65 percent (n = 25) of nests were destroyed by predators in New Mexico (Riley et al. 1992). In addition, predation during the nesting season can be a significant mortality factor for females. Haukos (1988) monitored 34 radio-tagged females from mid-March to mid-May. Of these, 16 (47 percent) were predated; eight mortalities were attributed to raptors and five to coyotes.

In Colorado, a landscape dominated by croplands and shortgrass rangelands limits the expansion of lesser prairie-chickens from core areas in the state (Giesen 1994a). Grazing is a common land use practice throughout the prairies of this region, and where grazing practices fail to leave adequate cover for nesting, it is likely detrimental to lesser prairie-chickens (Taylor and Guthery 1980a, Hagen et al. 2004). For instance, species of warm season native grasses (bluestems) that provide nesting cover are maintained by light to moderate grazing intensity (Mote et al. 1998) and are reduced greatly by heavy grazing (Riley et al. 1992). Additionally, the effects of grazing systems in Region 2 are influenced by the occurrence of periodic droughts, some of which may be severe (Mote et al. 1998). Drought conditions reduce vegetative growth and residual cover (Giesen 2000), as well as plant species richness in subsequent years (Tilman and Haddi 1992). During years of drought, rangelands may be overgrazed, resulting in loss of cover in subsequent years (Hamerstrom and Hamerstrom 1973, U.S. Fish and Wildlife Service 2002).

The first couple of weeks after hatch, when chicks are developing thermoregulatory ability, is a critical period for many species of galliformes (Dobson et al. 1988). Heat stress due to hot, dry weather during the nesting season has been suggested as a factor contributing to mortality of young chicks (Merchant

1982). Merchant (1982) recorded smaller brood sizes during a drought year when the high temperature during the first 10 days after hatch averaged 38.8 °C. Surveys conducted on his study area the following spring indicated a lower total number of males on leks, a lower number of occupied leks, and a lower number of males per lek than the previous spring.

Reduction in abundance of native forbs may negatively impact lesser prairie-chickens as broods preferentially select areas with high invertebrate biomass and these areas are associated with high forb abundance (Jamison et al. 2002a). Additionally, chick survival may be reduced if broods are forced to make extensive movements through unsuitable and potentially risky habitats. Many species of hawks, owls, and mammals are known predators of chicks, and mortality can be high, especially during the first couple of weeks after hatch. For instance, in southwestern Kansas, Jamison (2000) found 57 percent mortality of chicks and total brood loss for approximately 50 percent of broods during the first two weeks following hatch. The estimated mortality rate of chicks from hatch to 60 days of age was 81 percent.

Habitat fragmentation is increasingly common within lesser prairie-chicken range (Mote et al. 1998, Hagen et al. 2004), but its impact on survival and productivity is unclear. It has been suggested that habitat fragmentation may impact nest success negatively by forcing birds to nest in marginal habitats, increasing travel time through unsuitable areas, and increasing the diversity and density of predators (Ryan et al. 1998, Schroeder and Baydack 2001). Areas with less than 63 percent shinnery oak rangeland may be incapable of supporting lesser prairie-chicken populations in west Texas (Crawford and Bolen 1976a). Lesser prairie-chickens in Kansas appeared to avoid nesting near anthropogenic features (Pitman 2003). However, "threshold" levels of fragmentation are unknown for other parts of the range (Mote et al. 1998). In fragmented areas, nest loss for lesser prairie-chickens may be higher than in larger, more continuous tracts, as has been observed for other species of ground-nesting birds in grassland habitats (Braun et al. 1978, Johnson and Temple 1990). Lesser prairie-chickens have limited dispersal capabilities. Thus, populations may become isolated if separated by large areas of unsuitable habitat since dispersal rates may be inadequate for maintaining connectivity and genetic viability of populations (Mote et al. 1998).

The openness of lesser prairie-chicken habitat is important. Evidence suggests that predation of prairie grouse nests is lower in treeless grasslands than in areas interspersed with brushy cover (McKee et al. 1998). Taller trees may provide nest and roost locations for raptor species that prey on lesser prairie-chicken chicks and adults.

Conversion of cropland to CRP apparently has benefited lesser prairie-chickens in southwestern Kansas (U.S. Fish and Wildlife Service 2002). Although CRP acreage accounts for one third of the cropland in Baca County, Colorado, increases in occupied range and numbers of lesser prairie-chickens have not been observed in this state (Giesen 2000). However, several kilometers of shortgrass prairie often separate CRP lands from occupied lesser prairie-chicken range in the southeastern part of Colorado, perhaps precluding their use by prairie-chickens.

Community ecology

Predation

Intensity of predation pressure varies and is believed to be linked to changes in predator foraging strategies during population fluctuations of primary prey items (Schroeder and Baydack 2001). For example, during years of scarce prey, predators may search more intensively and, consequently, increase their probability of encountering grouse nests (Angelstam 1983). There is evidence that predation levels in grouse populations also are influenced by aspects of habitat quality, such as fragmentation and degradation. In fragmented landscapes, lesser prairie-chickens are forced to move greater distances and more frequently between patches of suitable habitat. This exposes them to higher predation risks. Ryan et al. 1998 found that fragmentation of nesting habitat subjected female greater prairie chickens to increased levels of predation as the density and diversity of predators may be increased in these areas (Braun et al. 1978, Schroeder and Baydack 2001).

The predator community of the prairies has changed significantly since pre-European settlement, and many generalist predators such as coyotes and skunks have increased in range and numbers (U.S. Fish and Wildlife Service 2002). Modification of grassland habitats by power poles, wind machines, fence lines, and tree plantings may increase predation levels by creating favorable hunting perches and nest sites for raptors, and establishment of livestock watering sites may alter the local distribution of some mammalian predators.

Observations of predation events involving lesser prairie-chickens are rare (Mote et al. 1998). One published account documented five instances where northern harriers (*Circus cyaneus*) successfully killed birds (Haukos and Broda 1989). Numerous avian and mammalian species are believed to be predators of lesser prairie-chickens and their nests (Giesen 1998). Primary predators of adult and juvenile birds include rough-legged hawk (*Buteo lagopus*), red-tailed hawk (*B. jamaicensis*), prairie falcon (*Falco mexicanus*), Cooper's hawk (*Accipiter cooperii*), northern harrier, ferruginous hawk (*B. regalis*), golden eagle (*Aquila chrysaetos*), great horned owl (*Bubo virginianus*), coyote (*Canis latrans*), and badger (*Taxidea taxus*; see reviews by Giesen 1998, Haukos and Broda 1989). Major nest predators include coyote, Chihuahuan raven (*Corvus cryptoleucus*), bull snake (*Pituophis melanoleucus*), striped skunk (*Mephitis mephitis*), badger, and ground squirrel (*Spermophilus spilosoma*; Haukos 1988, Riley et al. 1992, Giesen 1998, Jamison 2000).

Competition

The historical distributions of lesser prairie-chickens and greater prairie-chickens were geographically continuous but not overlapping (Aldrich 1963). Greater prairie-chickens generally were found in mixed to tallgrass prairies while lesser prairie-chickens occupied xeric grasslands with a shrub component of shinnery oak or sand sagebrush. Jones (1963) believed that these habitat differences were great enough to serve as an isolating mechanism between the two species. However, in recent years a sympatric distribution of greater and lesser prairie-chickens has been recorded in west-central Kansas as a result of range expansion by both species, and mixed leks are increasingly common (U.S. Fish and Wildlife Service 2002). How the sympatric occupation of habitat influences the use of resources by either species has not been established.

Anecdotal evidence indicates that ring necked-pheasants will harass male lesser prairie-chickens during the breeding season (Mote et al. 1998). Hagen et al. (2002) also found that there was a 4 percent probability of parasitism by ring-necked pheasants on lesser prairie-chicken nests during a study in Kansas. Nest parasitism adversely affects greater prairie-chicken nest success because host nests are less successful due to higher rates of predation and abandonment and, in some cases, females will leave the nest with pheasant chicks before their own eggs hatch (Vance and Westemeier 1979).

Parasites and disease

Parasites of lesser prairie-chickens, the intensity of parasite infections, and the impact of parasites and disease on populations are poorly understood (Peterson 2004). A summary of reported parasites and disease agents suggests that they are common throughout the range (**Table 4**). Although parasites are known to cause significant mortality in some grouse species, such as red grouse (*Lagopus lagopus scoticus*) in Scotland (Hudson 1992), there is little documentation of similar patterns in lesser prairie-chickens (Giesen 1998). Nevertheless, caution should be exercised before dismissing the potential for population-level impacts (Peterson 2004). For example, there has been no documented exposure of lesser prairie-chickens to the West Nile virus. Because that virus has had dramatic impacts on some populations of greater sage-grouse (Naugle et al. 2004), its potential impacts on lesser prairie-chickens should be considered. In some cases, ring-necked pheasants can carry *Heterakis gallinarum* with few effects while gray partridges (*Perdix perdix*) are likely to die (Tompkins et al. 2000a and b). Consequently, in areas of pheasant and partridge overlap, partridge populations may be reduced or eliminated. This type of relationship has not been observed in lesser prairie-chickens.

Envirogram

We developed an envirogram (Andrewartha and Birch 1984) to describe the relationship between lesser prairie-chickens and their environment (**Figure 9**). This envirogram considers resources (primarily habitat for cover and food), malentities (negative stressors in the environment), and predators. The diagram illustrates the continuum of potential relationships between baseline factors in the environment versus the more proximal causes. These factors are illustrated on a horizontal axis from left to right, or ultimate to proximal, respectively.

This type of relationship can be illustrated for lesser prairie-chicken chicks, which depend on insects during their first weeks after hatch. Insect abundance can depend on numerous factors, one of which is plant diversity. Likewise, plant diversity can depend on numerous factors, one of which is the introduction and expansion of noxious weeds. The prevalence of noxious weeds can be increased by reduced competition from native plant species and/or site disturbance. A site can be disturbed by numerous factors, such as the building of a road. Hence, the building of a road is one of the

Table 4. Reported parasites and disease agents of lesser prairie-chickens (modified from Peterson 2004).

Group/Species	State (*n* positive/total *n*)	Reference
Cestodes		
Rhabdometra odiosa	Texas (15/41)	Pence et al. 1983
Nematodes		
Heterakis isolonche	Texas (21/41)	Pence and Sell 1979, Pence et al. 1983
Subulura sp.	Kansas (54/91)	Robel et al. 2003
Tetrameras sp.	Kansas (81/88)	Addison and Anderson 1969
Oxyspirura petrowi	Kansas (53/56)	Robel et al. 2003
Oxyspirura petrowi	Unknown	Addison and Anderson 1969
Oxyspirura petrowi	Texas (25/41)	Pence and Sell 1979, Pence et al. 1983
Physaloptera sp.	Texas (16/41)	Pence et al. 1983
Mallophaga		
Lagopoecus sp.	Oklahoma	Emerson 1951
Goniodes cupido	Oklahoma	Emerson 1951
Hematozoa		
Plasmodium pedioecetii	New Mexico (2/29)	Stabler 1978
Plasmodium pedioecetii	Texas (2/8)	Stabler 1978
Plasmodium pedioecetii	New Mexico (4/32)	Smith et al. 2003
Other protozoa		
Eimeria tympanuchi	New Mexico (5/64)	Smith et al. 2003
Bacteria		
Mycoplasma sp.	Oklahoma and Kansas	Peterson 2004
Salmonella sp.	Oklahoma and Kansas	Peterson 2004
Pasteurella multocida	Kansas	Peterson 2004
Viruses		
Infectious bronchitis virus	Texas (10/35)	Peterson et al. 2002

root causes (but not the only one) in the loss of insects needed by lesser prairie-chickens.

CONSERVATION

Land Management and Its Implications for Lesser Prairie-Chicken Conservation

Land use conversion and habitat fragmentation

Land management practices significantly influence the quality and availability of habitat for lesser prairie-chickens as this species requires extensive areas of grassland with suitable cover throughout its range (Wildlife Habitat Management Institute 1999, Hagen et al. 2004). Because lesser prairie-chickens have relatively small home ranges (Copelin 1963, Giesen 1998), they require an interspersion of nesting, brood-rearing, roosting, and lekking habitats at the local scale. Prior to European settlement, a combination of disturbances (grazing by ungulates, fires, direct and indirect impacts of Native Americans) is believed to have created a patchy distribution of grasslands at differing stages of succession at both local and broad scales (Kay 1998, Fuhlendorf and Engle 2001, Samson et al. 2004). Disturbance patterns in the prairie landscape are believed to have resembled a shifting mosaic whereby recently disturbed patches were intermixed with areas undisturbed for several years (Fuhlendorf and Engle 2001), thus creating a heterogeneous landscape at spatial and temporal scales. This diversity of habitat at the landscape level is believed to be important for the persistence of lesser prairie-chicken populations (U.S. Fish and Wildlife Service 2002).

Landscape level evaluation of occupied range suggests that areas of population decline are characterized by greater rates of landscape change and loss of shrubland cover than areas of population stability or increase (Woodward et al. 2001). Stability

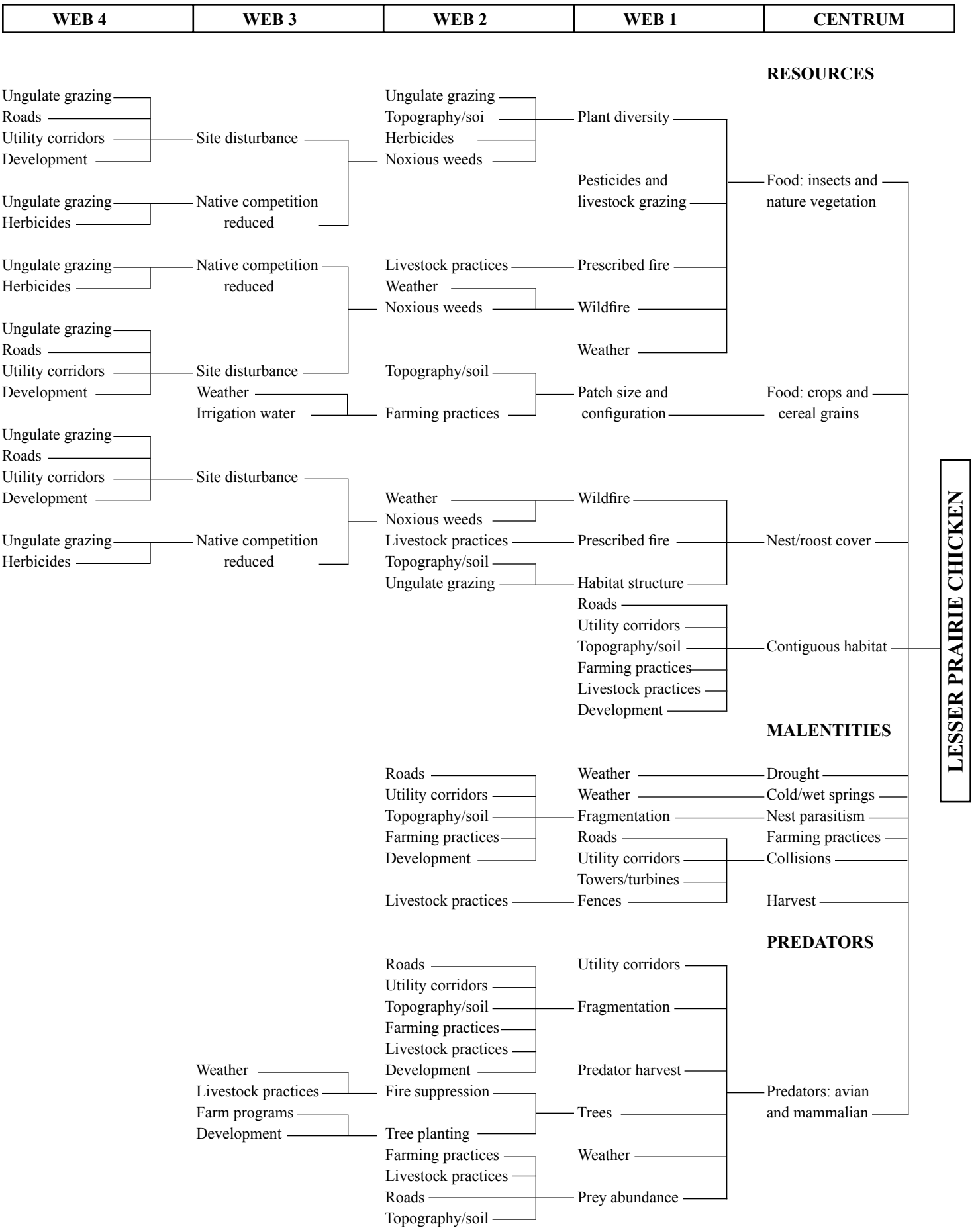

Figure 9. Envirogram (based on Andrewartha and Birch 1984) for lesser prairie-chickens.

of land use and continuity of grassland habitat in areas occupied by lesser prairie-chickens have been suggested as important factors in maintaining stable populations. However, many landscape level factors, such as patch size, configuration, and juxtaposition of required habitat types (e.g., nesting, brood-rearing, foraging), are poorly understood (Woodward et al. 2001). At the broad scale, habitat fragmentation increasingly isolates populations, placing them at greater risk of extinction due to loss of genetic heterogeneity and stochastic events. For instance, in Texas an entire population of 20 endangered Attwater's prairie-chickens (*Tympanuchus cupido attwateri*) was lost following a major hurricane (Silvy et al. 1999). Increases in fragmentation can also affect local predation rates (Braun et al. 1978, Schroeder and Baydack 2001), which in turn may impact nest success and chick survival, two factors that have the greatest impact on growth rates of lesser prairie-chicken populations (Hagen et al. 2004).

Small and isolated populations, such as those in Kiowa and Cheyenne counties, Colorado, may be at a particularly high risk of extirpation (Giesen 2000). Although Toepfer et al. (1990) suggested that 100 male greater prairie-chickens were enough to support population persistence over a relatively long period, the actual number needed may be much larger. For instance, Morrow et al. (2004) observed that a population with approximately 250 male Attwater's prairie-chickens declined rapidly toward extinction. Closed populations of greater prairie-chickens where the number of males is less than 500 have persisted for more than 25 years in Minnesota, and populations with less than 250 males have persisted for 50 years in Wisconsin (Westemeier and Gough 1999). However, recent evidence for Wisconsin indicates that those populations with between 70 and 327 males (1998 data, Anderson and Toepfer 1999) have been insufficient to maintain genetic heterogeneity (Bellinger et al. 2003, Johnson et al. 2003, Johnson et al. 2004).

Conversion of native prairie clearly has had a long-term impact on lesser prairie-chickens. Silvy et al. (2004) argued that the lack of sufficient quantity of suitable habitat was the factor most responsible for the long-term declines of this species. According to estimates by Samson et al. (2004), 45.9 percent of the central mixed-grass prairie (**Figure 3**) and 35.7 percent of the central shortgrass prairie (**Figure 4**) has been converted to cropland (**Table 1**). When condition and patch size are factored in, the remaining amount of suitable habitat for lesser prairie-chickens is much less than these figures would indicate.

Lesser prairie-chickens may use cropland as foraging areas in Region 2, but the relative value of cropland depends on the type of crop grown, its juxtaposition to suitable grassland cover, and farming practices that influence the availability of waste grain. As the proportion of cropland increases, the resulting loss and fragmentation of grassland areas reduce the quantity and quality of habitat for lesser prairie-chickens. Although areas in west Texas, where cultivation exceeds 37 percent of the landscape, appear unable to support populations of lesser prairie-chickens (Crawford and Bolen 1976a), threshold levels of cultivation are not known for other regions (Mote et al. 1998). Cannon and Knopf (1981a) determined that limited agriculture (0 to 32 percent) had an unclear effect on the density of displaying males, and this effect may have been overwhelmed by lesser prairie-chicken responses to rangeland quality. Lesser prairie-chickens are known to use alfalfa fields as foraging areas throughout their range (U.S. Fish and wildlife Service 2002). However, many pastures contain introduced grass species that do not provide the diversity of vegetation and structure required by lesser prairie-chickens (Mote et al. 1998). Center-pivot irrigated cropland also has eliminated or fragmented a significant amount of sand sagebrush prairie within the lesser prairie-chicken range in Kansas (Jensen et al. 2000). However, since 1981 water conservation measures have limited the increase in center-pivot irrigation.

The recent expansion of lesser prairie-chickens into 16 counties north of the Arkansas River in Kansas is believed to reflect increased CRP-enrolled acreage in the southwestern part of the state (U.S. Fish and Wildlife Service 2002). The landscape in the expanded range is dominated primarily by CRP-enrolled lands, crops, and shortgrass prairie (Jamison 2000). In some cases, CRP provides the only available grassland habitat (Rodgers et al. 2000), and nesting success on CRP-enrolled lands may be relatively high (Field 2004). CRP-enrolled lands comprise 13 percent of the total area of 15 core counties in southwestern Kansas enrolled in CRP (2004 statistics, http://www.fsa.usda.gov/crpstorpt/r1sumsn/ks.htm, December 1, 2004).

CRP-enrolled lands comprise a similar portion of the lesser prairie-chicken range in Colorado. Only 17 percent of the total area of Baca, Kiowa, and Prowers counties is enrolled in this program (based on 2004 statistics; http://www.fsa.usda.gov/crpstorpt/r1sumsn/co.htm, December 1, 2004). Although evidence suggests that birds in Colorado occasionally use CRP-enrolled lands as roosting cover, there has been no

apparent increase in lesser prairie-chicken populations in Colorado since the program was initiated, and no leks have been documented on CRP-enrolled lands (Giesen 2000). However, much of the CRP-enrolled lands adjacent to lesser prairie-chicken range lack both diversity and abundance of grass and forb species, in contrast to the CRP in Kansas (Fields 2004). Additionally, much of the early CRP-enrolled acreage in Colorado was planted in *Bromus* spp., which tends to flatten during winter and thus provides insufficient cover when compared with native habitat (Sullivan et al. 2000). Despite this observation, there has been no direct effort to compare the suitability of CRP for lesser prairie-chickens in Colorado with the suitability of CRP in Kansas. It is also of regional concern that CRP habitats are temporary and may disappear or change with future enrollments and the economics and politics of land use. Additionally, in times of severe drought, grazing and haying of CRP-enrolled fields may be permitted.

Livestock grazing

Lesser prairie-chickens are endemic to grasslands of the Great Plains, and like other species of grassland birds, they evolved with grazing ungulates, in particular bison (*Bison bison*). Historical patterns of grazing are believed to have created an interspersion of heavily, moderately, and lightly grazed habitat types (**Figure 10**). In contrast, modern grazing systems tend to reduce rangeland heterogeneity (Fuhlendorf and Engle 2001), and lesser prairie-chickens require a diversity of habitat types to meet their life history requirements. For instance, mid-tall grass species provide nesting habitat, while shortgrass vegetation sites are used for breeding display. Suitable nesting habitat is considered a limiting factor for prairie grouse (Kirsch 1974), and nest success and chick survival are believed to be the most important demographic factors influencing lesser prairie-chicken populations (Hagen et al. 2004). In Kansas, approximately 50 percent of broods experience total brood loss, and chick mortality at the end of 60 days post hatch approaches 81 percent (Jamison 2000). Residual vegetation provided by mid-tall grass species is a critical component of quality nesting habitat (Riley et al. 1992).

Habitat condition is now largely determined by land management practices associated with livestock production. Grazing is not necessarily detrimental to lesser prairie-chicken habitat, but grazing systems that reduce or eliminate cover used for nesting and brood rearing decrease habitat quality (Hagen et al. 2004, U.S. Fish and Wildlife Service 2002). Many of the mid-tall grass species used by lesser prairie-chickens for nesting habitat are also preferred forage by cattle. As a result, grazing practices may leave inadequate cover for nesting females in many areas (**Figure 11**; U.S. Fish and Wildlife Service 2002). Although various grazing systems (e.g., rest-rotation, deferred grazing) are practiced, grazing systems are of limited value if the stocking rate is too high (Svedarsky and Van Amburg 1996). Holechek et al. (1999) extensively reviewed published grazing studies and concluded that a stocking rate that uses 50 percent of the available forage results in rangeland deterioration of semi-arid grasslands.

Heavy grazing by livestock that results in lack of secure cover for nesting is considered a major threat to the long term persistence of lesser prairie-chicken populations (Hagen et al. 2004). In heavily grazed habitats, lesser prairie-chickens tend to nest under shrubs (Giesen 1994b); however, these nests are less successful as nest success is associated with increased cover of residual grasses at the nest site (Riley at al. 1992, Giesen 1994b). Grazing practices that do not leave adequate cover for nesting and brood rearing are also detrimental to lesser prairie chickens because birds are forced to nest in small patches of cover or in marginal areas where nest success may be lower due to increased predation (Mote et al. 1998). Hunt (2004) found that vegetative characteristics associated with overgrazing explained approximately 19 percent of the variation between active and inactive sites in New Mexico; overgrazed sites were less likely to be active.

Although nesting and brood-rearing habitats are vital to lesser prairie-chicken populations, grazing practices that leave adequate cover to meet all seasonal requirements are necessary (Hagen et al. 2004). Partial recovery of habitat on the Comanche National Grassland from historical levels of relatively heavy grazing is believed to be responsible for the apparent increase in lesser prairie-chicken numbers in Colorado between the 1970s and late 1990s (Giesen 2000). Direct interactions between livestock and lesser prairie-chickens are difficult to observe. However, one study of artificial nests in grassland habitat recorded 75 percent nest loss due to damage by cattle (e.g., trampling, crushing by muzzle, eggs kicked out of nest) in all grazing treatments studied (Paine et al. 1996).

Rangelands used by lesser prairie-chickens typically receive low levels of rainfall and are subject to periodic droughts (i.e., 1930s, 1950s, 1990s; Mote et al. 1998). Declines in lesser prairie-chicken populations have been noted to coincide with periodic drought conditions experienced in the Great Plains

Figure 10. Ungrazed habitat with a Daubenmire plot in southwestern Kansas. Photograph by Christian A. Hagen.

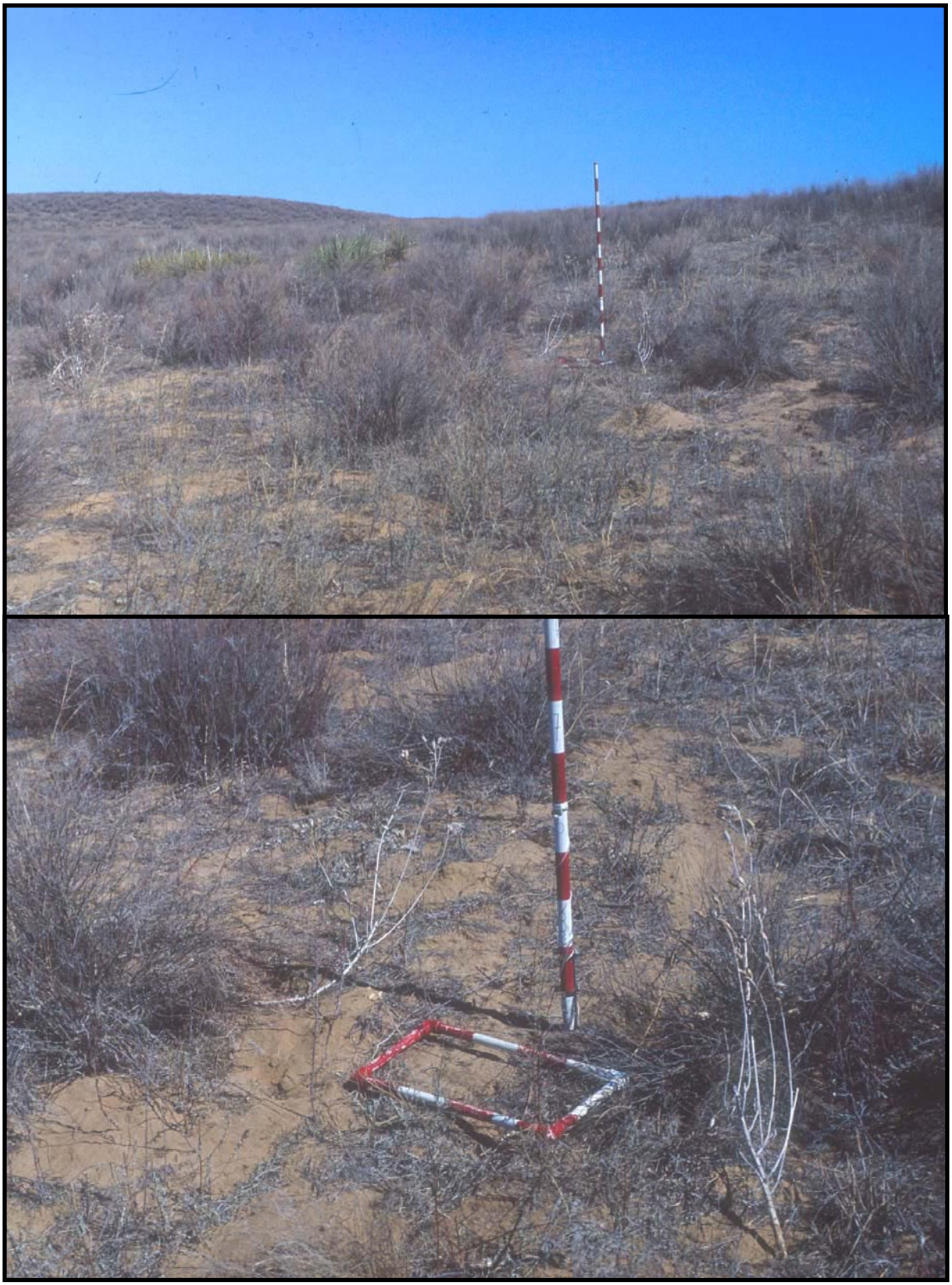

Figure 11. Grazed habitat with a Daubenmire plot in southwestern Kansas. Photograph by Christian A. Hagen.

region (Crawford 1980). In a drought year in New Mexico, female lesser prairie-chickens laid fewer eggs in first nests, produced fewer chicks per brood, and were less likely to renest than during a year with normal precipitation (Merchant 1982). The negative effect of drought is believed to be largely indirect, as lack of precipitation reduces vegetative growth, and hence residual cover, in subsequent years (Giesen 2000). In contrast, Giesen (2000) illustrated a positive relationship between annual precipitation and the total number of leks and males counted the following spring on a 41 km^2 area of the Comanche National Grassland. He suggested that above average precipitation levels experienced in the region between 1975 and 1998 may have indirectly had a positive effect on lesser prairie-chicken populations by influencing the quantity/quality of herbaceous growth, and hence, residual cover.

Under drought conditions, prairie-chicken habitat may easily be degraded by heavy livestock grazing (Hamerstrom and Hamerstrom 1961, Giesen 2000, U.S. Fish and Wildlife Service 2002). During drought conditions in New Mexico, lesser prairie-chickens used ungrazed or lightly grazed areas for nesting and brood rearing (Merchant 1982). During drought, forage consumed by livestock may not be replaced by vegetative growth, suggesting that stocking rates that maintain suitable cover requirements for lesser prairie-chickens need to be evaluated in terms of the periodic drought conditions that occur throughout its range.

Another implication of livestock grazing is the frequent control of shrubs within the range of the lesser prairie-chicken, usually in an effort to improve the forage for livestock. Broad-scale use of herbicides to eradicate sand sagebrush is known to decrease avian diversity and abundance for as long as five years post application (Rodgers and Sexson 1990). Jackson and DeArment (1963) determined the effects of sand sagebrush control to be deleterious to lesser prairie chickens in Texas. Cannon and Knopf (1981a) found a positive correlation between density of displaying males and sand sagebrush in sand sagebrush rangelands.

In contrast, carefully planned herbicide treatments may to help increase herbaceous cover when combined with appropriate grazing strategies (Donaldson 1966, Doerr and Guthery 1983, Olawsky and Smith 1991). Prescribed fire can have similar long-term effects on vegetation, for as long as seven years following the burn (Snyder 1997). However, such practices are believed to most often reduce the necessary shrub cover for lesser prairie-chickens. These practices have been especially common in the shinnery oak habitats outside of Region 2 (Boyd 1999, Boyd and Bidwell 2001, Jamison et al. 2002b, U.S. Fish and Wildlife Service 2002).

Pesticides and herbicides

Pesticide treatment of rangeland and cropland may indirectly impact lesser prairie-chickens, especially chicks, by reducing insect prey No studies have examined the direct effect of chemical spraying on lesser prairie-chicken populations (U.S. Fish and Wildlife Service 2002), but 63 of 200 greater sage-grouse died after feeding in an alfalfa field sprayed with dimethoate (Blus et al. 1989). Lesser prairie-chickens are known to use alfalfa fields throughout their range (U.S. Fish and Wildlife Service 2002), and exposure to organophosphorus insecticides appears to pose a potential direct threat. Chemical treatment to reduce sand sagebrush density may be detrimental to lesser prairie-chickens as has been found for other grassland bird species, especially when herbicides are applied over extensive solid-block treatment areas (Rodgers and Sexson 1990).

Development

Development may be a problem where incursions fragment, reduce, and/or degrade available lesser prairie-chicken habitat. In addition, development typically is accompanied by changes in land use practices and often introduces other changes that alter habitat suitability.

Road building and expansion may be a problem due to loss, fragmentation and degradation of habitat, noise, introduction of other disturbances, and mortality as a result of collisions with vehicles. In Texas, construction of an elevated road through a lek resulted in abandonment (Crawford and Bolen 1976b). Although the actual area occupied by a roadway may be relatively small, the total impact of a roadway on the surrounding habitat may be much greater. In a range-wide conservation assessment of the greater sage-grouse, Interstate 80 in southern Wyoming was found to have a significant impact on the distribution of leks, particularly within 4 km of the interstate (Connelly et al. 2004). This has been noted for other species of birds as well (Reijnen et al. 1995). Roadways create disturbed sites that are often favorable for incursion and/or spread of noxious weeds, and they may also increase the likelihood of wildfires (Connelly et al. 2004). Smaller roads may attract people with off-road vehicles that destroy vegetation (Bailey and Williams 2000). Noise pollution from vehicle traffic, oil/gas drilling operations, and gravel crushing operations

may degrade habitat quality for lesser prairie-chickens, but clear cause and effect relationships are difficult to quantify and most evidence is anecdotal (Massey 2001, Hagen et al. 2004, Hunt 2004). Moreover, impacts from noise may be confounded by the loss and fragmentation of habitat that usually accompanies such activities.

Oil and gas extraction sites directly eliminate habitat for lesser prairie-chickens; approximately 1.6 ha of habitat loss is associated with each site (Bailey and Williams 2000). Such activities also introduce roads that not only fragment habitat but may also contribute to degradation through incursions of weeds, predators, off road vehicles, vertical structures, and noise (Crawford and Bolen 1976b, Candelaria 1979, Davis et al. 1979). Bailey and Williams (2000) and Massey (2001) reported that lesser prairie-chickens in New Mexico are largely extirpated in areas where drilling operations are most dense. Hunt (2004) found that factors associated with petroleum development explained approximately 32 percent of the variation between active and inactive lek sites in New Mexico; leks in petroleum areas were much less likely to be active.

The resulting increase in habitat fragmentation and introduction of structures and human activity associated with development often create a cascade of environmental changes that affect habitat suitability. For instance, the diversity, abundance, and patterns of use by potential predators may be altered dramatically as human activity alters the natural landscape (Schroeder and Baydack 2001, Connelly et al. 2004). The introduction of vertical structures (e.g., trees, transmission lines, wind turbines, communication towers, buildings, and fences) increases nesting, perching, and roosting sites for raptors and corvids, and as such can impact lesser prairie-chicken populations by affecting the frequency of mortality by predation (Hagen et al. 2004). Fatal collisions with towers, lines, and fences have been recorded for many species of birds in prairie habitats (Faanes 1987), including lesser prairie-chickens. It has been suggested that lesser prairie-chickens may fly low to the ground, thus making collisions with fences more of a problem for them than other species of grouse (Bidwell 2003). The range of the lesser prairie-chicken is an area being targeted for development by wind power, due to the relatively high winds characteristic of northern Texas, western Oklahoma, western Kansas, eastern Colorado, and northeastern New Mexico (**Figure 12**; Elliott et al. 1987). Lesser prairie-chickens also may exhibit a behavioral aversion to anthropogenic structures in their environment (**Table 5**), indicating that the sphere of impact associated with these structures may be greater than supposed (Rodgers et al. 2000, Pitman 2003, Hagen et al. 2004, Robel 2004). Lesser prairie-chickens tended to avoid power lines and buildings in Kansas (Pitman 2003).

The planting of windbreaks, encroachment of eastern red cedar (*Juniperus virginiana*) and Osage orange (*Maclura pomifera*), and increased tree establishment in riparian areas degrade lesser prairie-chicken habitat by reducing the openness of grasslands. Tree encroachment in the eastern-most counties of their historical range is believed to limit the occurrence of lesser prairie-chickens. Collectively, these factors significantly contribute to landscape level changes recorded for areas with declining populations (Woodward et al. 2001). The negative impact of trees appears directly related to their use as perch and nest sites by potential predators and indirectly related to avoidance of vertical structures by lesser prairie-chickens.

Consumptive and non-consumptive recreational use

The role of regulated harvest as a factor in the decline or extirpation of some lesser prairie-chicken populations is not clear. Over-harvest of populations, particularly during the 1930s and 1950s, is one reason given for the long-term downward trend in lesser prairie-chicken populations (U.S. Fish and Wildlife Service 2001). The effects of hunting pressure may be disproportionately high for small or fragmented populations, as fragmentation of habitat may decrease the resilience of these populations to hunting (Braun et al. 1994). Hunter harvest of sharp-tailed grouse is known to have variable effects on populations; harvest rates acceptable in some populations may negatively impact others (Connelly et al. 1998). Recent analysis of patterns of mortality in hunted greater sage-grouse populations found that adult females sustain a higher hunting mortality during autumn than adult males, 42 percent and 15 percent, respectively (Connelly et al. 2000). They suggested that female greater sage-grouse may be more susceptible to hunting mortality than males because of their association with broods and brood behavior; males tend to be more dispersed at this time. In this case, hunting may be additive to winter mortality for sage-grouse, especially for females, and essentially reduce the spring breeding populations. If a similar pattern of hunting mortality of breeding age females occurs for lesser prairie-chickens, declining populations and those that are small and isolated may be especially vulnerable to hunting pressure.

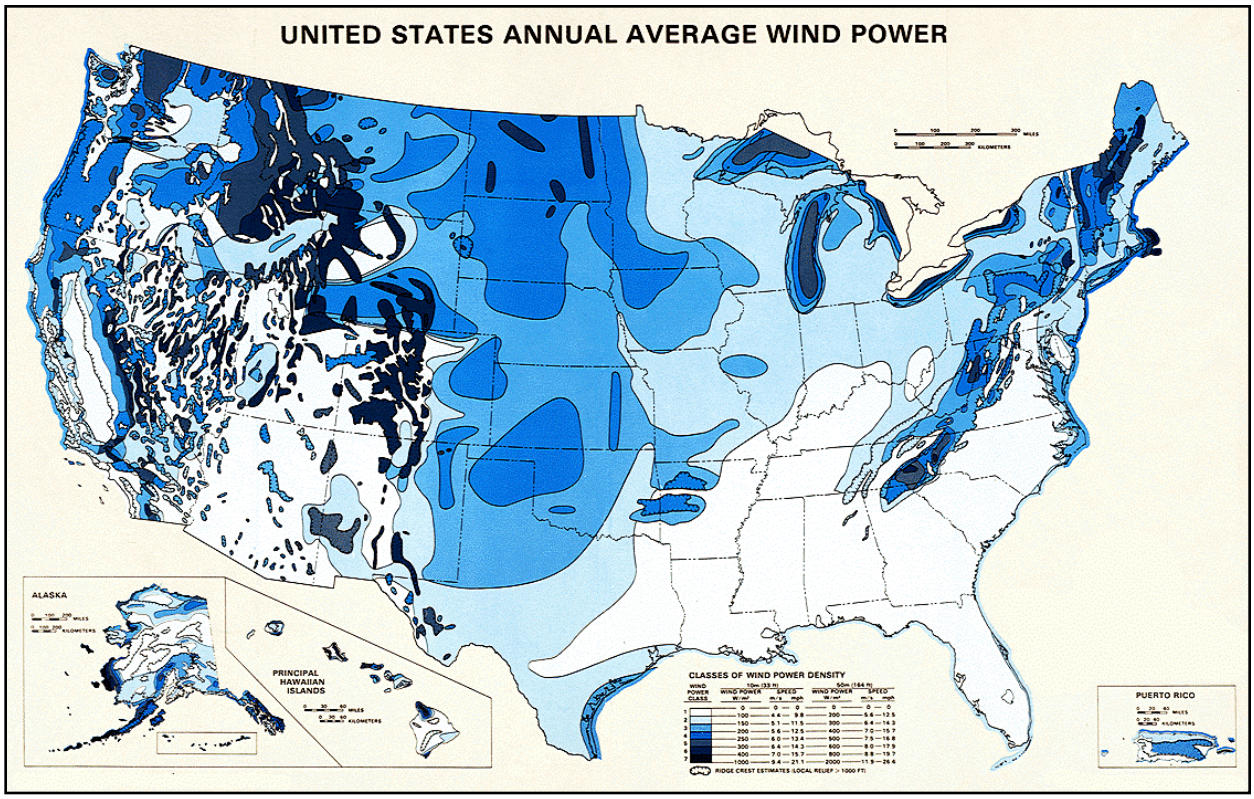

Figure 12. Map of average annual wind power and speed throughout the United States (http://rredc.nrel.gov/wind/pubs/atlas/maps/chap2/2-01m.html, December 1, 2004).

Table 5. Distances (m) to anthropogenic features from lesser prairie-chicken nest (n = 187), other use (n = 44), and non-use (n = 38) sites in southwestern Kansas (adapted from Hagen et al. 2004).

Use category	Power line	Wellhead	Building	Road
Nest sites	1,320	564	2,129	214
Other use sites	1,106	435	1,397	193
Non-use sites	666	446	1,061	178

The public has become increasingly interested in observing lesser prairie-chicken courtship behavior (**Figure 13**). This growing interest can be illustrated by the initiation of the first annual High Plains Prairie Chicken Festival in Milnesand, New Mexico in 2004 (http://www.birdingamerica.com/NewMexico/prairiechickenfestival.htm, March 3, 2005). The localized impact of bird watchers on courtship and breeding behavior at lek sites is unknown and may vary with factors such as degree of disturbance (number of times that leks are observed during the season), number of males attending the lek (U.S. Fish and Wildlife Service 2002), timing of observations, activity and behavior of observers, as well as other disturbances affecting a population. The disturbance threshold for lesser prairie-chickens may be difficult to quantify, but the cumulative impact of disturbance factors may be important, especially for small, isolated populations.

Tools and practices

Management approaches

Research and anecdotal observations of lesser prairie-chicken responses to management activities suggest that maintenance of viable populations is a critical component of any management plan. The following management elements should be considered in any plan (Bidwell 2003, Hagen et al. 2004):

- size of the management area

Figure 13. Sign and blind on lesser prairie-chicken lek on the Comanche National Grassland in southeastern Colorado. Photographs by Michael A. Schroeder.

- connection of adjacent sub-populations with suitable habitat

- incorporation of activities associated with livestock production and farming into the overall management scenario

- recommendations for land use activities that support seasonal and behavioral habitat requirements of lesser prairie-chickens

- consideration of the type and timing of potential disturbances, such as off-road vehicles, mineral extraction, wind turbines, and roads

- recommendations for harvest that consider timing, rate, production, and differential susceptibility by sex

- consideration of potential obstacles, including fences, power lines, towers, and guide wires

- development of scenarios for intervention, including habitat restoration and population introduction/augmentation

- consideration of management guidelines that will minimize the negative consequences of habitat degradation and fragmentation, including the increased risk of predation and nest parasitism

- development of research and adaptive management approaches to address questions pertaining to significant issues, such as survey protocol, habitat management and restoration, population viability, and accurate measures of population recruitment.

Hagen et al. (2004) also recommended development of a conservation plan for each state within the range of the lesser prairie-chicken.

In response to the petition for federal listing of the lesser prairie-chicken under the Endangered Species Act of 1973, federal, state, and private organizations united to form the Lesser Prairie-chicken Interstate Working Group (LPCIWG). The goal of this group is to work cooperatively to increase the range-wide distribution and abundance of lesser prairie-chickens so that federal listing would not be necessary. As a step toward achieving this goal, the LPCIWG published an "Assessment and Conservation Strategy for the Lesser Prairie-chicken (*Tympanuchus pallidicinctus*)" (Mote et al. 1998). This document was completed with cooperation from private landowners and other interest groups. It proposed to implement an adaptive management approach whereby recommendations are periodically modified to reflect increased understanding of lesser prairie-chicken biology.

Several management strategies were considered important by the LPCIWG (Mote et al. 1998). These focused on increasing our understanding of lesser prairie-chicken life history. Specific strategies include:

- determine current population status

- identify and evaluate historical and current status of habitat occupied by lesser prairie-chickens

- identify management practices that conserve habitat and are compatible with modern sustainable land use practices

- increase current knowledge of lesser prairie-chicken biology and management through research.

General habitat recommendations that were addressed by the LPCIWG (Mote et al. 1998) include:

- focus conservation efforts on currently occupied habitat

- manage rangeland for late seral stage vegetation to provide adequate nesting cover (i.e., utilize at most 25 to 35 percent of annual forage production)

- maintain large tracts of high quality nesting cover adjacent to lek sites and interspersed with adequate brood-rearing habitat

- conduct brush control in a manner not detrimental to lesser prairie chickens (i.e., maintain intermediate amounts of residual grass cover and avoid broad-scale control of large blocks of habitat; use localized spot treatment control measures only in areas where shrub canopy coverage is greater than 30 percent).

Management areas in sand sagebrush-dominated rangelands in Region 2 should be within or adjacent to currently occupied habitat, and they should be part of a

contiguous tract of habitat of at least 52 km^2. Specific features of the management area include a mean sand sagebrush density of 486 to 648 plants per ha and at least 10 percent of the area should have a Visual Obstruction Readings (VOR; Robel et al. 1970a) of at least 3.0 dm, with an average overall VOR of 1.0 dm (a minimum of 60 random VOR points should be used to determine the height density index; Mote et al. 1998).

Other plans exist within the range of the lesser prairie-chicken. Massey (2001) focuses on some of the generalities of management and, in particular, some of the socio-economic issues of lesser prairie-chicken management in New Mexico. Hunt (2004) recommended the elimination of overgrazing and a moratorium on petroleum development within areas occupied by lesser prairie-chickens in New Mexico. Bidwell (2003) suggested that 100 km^2 was the minimum land area needed to sustain a population in Oklahoma. Bidwell also has several other management recommendations, including:

- maintain grassland in a mosaic of successional stages using prescribed fire and livestock management
- eliminate widespread use of herbicides
- replace non-native plants in CRP lands with native plants
- consider food plots of 4 to 6 ha in size near protective cover
- remove trees from upland areas
- retain areas of dense grass within 1.6 km of historic lek sites.

In USFS Region 2, the Land and Resource Management Plan for the Pike and San Isabel National Forests, Comanche and Cimarron National Grasslands has guidelines for management of lesser prairie-chicken habitat (USDA Forest Service, Undated). Specific recommendations include:

- maintain plant species diversity of rangelands
- encourage native plant species
- protect leks from surface disturbance at all times
- protect nesting habitat from surface disturbance from 15 April to 30 June
- limit livestock/native herbivore forage use to 40 percent.

Declines in populations and genetic heterogeneity have been used as justification for efforts to augment and/or re-establish prairie-chicken populations. Between 1961 and 1994 transplant efforts involving the relocation of 245 lesser prairie-chickens were conducted both within and outside occupied range in Colorado; all transplant efforts failed to increase either the distribution or the number of birds in the state (Giesen 2000, Horton 2000). Failure in some cases resulted from too few birds released (many of these were males), as well as inadequate habitat to meet the seasonal requirements of lesser prairie-chickens (Toepfer et al. 1990, Giesen 2000). The failure of transplants in Colorado reflects the poor record of success for transplants of prairie grouse in general (Toepfer et al. 1990). Notable exceptions include translocations of greater prairie-chickens to help establish populations in formerly occupied range in northeastern Colorado and south-central Iowa, and augmentation to increase genetic heterogeneity of a small, isolated population of greater prairie-chickens in Illinois (Hoffman et al. 1992, Westemeier et al. 1998, Moe 1999).

Although most of these management activities and recommendations are reflected in the management recommendations of Hagen et al. (2004:77), there are some notable expansions. Hagen et al. (2004) recommends the identification of "Lesser Prairie-chicken Habitat Management Zones" of at least 4,096 km^2 throughout the range of lesser prairie-chickens. In an example of a potential management zone, Hagen et al. (2004) included the Cimarron National Grassland as a target area. They also recommended management of tracts of native habitat of at least 2,000 ha and within 30 km of adjacent tracts; smaller tracts with greater connectivity should also be managed (500 ha; Wildlife Habitat Management Institute 1999). Native grassland should comprise at least 63 percent of habitats managed for lesser prairie-chickens (Hagen et al. 2004). In addition, nesting habitat should be characterized by residual grasses greater than 40 cm tall that provide good vertical and horizontal protection, increased shrub cover in areas with reduced herbaceous cover, and a configuration with relatively open forb-rich brood habitats.

In recent years, considerable quantities of cropland in Region 2 have been enrolled in federal programs such as the CRP and the Environmental Quality Incentives Program (EQIP; Wildlife Habitat Management Institute 1999, Riley 2004). The restoration of prairie habitats with these incentives represents a broad-scale change in land use and has the potential to dramatically improve habitat and landscape conditions for lesser prairie-chickens.

Preferably, adaptive management can be applied to the needs of lesser prairie-chickens (Aldridge et al. 2004). Regardless of the quality of these plans, Robel (2004:122) noted "that any plan, no matter how well designed, that is not implemented aggressively is about as useful as wet toilet paper."

Inventory and monitoring

Monitoring of populations: Surveys to locate lesser prairie-chickens are conducted during the early spring when males are congregated on lek sites. Survey protocol generally follows the methodology outlined by Hamerstrom and Hamerstrom (1973); however, modifications by various state agencies have been made to accommodate funding and personnel available to complete the surveys. The work of Hamerstrom and Hamerstrom (1973) in Wisconsin summarizes findings of an extensive study of a marked population of greater prairie-chickens. This study has served as a valuable reference, in part, because many of the monitoring techniques used by the Hamerstroms became the foundation for surveys of other species of prairie grouse (i.e., greater prairie-chickens, sharp-tailed grouse, greater sage-grouse).

Survey efforts in the range of the lesser prairie-chicken generally last a month and overlap the peak in female lek attendance (Giesen 2000, Jensen et al. 2000). A higher proportion of leks are detected when surveys are conducted during the peak of female lek visitation. Surveys usually are conducted during the period when birds are most active, 45 minutes prior to sunrise and for 1 to 2 hours after sunrise (Copelin 1963, Crawford and Bolen 1975). Calm, clear mornings are best, as the "gobbling" sound produced by males can be audible for approximately 3 km. An observer determines the presence of active lek sites by listening at intervals along a predetermined survey route and recording all audible leks within a 1.6 km radius of the stop (Horton 2000). There has been increased effort to monitor number of leks within a determined area (Horton 2000, Sullivan et al. 2000), as lek density may also be a useful index of long-term population change (Cannon and Knopf 1981b). Survey routes through occupied lesser prairie-chicken range are monitored to determine an index of population abundance. Leks detected along the survey route and leks known to be active in previous years are visited one or two times per year, and the number of birds present is recorded (Giesen 2000, Horton 2000). In many cases, these surveys have been conducted for several years.

Cannon and Knopf (1981b) suggested that lek density (all leks within a given area), instead of the number of males on leks, could be used to derive a lek index that reflects population changes, and they recommended that surveys encompass an area of at least 2100 to 4200 ha. Although transect routes may be randomly selected, roads are not randomly distributed through lesser prairie-chicken habitat. Roads also may create edge habitats that influence lesser prairie-chicken behavior (Applegate 2000). It also is possible that permanent leks may be more detectable than temporary leks (Schroeder and Braun 1992, Haukos and Smith 1999). Consequently, annual surveys that determine the presence of satellite leks as well as known (i.e., permanent) leks are important for increasing the reliability of lek data as an index to long-term population change (Giesen 2000).

Various other factors such as weather, timing (time of year and day), predators, survey effort, and observer bias (Copelin 1963, Applegate 2000) may also influence detection of leks. Local changes in lek densities and male lek attendance are also assumed to represent changes at a broader scale, however, this may not be a valid assumption. For instance, fluctuations in lek visitation may be caused by local, rather than regional, changes in the pattern of male lek attendance (Schroeder and Braun 1992). Additionally, accuracy of male lek attendance data is influenced by numerous factors such as the methods used to determine the count (flushing vs. observation), lek stability, timing, and number of surveys conducted (Schroeder and Braun 1992, Applegate 2000). Furthermore, estimates of lek density are rarely determined with a corresponding estimate of precision (Schroeder and Braun 1992). For example, assumptions regarding sex ratios, proportion of males attending leks, sampling areas, and proportion of the population observable in the sampling area need to be verified (Applegate 2000); multiplying the number of birds per area by the area of total occupied habitat does not account for the effect of habitat fragmentation (Walsh 1995).

Despite the potential problems with lek surveys, they appear to offer the best opportunity to monitor

populations over the long-term (greater prairie-chickens, Schroeder and Braun 1992). Connelly et al. (2004) showed that data collected with counts of greater sage-grouse leks were defendable in long-term trend evaluations. It also is likely that monitoring sage-grouse leks is more problematic than monitoring greater prairie-chicken leks due to the higher variability and lower male visitation rates of sage-grouse (Jenni and Hartzler 1978, Emmons and Braun 1984, Schroeder and Braun 1992, Walsh et al. 2004). Even so, it is important to recognize the limits of lek survey data as a method of monitoring lesser prairie-chicken populations. Lek survey data can be used to determine the presence or absence of lesser prairie-chickens in potential habitat and provide indices of population change (Applegate 2000). Whether these indices represent local or broad-scale changes depends on the sampling design (i.e., stratification of the survey routes, number of transects, and/or areas surveyed). In addition to annual survey routes, efforts to locate and estimate the density of leks have been attempted with aircraft (Schroeder et al. 1992).

Breeding Bird Survey (BBS) data and Audubon Christmas Bird Counts (CBC) provide information regarding the regional distribution of lesser prairie-chickens. However, BBS routes are not distributed uniformly throughout Region 2, and CBCs are typically centered around developed areas (towns, cities) and are conducted during December when lesser prairie-chickens may be difficult to detect. In general, information gathered from various sources is used to evaluate and determine distributional changes for prairie grouse. This includes information collected from historical records, published literature, museum specimens, agency survey data, hunter surveys, miscellaneous observations, and presence of available, suitable habitat (see Schroeder et al. 2004 for greater sage-grouse example).

Monitoring of habitats: Important aspects of habitat monitoring are the measurements used and their scale and timing. Johnson (1980) described habitat selection as a hierarchical process and used different levels of selection to illustrate this process. First-order selection represents the geographic range, second-order the home range, third-order the use of the different habitat components in the home range, and fourth-order is use of specific resources in these habitats. The orders range from macro-scale to micro-scale components of habitat selection, and examination of both scales is important for understanding animal-habitat relationships (Litvaitis et al. 1994).

At the broadest scale, habitat data can be collected by maps, aerial photographs, and satellite imagery (Litvaitis et al. 1994, Samson et al. 2004). This scale of resolution provides general information regarding distribution of the major habitat types occupied or potentially occupied by lesser prairie-chickens. Satellite imagery can refine this picture further by discerning the degree of fragmentation within the general range. Satellite imagery also can indicate changes in habitat type over time; for example, conversion of native grassland habitat to cultivated agriculture or conversion of cropland to CRP. However, in some cases confusion may occur among land-cover classes with similar spectral characteristics (Washington Department of Fish and Wildlife 2000). General habitat surveys also tend to result in classification by vegetation type rather than by condition, even though condition of occupied and potential habitat plays a major role in the distribution and abundance of lesser prairie-chickens.

The next level of resolution is to examine lesser prairie-chicken habitat at a local scale, where birds occur. At the local scale, factors such as habitat patch size and configuration in the landscape, vegetation type and succession, cover density and height, and juxtaposition of habitats are important variables to monitor. Within lesser prairie-chicken home ranges, practices such as grazing, farming, mowing, burning, and spraying all influence the availability of resources and how birds use habitat. To monitor the effects of habitat at the local scale, sampling could be done through stratified sampling of areas of low, medium, and high lesser prairie-chicken densities. These areas and the habitats they encompass would be monitored simultaneously to evaluate population responses to various habitat variables. Numerous techniques have been employed to address specific features of lesser prairie-chicken habitat, such as species composition and cover and height of grasses, shrubs, forbs, and residual vegetation. These techniques include, but are not limited to, line intercept (Canfield 1941), point intercept (Evans and Love 1957), Daubenmire plot (Daubenmire 1959), ocular estimate (Daubenmire 1968), and point intercept frame (Floyd and Anderson 1982). There has not been a clear effort to standardize sampling techniques across the range (see Connelly et al. 2003 for greater sage-grouse example).

Information Needs

Although lesser prairie-chickens have been studied for several decades, many aspects of their basic

biology, ecology, and management, at broad and local scales, are poorly understood (Applegate et al. 2004). For example, we still lack critical information on dispersal, recruitment, and the importance of parasites and infectious diseases (Peterson 2004). This lack of research makes it challenging to address many of the issues important for the management of lesser prairie-chicken populations.

An accurate range-wide assessment of the distribution and abundance of lesser prairie-chickens and their habitats is critical for the implementation and evaluation of management or conservation plans. In particular, specific information on population size and connectivity is needed. This is important since populations may cross political boundaries and require cooperative management efforts among numerous agencies. Lek survey data are used as indices of population change; thus, the development and implementation of a standardized, statistically valid technique is needed to monitor population densities of lesser prairie-chickens (Giesen 1998, Mote et al. 1998, Hagen et al. 2004). Accurate estimates of lesser prairie-chicken populations are needed to evaluate and monitor management strategies at both the broad and local scales in Region 2. This necessitates accurate information regarding sex ratios, male and female lek attendance, and lek stability (Mote et al. 1998, Giesen 2000). Even more importantly, this necessitates the establishment of a relationship between survey results and actual long-term trends (Connelly et al. 2004, Walsh et al. 2004).

The metapopulation dynamics of lesser prairie-chicken populations need to be examined. This will require an improved understanding of the relationship between behavior (dispersal, migration, home range), seasonal habitat selection, and characteristics of the habitat (quality, quantity, and configuration). In addition, the genetic ramifications of population isolation need to be quantified so that the appropriate time and techniques for intervention (such as with population augmentations and predator controls) can be determined (Hagen et al. 2004).

At both the broad and local scale the relationship between lesser prairie-chickens and habitat needs further understanding, especially in sand sagebrush grasslands. Considerations of habitat quantity, quality, configuration, fragmentation, seasonal habitat needs and nutritional requirements, and limiting factors are all important. Habitat fragmentation is increasingly common, and accurate information is needed regarding aspects of habitat use (patterns of movement and patch size), nest/brood success, and recruitment rate in fragmented landscapes. The nest/brood period potentially is a demographic bottle-neck for lesser prairie-chickens, especially during drought. Consequently, it is important to understand how habitat can mitigate mortality factors during this period.

Although populations of lesser prairie-chickens in Kansas have responded positively to the CRP, long-term uncertainty in the future of the program needs to be considered in future management plans. In addition, it is important to evaluate the reasons why some CRP habitats are used by lesser prairie-chickens and others apparently are not.

Grazing of rangeland can impact lesser prairie-chicken populations significantly when grazing practices do not leave adequate residual vegetation to meet seasonal habitat requirements. Negative impacts attributed to grazing are exacerbated by drought conditions that periodically occur throughout the lesser prairie-chicken's range. Grazing practices that are economically feasible for livestock producers and beneficial for lesser prairie-chickens need to be determined.

Prairie systems have been largely converted for the production of row crops across the Great Plains, and the few remaining patches of prairie have been subdivided with fences into grazing allotments. Samson et al. (2004:11) suggested that "fences are the problem in, not the solution to, conservation of historically grazed ecosystems." In any case, research on the restoration of prairie ecosystems is desperately needed, not only for the lesser prairie-chicken, but for the many other species of wildlife that depend on grasslands for their survival (Rich et al. 2004, Samson et al. 2004).

DEFINITIONS

The terms “use”, “selection”, and “preference” generally are used when examining the relationship between a species and its habitat. “Use” indicates an association with a resource; “selection” implies actively choosing a particular resource from an available range of options (Johnson 1980, Litvaitis et al. 1994). Habitat selection occurs at a broad range of scales; macro-scale characteristics include biogeographic and home range, and micro-scale characteristics include specific features at use sites such as stem density, canopy cover height, and percent bare ground (Johnson 1980, Litvaitis et al. 1994). “Preference” for a particular resource is determined independent of its availability and usually is evaluated by experimental manipulation, such as with habitat exclosures (Litvaitis et al. 1994).

REFERENCES

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

Ahlborn, G.G. 1980. Brood-rearing habitat and fall-winter movements of lesser prairie-chickens in New Mexico. M.Sc. Thesis. New Mexico State University, Las Cruces, NM.

Aldrich, J.W. 1963. Geographic orientation of American Tetraonidae. Journal of Wildlife Management. 27:529-545.

Aldrich, J.W. and A.J. Duvall. 1955. Distribution of American gallinaceous game birds. U.S. Department of the Interior, Fish and Wildlife Service, Circular 34.

Aldridge, C.L., M.S. Boyce, and R.K. Baydack. 2004. Adaptive management of prairie grouse: how do we get there? Wildlife Society Bulletin 32:92-103.

American Ornithologists' Union. 1957. Check-list of North American birds. 5th edition. American Ornithologists' Union, Washington, D.C.

American Ornithologists' Union. 1983. Check-list of North American birds. 6th edition. American Ornithologists' Union, Washington, D.C.

Ammann, R.K. 1957. The prairie grouse of Michigan. Michigan Department of Conservation, P-R Report, Projects W-5-R, W-37-R, and W-70-R.

Anderson, R.K. and J.E. Toepfer. 1999. History, status, and management of the greater prairie-chicken in Wisconsin. Pages 39-58 *in* W.D. Svedarsky, R.H. Hier, and N.J. Silvy, editors. The greater prairie-chicken a national look. Miscellaneous Publication 99-1999, Minnesota Agricultural Experiment Station, University of Minnesota, Saint Paul, MN.

Andrewartha, H.G. and L.C. Birch. 1984. The ecological web: more on the distribution and abundance of animals. University of Chicago Press, Chicago, IL.

Andrews, R. and R. Righter. 1992. Colorado birds: a reference to their distribution and habitat. Denver Museum of Natural History, Denver, CO.

Angelstam, P.K. 1983. Population dynamics of tetraonids, especially the black grouse *Tetrao tetrix* L., in boreal forests. Ph.D. Thesis, Uppsala University, Uppsala Sweden.

Angelstam, P.K. 1988. Population dynamics in tetraonids: the role of extrinsic factors. Pages 2458-2477 *in* H. Ouellet, editor. Acta XIX Congressus Internationalis Ornithologici. University of Ottawa Press, Canada.

Applegate, R.D. 2000. Use and misuse of prairie chicken lek surveys. The Wildlife Society Bulletin 28:457-459.

Applegate, R.D. and T.Z. Riley. 1998. Lesser prairie-chicken management. Rangelands 20:13-15.

Applegate, R.D., C.K. Williams, and R.R. Manes. 2004. Assuring the future of prairie grouse: dogmas, demagogues, and getting outside the box. Wildlife Society Bulletin 32:104-111.

Bailey, A.M. and R.J. Niedrach. 1965. Birds of Colorado, Vol. 1. Denver Museum of Natural History, Denver, CO.

Bailey, F.M. 1928. Birds of New Mexico. Judd and Detweiler, Inc., Washington D.C.

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.

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.

Baird, S.F. and R. Ridgway. 1873. On some new forms of North American birds. Bulletin of the Essex Institute 5: 199.

Baker, M.F. 1953. Greater prairie-chickens of Kansas. University of Kansas Museum of Natural History and State Biological Survey, Miscellaneous Publications Number 5.

Bellinger, M.R., J.A. Johnson, J. Toepfer, and P. Dunn. 2003. Loss of genetic variation in greater prairie chickens following a population bottleneck in Wisconsin, U.S.A. Conservation Biology 17:717-724.

Bendire, C.E. 1892. Life histories of North American birds with special reference to their breeding habits and eggs. U.S. National Museum, Special Bulletin Number 1.

Bent, A.C. 1932. Life histories of North American gallinaceous birds. U.S. National Museum Bulletin 162.

Bergerud, A.T. 1988a. Increasing the numbers of grouse. Pages 686-731 *in* A.T. Bergerud and M.W. Gratson, editors. Adaptive strategies and population ecology of northern grouse. The Wildlife Management Institute, University of Minnesota Press, Minneapolis, MN.

Bergerud, A.T. 1988b. Population ecology of North American grouse. Pages 578-685 *in* A.T. Bergerud and M.W. Gratson, editors. Adaptive strategies and population ecology of northern grouse. The Wildlife Management Institute. University of Minnesota Press, Minneapolis, MN.

Bergmann H.H. and S. Klaus. 1994. Distribution, status and limiting factors of black grouse in central Europe, particularly in Germany, including an evaluation of reintroductions. Gibier Faune Sauvage 11:99-124.

Bidwell, T.G. 2003. Ecology and management of the lesser prairie-chicken. Oklahoma Cooperative Extension Service, E-970. Oklahoma State University, Stillwater, OK.

Bidwell, T.G., A.D. Peoples, and R.E. Masters. 1995. Prairie chicken management in Oklahoma. Oklahoma Cooperative Extension Service, Division of Agricultural Sciences and Natural Resources, Oklahoma State University, Stillwater, OK.

Blus, L.J., C.S. Staley, C.J. Henny, G.W. Pendleton, T.H. Craug, E.H. Craig, and D.K. Halford. 1989. Effects of organophosphorus insecticides on sage grouse in southwestern Idaho. Journal of Wildlife Management 53: 1139-1146.

Boag, D.A. and M.A. Schroeder. 1992. Spruce grouse (*Dendragapus canadensis*). *In*: A. Poole, P. Stettenheim, and F. Gill, editors. The Birds of North America, Number 5. Philadelphia: The Academy of Natural Sciences, Washington, DC: The American Ornithologists' Union.

Bouzat, J.L. and K. Johnson. 2004. Genetic structure among closely spaced leks in a peripheral population of lesser prairie-chickens. Molecular Ecology 13:499-505.

Bouzat, J.L., H.H. Cheng, H.A. Lewin, R.L. Westemeier, J.D. Brawn, and K.N. Paige. 1997. Genetic evaluation of a demographic bottleneck in the greater prairie-chicken. Conservation Biology 12:836-843.

Bowman, T.J. and R.J. Robel. 1977. Brood break-up, dispersal, mobility, and mortality of juvenile greater prairie-chickens. Journal of Wildlife Management 41:27-34.

Boyd, C.S. 1999. The effects of burning season and frequency on the vegetative character and insect abundance of sand shinnery oak range in western Oklahoma. Ph.D. Dissertation. Oklahoma State University, Stillwater.

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.

Bradbury, J.W. 1981. The evolution of leks. Pages 138-169 *in* R.D. Alexander and D.W. Tinkle, editors. Natural Selection and social behavior: recent research and new theory. Chiron Press, New York, NY.

Braun, C.E., K. Martin, and L.A. Robb. 1993. White-tailed ptarmigan (*Lagopus leucurus*) *in* A. Poole and F. Gill, editors. The Birds of North America, Number 68. Philadelphia: The Academy of Natural Sciences, Washington, DC: The American Ornithologists' Union.

Braun, C.E., K.W. Harmon, J.A. Jackson, and C.D. Littlefield. 1978. Management of national wildlife refuges in the United States: its impacts on birds. The Wilson Bulletin 90:309-321.

Braun, C.E., K. Martin, T.E. Remington, and J.R. Young. 1994. North American grouse: issues and strategies for the 21st century. Transactions of the 59th North American Wildlife and Natural Resources Conference 59:428-438.

Brown, D.E. 1978. Grazing, grassland cover, and gamebirds. Transactions of the North American Wildlife Conference 43:477-485.

Bureau of Land Management. 2005. Special status species resource management plan amendment. Analysis of management situation. USDI Bureau of Land Management, Pecos District Office, Roswell, NM.

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

Candelaria, M.A. 1979. Movements and habitat-use by lesser prairie-chickens in eastern New Mexico. M.Sc. Thesis. New Mexico State University, Las Cruces, NM.

Canfield, R.H. 1941. Application of the line interception method in sampling range vegetation. The Journal of Forestry 39:388-394.

Cannon, R.W. and F.L. Knopf. 1981a. Lesser prairie-chicken densities on shinnery oak and sand sagebrush rangelands in Oklahoma. Journal of Wildlife Management 45:521-524.

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

Cannon, R.W., F.L. Knopf, and L.R. Pettinger. 1982. Use of landsat data to evaluate lesser prairie-chicken habitats in western Oklahoma. Journal of Wildlife Management 46:915-922.

Caswell, H. 2001. Matrix population models: construction, analysis, and interpretation. Second Edition. Sinauer Associates, Inc., Sunderland, MA.

Colvin, W.S. 1914. The lesser prairie hen. Outing 63:608-614.

Connelly, J.W., A.D. Apa, R.B. Smith, and K.P. Reese. 2000. Effects of predation and hunting on adult sage grouse *Centrocercus urophasianus* in Idaho. Wildlife Biology 6:227-232.

Connelly, J.W., M.W. Gratson, and K.P. Reese. 1998. Sharp-tailed grouse (*Tympanuchus phasianellus*). *In*: A. Poole and F. Gill, editors. The Birds of North America, Number 354. The Birds of North America, Inc., Philadelphia, PA.

Connelly, J.W., S.T. Knick, M.A. Schroeder, and S.J. Stiver. 2004. Conservation assessment of greater sage-grouse and sagebrush habitats. Western Association of Fish and Wildlife Agencies. Cheyenne, WY.

Connelly, J.W., K.P. Reese, and M.A. Schroeder. 2003. Monitoring of greater sage-grouse habitats and populations. University of Idaho, College of Natural Resources Experiment Station Bulletin 80. Moscow, ID.

Cooke, W.W. 1897. Birds of Colorado. The State Agricultural College Bulletin Number 37, Technical Series Number 2. Fort Collins, CO.

Copelin, F.F. 1959. Notes regarding the history and current status of the lesser prairie-chicken in Oklahoma. Proceedings of the Oklahoma Academy of Science 37:158-161.

Copelin, F.F. 1963. The lesser prairie-chicken in Oklahoma. Oklahoma Wildlife Conservation Department Technical Bulletin Number 6. Oklahoma City, OK.

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. Pages 1-7 *in* P.A. Vohs, Jr. and F.L. Knopf, editors. Proceedings of the Prairie Grouse Symposium, Oklahoma State University, Stillwater, OK.

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. Auk 92:808-810.

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

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

Daubenmire, R.F. 1959. A canopy-coverage method of vegetation analysis. Northwest Science 33:43-64.

Daubenmire, R.F. 1968. Plant communities: a textbook of plant synecology. Harper and Rowe, Publishers, New York, NY.

Davies, B. 1992. Lesser prairie-chicken recovery plan. Colorado Division of Wildlife, Denver, CO.

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. New Mexico State University Agricultural Experiment Station, Las Cruces, NM.

Davis, C.A., T.Z. Riley, R.A. Smith, and M.J. Wisdom. 1980. Spring-summer foods of lesser prairie-chickens in New Mexico. Pages 75-80 *in* P.A. Vohs and F.L. Knopf, editors. Proceedings of the Prairie Grouse Symposium, Oklahoma State University, Stillwater, OK.

Davison, V.E. 1940. An 8-year census of lesser prairie-chickens. Journal of Wildlife Management 4:55-62.

Dobson, A.P., E.R. Carper, and P.J. Hudson. 1988. Population biology and life-history variation of gamebirds. Pages 48-71 *in* P.J. Hudson and M.R.W. Rands, editors. Ecology and Management of Gamebirds. Blackwell Scientific Publications Professional Books, Oxford, UK.

Doerr, T.B. and F.S. Guthery. 1983. Effects of tebuthiuron on lesser prairie-chicken habitat and foods. Journal of Wildlife Management 47:1138-1142.

Donaldson, D.D. 1966. Brush control and the welfare of lesser prairie-chickens in western Oklahoma. Proceedings of the Oklahoma Academy of Science 42:221-228.

Donaldson, D.D. 1969. Effect on lesser prairie-chickens of brush control in western Oklahoma. M.Sc. Thesis. Oklahoma State University, Stillwater, OK.

Drovetski, S.V. 2002. Molecular phylogeny of grouse: individual and combined performance of W-linked, autosomal, and mitochondrial loci. Systematics Biology 51:930-945.

Drovetski, S.V. 2003. Plio-Pleistocene climatic oscillations, Holarctic biogeography and speciation in an avian subfamily. Journal of Biogeography 30:1173-1181.

Duck, L.G. and J.B. Fletcher. 1944. A survey of the game and furbearing animals of Oklahoma. Division of Wildlife Restoration and Research, Oklahoma Game and Fish Commission, OK.

Elliott, D.L., C.G. Holladay, W.R. Barchet, H.P. Foote, and W.F. Sandusky. 1987. Wind energy resource atlas of the United States. DOE/CH 10093-4, Solar Energy Research Institute, Golden, CO.

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

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.

Emerson, K.C. 1951. A list of Mallophaga from gallinaceous birds of North America. Journal of Wildlife Management 15:193-195.

Emmons, S.R. and C.E. Braun. 1984. Lek attendance of male sage grouse. Journal of Wildlife Management 48:1023-1028.

Evans, R.A. and R.M. Love. 1957. The step-point method of sampling - a practical tool in range research. The Journal of Range Management 10:208-212.

Ewens, W.J., P.J. Brockwell, J.M. Gani, and S.I. Resnick. 1987. Minimum viable population size in the presence of catastrophes. Pages 59-68 *in* M.E. Soulé, editor. Viable population for conservation. Cambridge University Press.

Faanes, C.A. 1987. Bird behavior and mortality in relation to power lines in prairie habitats. U.S. Fish and Wildlife Service. Fish and Wildlife Technology Report 7.

Fields, T.L. 2004. Breeding season habitat use of Conservation Reserve Program (CRP) land by lesser prairie chickens in west central Kansas. M.Sc. Thesis, Fort Collins, CO.

Flanders-Wanner, B.L., G.C. White, and L.L. McDaniel. 2004. Weather and prairie grouse: dealing with effects beyond our control. Wildlife Society Bulletin 32:22-34.

Floyd, D.A. and J.E. Anderson. 1982. A new point frame for estimating cover of vegetation. Vegetation 50:185-186.

Fritz, R.S. 1979. Consequences of insular population structure: distribution and extinction of spruce grouse populations. Oecologia 42:57-65.

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

Giesen, K.M. 1991. Population inventory and habitat use by lesser prairie-chickens in southeast Colorado. Federal Aid in Wildlife Restoration Report. W-152-R, Colorado Division of Wildlife.

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

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

Giesen, K.M. 1998. Lesser prairie-chicken (*Tympanuchus pallidicinctus*). *In*: A. Poole and F. Gill, editors. The Birds of North America, Number 364. The Birds of North America, Inc. Philadelphia, PA.

Giesen, K.M. 2000. Populations status and management of lesser prairie-chicken in Colorado. The Prairie Naturalist 32:137-148.

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

Gutiérrez, R.J., G.F. Barrowclough, and J.G. Groth. 2000. A classification of the grouse (Aves: Tetraoninae) based on mitochondrial DNA sequences. Wildlife Biology 6:205-211.

Hagen, C.A. 2003. A demographic analysis of lesser prairie-chicken populations in southwestern Kansas: survival, population viability, and habitat use. Ph.D. Dissertation, Kansas State University, Manhattan, KS.

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. Wilson Bulletin 114:522-524.

Hagen, C.A., B.E. Jamison, K.M. Giesen, and T.Z. Riley. 2004. Guidelines for managing lesser prairie-chicken populations and their habitats. Wildlife Society Bulletin 32:69-82.

Hagen, C.A., J.C. Pitman, B.K. Sandercock, R.J. Robel, and R.D. Applegate. 2005. Age-specific variation in apparent survival rates of male lesser prairie-chickens. Condor 107:78-86.

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

Hamerstrom, F.N. Jr., and F. Hamerstrom. 1973. The greater prairie-chicken in Wisconsin - highlights of a 22 year study of counts, behavior, movements, turnover, and habitat. Wisconsin Department of Natural Resources. Technical Bulletin Number 64.

Hannon, S.J. 1988. Intrinsic mechanisms and population regulation in grouse – a critique. Pages 2478-2489 *in* H. Ouellet, editor. Acta XIX Congressus Internationalis Ornithologici. University of Ottawa Press, Canada.

Haukos, D.A. 1988. Reproductive ecology of lesser prairie-chickens in west Texas. M.Sc. Thesis. Texas Tech University, Lubbock, TX.

Haukos, D.A. and G.S. Broda. 1989. Northern harrier (*Circus cyaneus*) predation of lesser prairie-chicken (*Tympanuchus pallidicinctus*). The Journal of Raptor Research 23:182-183.

Haukos, D.A. and L.M. Smith. 1989. Lesser prairie-chicken nest site selection and vegetation characteristics in tebuthiuron-treated and untreated sand shinnery oak in Texas. The Great Basin Naturalist 49:624-626.

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 behaviour in Tetraonidae. Viltrevy 7:388-406.

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

Hoffman, R.W., W.D. Snyder, G.C. Miller, and C.E. Braun. 1992. Reintroduction of greater prairie-chickens in northeastern Colorado. The Prairie Naturalist 24:197-204.

Höglund, J. and R.V. Alatalo. 1995. What are Leks? Pages 3-22 *in* J.R. Krebs and T. Clutton-brock, editors. Leks. Monographs in Behavior and Ecology. Princeton University Press, Princeton, NJ.

Holechek, J.L., H. Gomez, F. Molinar, and D. Galt. 1999. Grazing studies: what we've learned. Rangelands 21:12-16.

Horak, G.J. 1985. Kansas greater prairie-chickens. Kansas Fish and Game Commission, Wildlife Bulletin Number 3.

Horton, R.E. 2000. Distribution and abundance of lesser prairie-chicken in Oklahoma. The Prairie Naturalist 32:187-195.

Hudson, P.J. 1992. Grouse in space and time. Game Conservancy Trust, Fordingbridge, UK.

Hunt, J.L. 2004. Investigation into the decline of populations of the lesser prairie-chicken (*Tympanuchus pallidicinctus* Ridgway) in southeastern New Mexico. Ph.D. Dissertation, Auburn University, AL.

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

Jamison, B.S. 2000. Lesser prairie-chicken chick survival, adult survival, and habitat selection and movements of males in fragmented rangelands of southwestern Kansas. M.Sc. Thesis, Kansas State University, Manhatten, KS.

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

Jamison, B.E., J.A. Dechant, D.H. Johnson, L.D. Igl, C.M. Goldade, and B.R. Euliss. 2002b. Effects of management practices on grassland birds: lesser prairie-chicken. Northern Prairie Wildlife Research Center, Jamestown, ND. Jamestown, ND. Online at http//www.npwrc.usgs.gov/resource/literatr/grasbird/lpch/lpch.htm (Version 28MAY2004).

Jensen, W.E., D.A. Robinson, Jr., and R.D. Applegate. 2000. Distribution and population trend of lesser prairie-chicken in Kansas. The Prairie Naturalist 32:169-175.

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

Johnson, D.H. 1980. The comparison and usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

Johnson, G.D. and M.S. Boyce. 1990. Feeding trials with insects in the diet of sage grouse chicks. Journal of Wildlife Management 54:89-91.

Johnson, J.A., M.R. Bellinger, J.E. Toepfer, and P. Dunn. 2004. Temporal changes in allele frequencies and low effective population size in greater prairie-chickens. Molecular Ecology 13:In press.

Johnson, J.A., J.E. Toepfer, and P.O. Dunn. 2003. Contrasting patterns of mitochondrial and microsatellite population structure in fragmented populations of greater prairie-chickens. Molecular Ecology 12:3335-3347.

Johnson, R.G. and S.T. Temple. 1990. Nest predation and brood parasitism of tallgrass prairie birds. Journal of Wildlife Management 54:106-111.

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

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

Jones, R.E. 1964b. Habitat used by lesser prairie-chicken for feeding related to seasonal behavior of plants in Beaver County, Oklahoma. The Southwestern Naturalist 9:111-117.

Judd, S.D. 1905. The grouse and wild turkeys of the United States, and their economic value. U.S. Department of Agriculture Biological Survey Bulletin Number 24.

Kay, C.E. 1998. Are ecosystems structured from the top-down or bottom-up: a new look at an old debate. Wildlife Society Bulletin 26:484-498.

Kirsch, L.M. 1974. Habitat management considerations for prairie-chickens. The Wildlife Society Bulletin 2:124-129.

Kuchler, A.W. 1964. Potential natural vegetation of the conterminous United States. Amercian Geographical Society Special Publication Number 36.

Lande, R.L. and G.F. Barrowclough. 1987. Effective population size, genetic variation, and their use in population management. Pages 87-123 *in* M.E. Soulé, editor. Viable populations and their conservation. Cambridge University Press.

Lawrence, G.N. 1877. A note on *Cupidonia cupido* var. *pallidicinctus*, Ridgway. Bulletin of the Nuttall Ornithological Club 2:52.

Lincoln, F.C. 1918. Notes on some species new to the Colorado list of birds. Auk 35:236-237.

Litton, G.W. 1978. The lesser prairie-chicken and its management in Texas. Texas Parks and Wildlife Department Booklet 7000-25.

Litvaitis, J.A., K. Titus, and E.M. Anderson. 1994. Measuring vertebrate use of terrestrial habitats and foods. Pages 254-274 *in* T.A. Bookhout, editor. Research and management techniques for wildlife habitats. U.S. Fish and Wildlife Service, Ohio Cooperative Fish and Wildlife Research Unit. Ohio State University, Columbus, OH.

Locke, B.A. 1992. Lek hypothesis and the location, dispersion, and size of lesser prairie-chicken leks. Ph. D. Dissertation. New Mexico State University, Las Cruces, NM.

Massey, M. 2001. Long-range plan for the management of lesser prairie chickens in New Mexico 2002-2006. New Mexico Department of Game and Fish, Santa Fe, NM.

McKee, G., M.R. Ryan, and L.M. Mechlin. 1998. Predicting greater prairie-chicken nest success from vegetation and landscape characteristics. Journal of Wildlife Management 62:314-321.

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

Moe, M. 1999. Status and management of the greater prairie-chicken in Iowa. Pages 123-127 *in* W.D. Svedarsky, R.H. Hier, and N.J. Silvy, editors. The greater prairie-chicken a national look. Miscellaneous Publication 99-1999, Minnesota Agricultural Experiment Station, University of Minnesota, Saint Paul, MN.

Morrow, M.E., T.A. Rossignol, and N.J. Silvy. 2004. Federal listing of prairie grouse: lessons from the Attwater's prairie-chicken. Wildlife Society Bulletin 32:112-118.

Mote, K.D., R.D. Applegate, J.A. Bailey, K.E. Giesen, R. Horton, J.L. Sheppard, Technical Editors. 1998. Assessment and conservation strategy for the lesser prairie-chicken (*Tympanuchus pallidicinctus*). Emporia, Kansas. Kansas Department of Wildlife and Parks.

Naugle, D.E., C.L. Aldridge, B.L. Walker, T.E. Cornish, B.J. Moynahan, M.J. Holloran, K. Brown, G.D. Johnson, E.T. Schmidtman, R.T. Mayer, C.Y. Kato, M.R. Matchett, T.J. Christiansen, W.E. Cook, T. Creekmore, R.D. Falise, E.T. Rinkes, and M.S. Boyce. 2004. West Nile virus: pending crisis for greater sage grouse. Ecology Letters. In press.

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

Paine, L., D.J. Undersander, D.W. Sample, G.A. Bartlet, and T.A. Schatteman. 1996. Cattle trampling of simulated ground nests in rotationally grazed pastures. The Journal of Range Management 49:294-300.

Pence, D.B. and D.L. Sell. 1979. Helminths of the lesser prairie-chicken, *Tympanuchus pallidicinctus* (sic) (Ridgway) (Tetraonidae), from the Texas panhandle. Proceedings of the Helminthological Society of Washington 46: 146-149.

Pence, D.B., J.T. Murphy, F.S. Guthery, and T.B. Doerr. 1983. Indications of seasonal variation in the helminth fauna of the lesser prairie chicken, *Tympanuchus pallidicinctus* (Ridgway) (Tetraonidae), from northwestern Texas. Proceedings of the Helminthological society of Washington 50:345-347.

Peterson, M.J. 2004. Parasites and infectious diseases of prairie grouse: should managers be concerned? Wildlife Society Bulletin 32:35-55.

Peterson, M.J. and N.J. Silvy. 1996. Reproductive stages limiting productivity of the endangered Attwater's prairie-chicken. Conservation Biology 10:1264-1276.

Peterson, M.J., P.J. Ferro, M.N. Peterson, R. Sullivan, B.E. Toole, and N.J. Silvy. 2002. Infectious disease survey of lesser prairie chickens in the northern Rolling Plains of Texas. Journal of Wildlife Diseases 38:834-839.

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

Pitman, J.C. 2003. Lesser prairie-chicken nest site selection and nest success, juvenile gender determination and growth, and juvenile survival and dispersal in southwestern Kansas. M.Sc. Thesis, Kansas State University, Manhattan, KS.

Pitman, J.C., C.A. Hagen, R.J. Robel, T.M. Loughin, and R.D. Applegate. 2005. Gender identification and growth of juvenile lesser prairie-chickens. Condor 107:87-96.

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.

Rich, T.D., C.J. Bearedmore, H. Berlanga, P.J. Blancher, M.S.W. Bradstreet, G.S. Butcher, D.W. Demarest, E.H. Dunn, W.C. Hunter, E.E. Iñigo-Elias, J.A. Kennedy, A.M. Martell, A.O. Panjabi, D.N. Pashley, K.V. Rosenberg, C.M. Rustay, J.S. Wendt, and T.C. Will. 2004. Partners in Flight North American landbird conservation plan. Cornell Lab of Ornithology, Ithaca, NY.

Ridgway, R. 1885. Some emended names of North American birds. Proceedings of United States Museum 8:354-357.

Riley, T.Z. 1978. Nesting and brood-rearing habitat of lesser prairie-chickens in southeastern New Mexico. M. Sc. Thesis. New Mexico State University, Las Cruces, NM.

Riley, T.Z. 2004. Private-land habitat opportunities for prairie grouse through federal conservation programs. Wildlife Society Bulletin 32:83-91.

Riley, T.Z. and C.A. Davis. 1993. Vegetative characteristics of lesser prairie-chicken brood foraging sites. The Prairie Naturalist 25:243-248.

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

Riley, T.Z., C.A. Davis, and R.A. Smith. 1993a. Autumn-winter habitat use of lesser prairie-chickens (*Tympanuchus pallidicinctus*, Tetraonidae). The Great Basin Naturalist 53:409-411.

Riley, T.Z., C.A. Davis, and R.A. Smith. 1993b. Autumn and winter foods of the lesser prairie-chicken (*Tympanuchus pallidicinctus*) (Galliformes: Tetraonidae). The Great Basin Naturalist 53:186-189.

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.

Robel, R.J. 1970. Possible role of behavior in regulating greater prairie-chicken populations. Journal of Wildlife Management 43:306-312.

Robel, R.J. 2004. Summary remarks and personal observations of the situation by an old hunter and researcher. Wildlife Society Bulletin 32:119-122.

Robel, R.J., J.N. Briggs, J.J. Cebula, N.J. Silvy, C.E. Viers, and P.G. Watt. 1970a. Relationship between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-297.

Robel, R.J., J.N. Briggs, J.J. Cebula, N.J. Silvy, C.E. Viers, and P.G. Watt. 1970b. Greater prairie-chicken ranges, movements, and habitat usage in Kansas. Journal of Wildlife Management 34:286-306.

Robel, R.J., T.J. Walker, Jr., C.A. Hagen, R.K. Ridley, K.E. Kemp, and R.D. Applegate. 2003. Internal helminth parasites of lesser prairie-chicken *Tympanuchus pallidicinctus* in southwestern Kansas: incidence, burdens, and effects. Wildlife Biology 9:341-349.

Rockwell, R.R. 1908. The history of Colorado ornithology. Condor 11:24-32.

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

Rodgers, R.D., R. Applegate, B. Crouch, R. Ruthstrom, T. Schroeder, K. Sexson, and T. Swan. 2000. Kansas upland game birds - problems and recommended actions. Kansas Department of Wildlife and Parks, Upland Game Bird Initiative Committee.

Ryan, M.R., L.W. Burger, Jr., D.P. Jones, and A.P. Wywialowski. 1998. Breeding ecology of greater prairie-chicken (*Tympanuchus cupido*) in relation to the prairie landscape configuration. The American Midland Naturalist 140:111-121.

Samson, F.B., F.L. Knopf, and W.R. Ostlie. 2004. Great Plains ecosystems: past, present, and future. Wildlife Society Bulletin 32:6-15.

Sands, J.L. 1968. Status of the lesser prairie-chicken. Audubon Field Notes 22:454-456.

Schroeder, M.A. 1991. Movement and lek visitation by female greater prairie-chickens in relation to predictions of the female preference hypothesis of lek evolution. Auk 108:896-903.

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

Schroeder, M.A. and C.E. Braun. 1992. Seasonal movement and habitat use by greater prairie-chickens in northeastern Colorado. Colorado Division of Wildlife, Special Report Number 68.

Schroeder, M.A. and L.A. Robb. 1993. Greater prairie-chicken (*Tympanuchus cupido*). *In*: A. Poole, P. Stettenheim, and F. Gill, editors. The Birds of North America, Number 36. The Academy of Natural Sciences. The American Ornithologists' Union. Washington, D.C.

Schroeder, M.A., C.L. Aldridge, A.D. Apa, J.R. Bohne, C.E. Braun, S.D. Bunnell, J.W. Connelly, P.A. Deibert, S.C. Gardner, M.A. Hilliard, G.D. Kobriger, S.M. McAdam, C.W. McCarthy, J.J. McCarthy, D.L. Mitchell, E.V. Rickerson, and S.J. Stiver. 2004. Distribution of sage-grouse in North America. The Condor 106:363-376.

Schroeder, M.A., K.M. Giesen, and C.E. Braun. 1992. Use of helicopters for estimating numbers of greater and lesser prairie-chicken leks in eastern Colorado. Wildlife Society Bulletin 20:106-113.

Schroeder, M.A., J.R. Young, and C.E. Braun. 1999. Sage grouse (*Centrocercus urophasianus*). *In*: A. Poole and F. Gill, editors. The Birds of North America, Number 425. The Birds of North America, Inc., Philadelphia, PA.

Schwilling, M.D. 1955. A study of the lesser prairie-chicken in Kansas. Kansas Forestry, Fish and Game Commission.

Sell, D.L. 1979. Spring and summer movements and habitat use by lesser prairie-chicken females in Yoakum County, Texas. M. Sc. Thesis. Texas Tech University, Lubbock, TX.

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

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

Silvy, N.J. and C.A. Hagen. 2004. Introduction: management of imperiled prairie grouse species and their habitat. Wildlife Society Bulletin 32:2-5.

Silvy, N.J., C.P. Griffin, M.A. Lockwood, M.E. Morrow, and M.J. Peterson. 1999. The Attwater's prairie-chicken - a lesson in conservation biology research. Pages 153-168 *in* W.D. Svedarsky, R.H. Hier, and N.J. Silvy, editors. The greater prairie-chicken a national look. Miscellaneous Publication 99-1999, Minnesota Agricultural Experiment Station, University of Minnesota, Saint Paul, MN.

Silvy, N.J., M.J. Peterson, and R.R. Lopez. 2004. The cause of the decline of pinnated grouse: the Texas example. Wildlife Society Bulletin 32:16-21.

Slatkin, M. 1987. Gene flow and the geographic structure of natural populations. Science 236:787-792.

Smith, B.H., D.W. Duszynski, and K. Johnson. 2003. Survey for coccidian and haemosporidia in the lesser prairie-chicken (*Tympanuchus pallidicinctus*) from New Mexico with description of a new *Eimeria* species. Journal of Wildlife Diseases 39:347-353.

Snyder, W.D. 1997. Sandsage-bluestem prairie renovation to benefit prairie grouse. Special Report No. 71. Colorado Division of Wildlife, Denver, CO.

Soulé, M.E. 1987. Introduction. Pages 1-10 *in* M.E. Soulé, editor. Viable populations for conservation. Cambridge University Press.

Sparling, D.W. Jr. 1980. Hybridization and taxonomic status of greater prairie-chickens and sharp-tailed grouse (hybridization in grouse). The Prairie Naturalist 12:92-101.

Sparling, D.W. Jr. 1981. Communication in prairie grouse I. Infomation content and interspecific functions of principal vocalizations. Behavioral and Neural Biology 32:463-486.

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

Storch, I., compiler. 2000. Grouse status survey and conservation action plan 2000-2004. WPA/BirdLife/SSC Grouse Specialist Group, IUCN, Gland. Switzerland and Cambridge, UK and the World Pheasant Association, Reading, UK.

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 32:177-188.

Svedarsky, D. and G. Van Amburg. 1996. Integrated management of the greater prairie-chicken and livestock on the Sheyenne National Grassland. North Dakota Game and Fish Department, Bismark, North Dakota, Jamestown, North Dakota: Northern Prairie Wildlife Research Center home page. Online at htt://www.npwrc.usgs.gov/resource/othrdata/sheyenne/sheyenne.htm (Version 16JUL97).

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. 1980a. Status, ecology, and management of the lesser prairie-chicken. U.S. Department of Agriculture General Technical Report RM-77.

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

Taylor, M.A. and F.S. Guthery. 1980c. Dispersal of a lesser prairie-chicken (*Tympanuchus pallidicinctus*). The Southwestern Naturalist 25:124-125.

Tilman, D. and A. El Haddi. 1992. Drought and biodiversity in grasslands. Oecologia 89:257-264.

Toepfer, J.E., R.L. Eng, and R.K. Anderson. 1990. Translocating prairie grouse: what have we learned? Transactions of the 55th North American Wildlife and Natural Resources Conference 55:569-579.

Tompkins, D.M., R.A.H. Draycott, and P.J. Hudson. 2000a. Field evidence for apparent competition mediated via the shared parasites of two gamebird species. Ecology Letters 3:10-14.

Tompkins, D.M., J.V. Greenman, P.A. Robertson, and P.J. Hudson. 2000b. The role of shared parasites in the exclusion of wildlife hosts: *Heterakis gallinarum* in the ring-necked pheasant and the grey partridge. Journal of Animal Ecology 69:829-840.

USDA Forest Service. Undated. Land and resource management plan. Pike and San Isabel National Forests; Comanche and Cimarron National Grasslands. Pueblo, CO.

USDA Forest Service. 2003. Land and resource management plan monitoring report. Pike and San Isabel National Forests, Cimarron and Comanche National Grasslands. Pueblo, CO.

U.S. Fish and Wildlife Service. 1993. Attwater's prairie chicken recovery plan. Albuquerque, NM.

U.S. Fish and Wildlife Service. 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. Federal Register 63:31400-31406.

U.S. Fish and Wildlife Service. 2001. Twelve-month administrative finding on petition to list the lesser prairie-chicken (*Tympanuchus pallidicinctus*) as threatened. Ecological Services, U.S. Fish and Wildlife Service, Tulsa, OK.

U.S. Fish and Wildlife Service. 2002. Twelve-month administrative finding on petition to list the lesser prairie-chicken (*Tympanuchus pallidicinctus*) as threatened. Ecological Services, U.S. Fish and Wildlife Service, Tulsa, OK.

U.S. Fish and Wildlife Service. 2004. Endangered and threatened wildlife and plants; review of species that are candidates or proposed for listing as endangered or threatened; annual notice of findings on resubmitted petitions; annual description of progress on listing actions; proposed rule. Federal Register 69:24876-24904.

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.

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

Walsh, D.P., G.C. White, T.E. Remington, and D.C. Bowden. 2004. Evaluation of the lek count index for greater sage-grouse. Wildlife Society Bulletin 32:56-68.

Walsh, P.D. 1995. PVA in theory and practice. Conservation Biology 9:704-705.

Washington Department of Fish and Wildlife. 2000. Shrubsteppe mapping of eastern Washington using landsat satellite thematic mapper data. Washington Department of Fish and Wildlife, Olympia, WA.

Westemeier, R.L. and S. Gough. 1999. National outlook and conservation needs for greater prairie-chickens. Pages 169-187 *in* W.D. Svedarsky, R.H. Hier, and N.J. Silvy, editors. The greater prairie-chicken a national look. Miscellaneous Publication 99-1999, Minnesota Agriculture Experiment Station, University of Minnesota, Saint Paul, MN.

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

Wildlife Habitat Management Institute. 1999. Lesser prairie-chicken (*Tympanuchus pallidicinctus*). USDA, NRCS, Fish and Wildlife Habitat Management Leaflet Number 6.

Wilson, D.L. 1982. Nesting habitat of lesser prairie-chickens in Roosevelt and Lea counties, New Mexico. M. Sc. Thesis. University of New Mexico, Las Cruces, NM.

Wisdom, M.J. 1980. Nesting habitat of lesser prairie-chickens in eastern New Mexico. M. Sc. Thesis. New Mexico State University, Las Cruces, NM.

Wisdom, M.J. and L.S. Mills. 1997. Sensitivity analysis to guide population recovery: prairie-chickens as an example. Journal of Wildlife Management 61:302-312.

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

Zwickel, F.C. 1992. Blue grouse (*Dendragapus obscurus*). *In*: A. Poole, P. Stettenheim, and F. Gill, editors. The Birds of North America, Number 15. Academy of Natural Sciences and American Ornithologists' Union, Philadelphia, PA.