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The Effects of Management Practices on Grassland Birds—Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*)

Chapter D of

The Effects of Management Practices on Grassland Birds

Professional Paper 1842–D

U.S. Department of the Interior
U.S. Geological Survey

Cover. Lesser Prairie-Chicken. Photograph by Greg Kramos, U.S. Fish and Wildlife Service.
Background photograph: Northern mixed-grass prairie in North Dakota, by Rick Bohn, used with permission.

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By Brent E. Jamison,[1,2] Lawrence D. Igl,[1] Jill A. Shaffer,[1] Douglas H. Johnson,[1] Christopher M. Goldade,[1,3] and Betty R. Euliss[1]

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The Effects of Management Practices on Grassland Birds

Edited by Douglas H. Johnson,[1] Lawrence D. Igl,[1] Jill A. Shaffer,[1] and John P. DeLong[1,4]

[1]U.S. Geological Survey.

[2]Bureau of Land Management (current).

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U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
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U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2020

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Suggested citation:
Jamison, B.E., Igl, L.D., Shaffer, J.A., Johnson, D.H., Goldade, C.M., and Euliss, B.R., 2020, The effects of management practices on grassland birds—Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*), chap. D *of* Johnson, D.H., Igl, L.D., Shaffer, J.A., and DeLong, J.P., eds., The effects of management practices on grassland birds: U.S. Geological Survey Professional Paper 1842, 36 p., https://doi.org/10.3133/pp1842D.

ISSN 2330-7102 (online)

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
decimeter (dm)	3.937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square meter (m^2)	0.0002471	acre
hectare (ha)	2.471	acre
square kilometer (km^2)	247.1	acre
square meter (m^2)	10.76	square foot (ft^2)
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Mass	
kilogram (kg)	2.205	pound (lb)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as

°F = (1.8 × °C) + 32.

Abbreviations

2,4–D 2,4–Dichlorophenoxyacetic acid

2,4,5–T 2,4,5–Trichlorophenoxyacetic acid

AUM animal unit month

CP Conservation Practice

CRP Conservation Reserve Program

n sample size number

n.d. no date

PDSI Palmer Drought Severity Index

SAFE State Acres for Wildlife Enhancement

sp. species (an unspecified species within the genus)

spp. species (applies to two or more species within the genus)

VOR visual obstruction reading

Acknowledgments

Major funding for this effort was provided by the Prairie Pothole Joint Venture, the U.S. Fish and Wildlife Service, and the U.S. Geological Survey. Additional funding was provided by the U.S. Forest Service, The Nature Conservancy, and the Plains and Prairie Potholes Landscape Conservation Cooperative. We thank the following cooperators who provided access to their bibliographic files: Louis B. Best, Carl E. Bock, Brenda C. Dale, Stephen K. Davis, James J. Dinsmore, Fritz L. Knopf (deceased), Rolf R. Koford, David R. C. Prescott, Mark R. Ryan, David W. Sample, David A. Swanson, Peter D. Vickery (deceased), and John L. Zimmerman. We thank Christopher Goldade for his illustration of the Lesser Prairie-Chicken. We thank Courtney L. Amundson, Joel S. Brice, Rachel M. Bush, James O. Church, Shay F. Erickson, Silka L.F. Kempema, Emily C. McLean, Susana Rios, Bonnie A. Sample, and Robert O. Woodward for their assistance with various aspects of this effort. Lynn M. Hill and Keith J. Van Cleave, U.S. Geological Survey, acquired many publications for us throughout this effort, including some that were very old and obscure. Earlier versions of this report benefitted from insightful comments from Kenneth M. Giesen, Brian A. Tangen, and Donald H. Wolfe.

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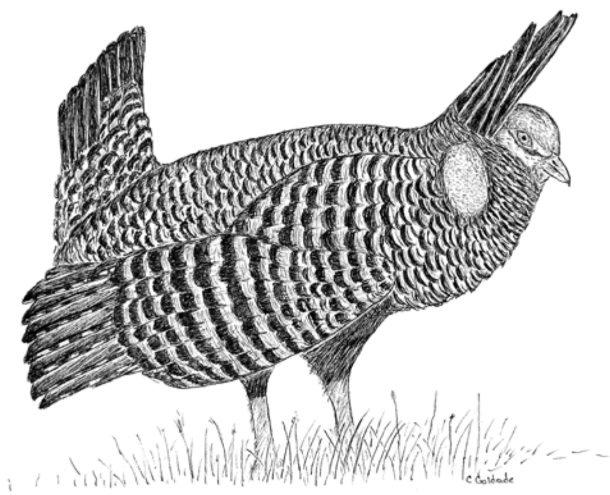
Capsule Statement

The key to Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*) management is maintaining expansive sand shinnery oak (*Quercus havardii*; hereafter "shinnery oak") or sand sagebrush (*Artemisia filifolia*) grasslands. Within these grasslands, areas should contain short herbaceous cover for lek sites (that is, an area where male prairie-chickens gather to engage in courtship displays to attract mates); shrubs or tall residual grasses for nesting; and areas with about 25 percent canopy cover of shrubs, forbs, or grasses 25–30 centimeters (cm) tall for brood rearing. Historically, the Lesser Prairie-Chicken was considered a gamebird that was hunted throughout its range (Rodgers, 2016). In response to low population levels and considerations related to listing the species as State or Federally threatened, recreational hunting seasons currently are closed throughout the species' range (Haukos and others, 2016). This account does not address harvest or its effects on populations but instead focuses on the effects of habitat management. Lesser Prairie-Chickens have been reported to use habitats with less than or equal to (≤) 600 cm average vegetation height (including shrubs), ≤70 cm visual obstruction reading (VOR), 4–78 percent grass cover, ≤30 percent forb cover, ≤66 percent shrub cover, 3–61 percent bare ground, 2–58 percent litter cover, and ≤3 cm litter depth. The descriptions of key vegetation characteristics are provided in table D1 (after the "References" section). Vernacular and scientific names of plants and animals follow the Integrated Taxonomic Information System (https://www.itis.gov).



Lesser Prairie-Chicken. Illustration by Christopher M. Goldade, used with permission.

Breeding Range

Lesser Prairie-Chickens presumably were widely distributed across the southern Great Plains, but there is considerable uncertainty concerning the species' historical range because of a paucity of documented records before Euro-American settlement in the late 1800s (Boal and Haukos, 2016). The species currently occupies about 16 percent of its purported historical range (Garton and others, 2016). Lesser Prairie-Chickens are year-round residents from southeastern Colorado and southwestern Kansas, and south through western Oklahoma, extreme eastern New Mexico, and the Texas Panhandle (National Geographic Society, 2011). One of the largest remaining populations of Lesser Prairie-Chickens currently is in Kansas outside of the boundaries of the species' historical range (Dahlgren and others, 2016; Hagen and Elmore, 2016). The historical and current ranges of the Lesser Prairie-Chicken are shown in figure D1 and are based on information from Bartuszevige and Daniels (2016) and K.M. Giesen (Colorado Division of Wildlife, Fort Collins, Colorado, written commun. [n.d.]) (not all geographic places mentioned in report are shown on figure).

[1]U.S. Geological Survey.

[2]Bureau of Land Management (current).

[3]South Dakota Game, Fish and Parks (current).

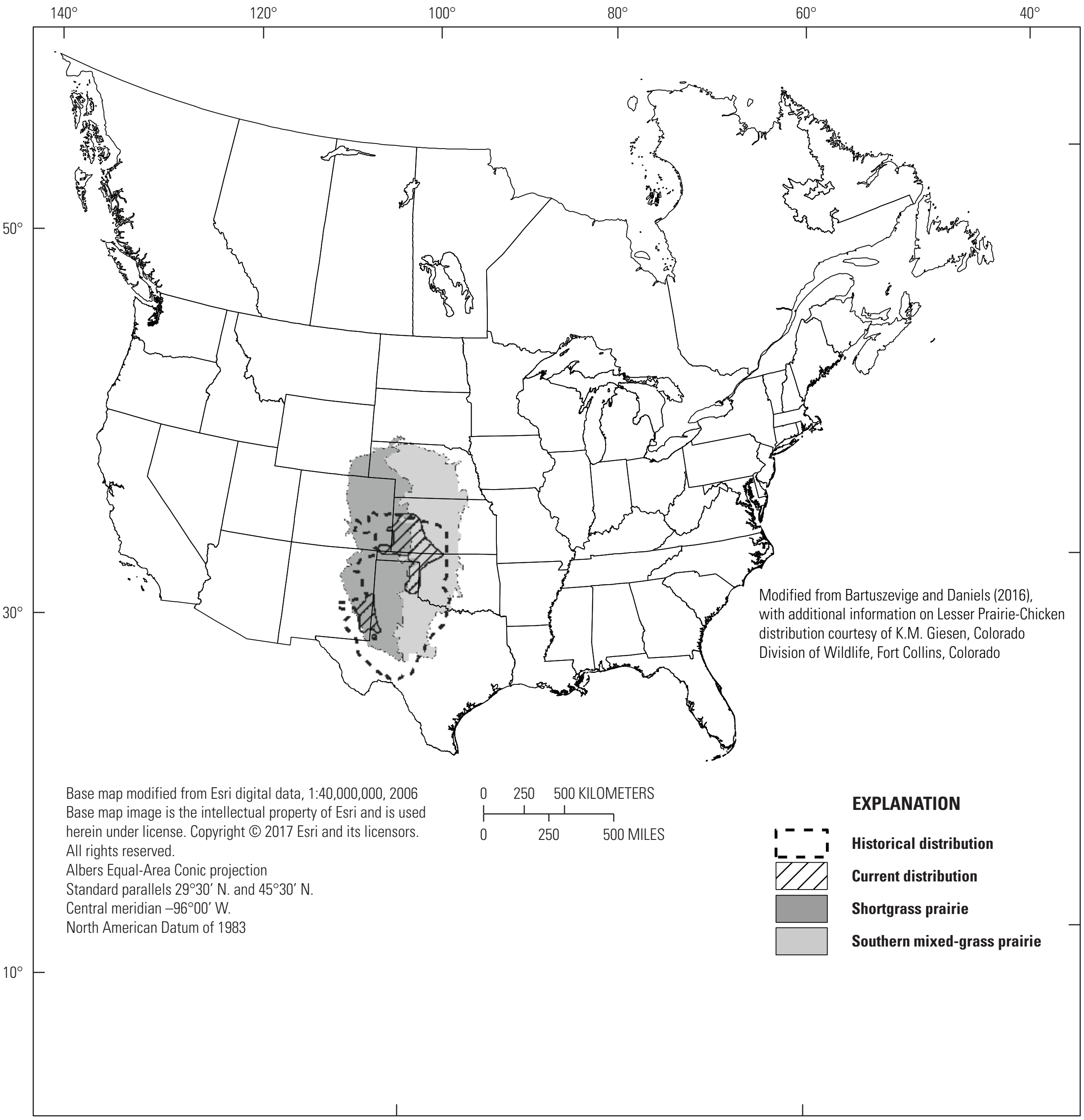


Figure D1. The historical and current range of the Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*) in the shortgrass and southern mixed-grass prairies of the Great Plains of the United States.

Suitable Habitat

In general, the Lesser Prairie-Chicken inhabits shrub-grassland communities dominated by shinnery oak or sand sagebrush with an understory of mixed-grass or tallgrass species and a variety of forb species (Lee, 1950; Schwilling, 1955; Bent, 1963; Copelin, 1963; Hoffman, 1963; Jones, 1963a, 1963b; Crawford, 1974; Cannon and Knopf, 1979; Wisdom, 1980; Merchant, 1982; Riley and others, 1992, 1993; Litton and others, 1994; Cable, 1996; Wildlife Habitat Management Institute, 1999; Jamison, 2000; Patten and others, 2005a; Haukos and Zavaleta, 2016; Hagen and Giesen, 2020). The characteristics of habitat used by Lesser Prairie-Chickens, including vegetation height, density, and species, vary in accordance with the species' seasonal life-history requirements. Lesser Prairie-Chickens use short, herbaceous cover for lek sites; shrubs or tall residual grasses for nesting; areas with about 25 percent canopy coverage of shrubs, forbs, or grasses 25–30 cm tall for brood rearing; and areas with approximately equal proportions of shrubs, grasses, and bare ground for adult foraging. Sandhill habitats used by Lesser Prairie-Chickens are characterized by sandy or sandy loam soils in the Brownfield, Patricia, Tivoli, Brownfield-Tivoli, Tivoli-Vona, and Amarillo-Clovis associations that are in level to undulating topography (Bent, 1963; Copelin, 1963; Crawford, 1974; Sell, 1979; Wilson, 1982; Doerr and Guthery, 1983; Olawsky, 1987; Olawsky and Smith, 1991; Jamison, 2000).

Larsson and others (2013) indicated that vegetation structure and composition play an important role in predator avoidance, thermoregulation, survival, and reproductive needs, and that habitat selection may result in a trade-off among these factors across seasons. Planted cover, such as grasslands enrolled in the Conservation Reserve Program (CRP), may provide suitable habitat in some parts of the species' range or during some periods in the species' annual cycle (Leslie and others, 1999; Giesen, 2000; Jamison, 2000; Rodgers and Hoffman, 2005; Oyler-McCance and others, 2016; Sullins and others, 2018; Harryman and others, 2019). From spring through fall in southwestern Kansas, radio-marked male Lesser Prairie-Chickens used native habitats vegetated by sand sagebrush, blue grama, sideoats grama (*Bouteloua curtipendula*), paspalum (*Paspalum* species [sp.]), bluestem (*Andropogon* species [spp.]), western ragweed (*Ambrosia psilostachya*), sunflowers (*Helianthus* spp.), Russian thistle (*Salsola iberica*), pricklypear (*Opuntia* spp.), and yucca (*Yucca glauca*) (Jamison, 2000). In mixed-grass prairies in Kansas, radio-marked prairie-chickens selected microsite areas (4 meters [m] from flush location) characterized by greater than [>] 75 percent grass cover and less than [<] 10 percent forb cover. At the patch scale (100 m from flush location), prairie-chickens selected areas characterized by >60 percent forb cover and <25 percent grass cover. The selected microsite areas also were characterized by taller and denser vegetation compared to patch locations (Lautenbach, 2017). Throughout the year in Kansas, male Lesser Prairie-Chickens selected sand sagebrush grasslands over cropland, tallgrass prairies, CRP grasslands, and other grassland habitats (for example, shortgrass, mixed-grass, western wheatgrass [*Pascopyrum smithii*], and alkali sacaton [*Sporobolus airoides*] prairies) (Jamison, 2000). In Oklahoma across all seasons, the occurrence of Lesser Prairie-Chickens was most associated with alfalfa (*Medicago sativa*) and sand dropseed (*Sporobolus cryptandrus*) and least associated with wheat (*Triticum* spp.) and three species of *Bouteloua* (Larsson and others, 2013). In Oklahoma and New Mexico, survival was higher for radio-marked adult Lesser Prairie-Chickens that chose microhabitats with a higher coverage of shrubs and grasses and higher density of vegetation (Patten and others, 2005a). Survival was higher for prairie-chickens that used sites with >20 percent shrub coverage than for those that used 10–20 percent coverage; survival was higher for prairie-chickens choosing 10–20 percent shrub coverage than for those choosing <10 percent coverage. In Texas during autumn and winter, Lesser Prairie-Chickens used shinnery oak-sand sagebrush, cultivated sunflowers, and shinnery oak/little bluestem (*Schizachyrium scoparium*) habitats more than expected based upon habitat availability; the species used all other habitats (that is, shinnery oak, honey mesquite [*Prosopis glandulosa*]-shinnery oak, honey mesquite-blue grama [*Bouteloua gracilis*], and oldfield habitats [idle or neglected arable lands that have naturally reverted back to perennial cover]) less than expected (Taylor and Guthery, 1980a). In northwest Texas during the winter, Pirius and others (2013) reported that radio-marked Lesser Prairie-Chickens used grassland-dominated areas (greater than or equal to [≥] 70 percent) with co-occurring shinnery oak (≤30 percent) more than expected based on availability. Lesser Prairie-Chickens also used two other cover types, sand sagebrush-dominated areas (≥70 percent) with grassland (≤30 percent) and sand sagebrush-dominated areas (≥70 percent) with bare ground (≤30 percent), less than expected based on availability (Pirius and others, 2013).

Specific information on habitats used for courtship activities (lek sites), nesting, brood rearing, foraging, and water use appear in the following subsections.

Lek Sites

Lesser Prairie-Chickens prefer lek sites in native grasslands and other areas with short (<10 cm) herbaceous cover and unrestricted visibility that are on ridges, knolls, or in broad swales in pastures; the species also will establish leks on abandoned oil-drilling sites (oil pads) with little or no vegetation, unimproved roads with little traffic, areas treated with shrub-specific herbicide, recently burned areas, heavily grazed areas (especially near livestock-watering facilities), black-tailed prairie dog (*Cynomys ludovicianus*) towns, areas around livestock watering facilities, and cultivated fields adjacent to grassland (Davison, 1940; Schwilling, 1955; Bent, 1963; Copelin, 1963; Hoffman, 1963; Jones, 1963a, 1963b; Donaldson, 1969; Crawford and Bolen, 1976a; Cannon and Knopf, 1979; Taylor, 1979; Locke, 1992; Applegate and Riley, 1998; Hagen and Giesen, 2020). Jarnevich and Laubhan (2011) indicated that Lesser Prairie-Chickens favored lek sites with a slight topographic relief. In Kansas, leks were discovered in openings in sand sagebrush on hilltops; in broad, flat areas; in low spots in choppy sandhills; and in cultivated fields (Schwilling, 1955). Most of these lek sites were vegetated by buffalograss (*Bouteloua dactyloides*) or blue grama, which were on small rises in sagebrush pastures, and were nearly devoid of shrubs (Schwilling, 1955).

In Oklahoma, mean height of vegetation on leks (number of leks not given) was 10 cm, and plant coverage averaged 64 percent (Jones, 1963a, 1963b). Percentage composition of perennial plants was 26.2 percent buffalograss, 4.2 percent sand dropseed, 3.8 percent blue grama, 8.8 percent sideoats grama, and <3 percent other species (Jones, 1963a). In New Mexico, Oklahoma, and Texas, Leslie and others (1999) found 21 leks in landscapes that included native grassland, cultivated land, and CRP fields. In Texas, males used pastures vegetated by sand sagebrush, Chickasaw plum (*Prunus angustifolia*), fragrant sumac (*Rhus aromatica* variety *aromatica*), shinnery oak, sand bluestem

(*Andropogon gerardii* subspecies *hallii*), little bluestem, sand lovegrass (*Eragrostis trichodes*), sand dropseed, thin paspalum (*Paspalum setaceum*), switchgrass (*Panicum virgatum*), Indiangrass (*Sorghastrum nutans*), and various forbs (Jackson and DeArment, 1963). In another Texas study, 69 percent of 13 leks were in pastures (Crawford and Bolen, 1976b). After cultivation of the area surrounding these leks, leks that were traditionally occupied were no longer consistently used by displaying males. In a third Texas study, 14 percent of 14 leks on a 5,200-hectare (ha) shinnery oak-sand sagebrush study site were in areas of relatively undisturbed natural vegetation, and 86 percent were on areas disturbed by human activities (Taylor, 1979). In the disturbed areas, eight leks were on oil pads, three were on tilled areas, and one was on a plot treated with tebuthiuron (1-[5-*tert*-Butyl-1,3,4-thiadiazol-2-yl]-1,3-dimethylurea), a shrub-specific herbicide. The two leks on natural sites were on slightly elevated terrain, where shinnery oak was 10–20 cm tall. In New Mexico, males established leks in areas with a greater composition of shinnery oak and bluestem (*Schizachyrium scoparium* and *Andropogon gerardii*), shinnery oak and three-awn (*Aristida* spp.), and shinnery oak and mixed-grass habitats than was generally available on the 14,500-ha study area (Ahlborn, 1980). In another New Mexico study, Hunt and Best (2004, 2010) compared vegetative composition of active and abandoned leks of Lesser Prairie-Chickens and the pastures in which they were located. Active leks and surrounding pastures had significantly more bluestem (*Andropogon* spp.) and less dropseed (*Sporobolus* spp.) than abandoned leks and surrounding pastures, and abandoned leks were closer to honey mesquite trees >60 cm in height than were active leks. In southeastern New Mexico, McWilliams (2013) reported that pastures containing active leks with bluestem (*Andropogon* spp.), three-awn, shinnery oak, honey mesquite, and broom groundsel (*Senecio* spp.) were 1.16, 1.14, 0.85, 1.22, and 1.26 times, respectively, more likely to be used by Lesser Prairie-Chickens than pastures not containing these species. Pastures containing muhly grasses (*Muhlenbergia* spp.) were 0.85 times less likely to be used by Lesser Prairie-Chickens than pastures not containing muhly grasses (McWilliams, 2013).

Lesser Prairie-Chickens may establish leks on oil pads and on or near other anthropogenic features (Davis and others, 1979; Sell, 1979; Locke, 1992). Although abandoned oil pads frequently are used as lek sites by the Lesser Prairie-Chicken, gas and oil production may affect lek activity, survival, and displacement (Candelaria, 1979; Davis and others, 1979, Hovick and others, 2014). In Texas, Sell (1979) found three leks on oil pads, three near windmills, one in a cultivated field, one in an area in which shrubs had been treated with herbicide, and one in native grassland. In New Mexico, 8 of 21 leks were on oil pads, seven were in honey mesquite-shortgrass habitats, and six were in shinnery oak-tallgrass habitat (Davis and others, 1979). Oil pads used as lek sites had no vegetation; however, leks in honey mesquite-shortgrass habitat generally had grass cover that was 5–10 cm tall. One lek in shinnery oak-tallgrass habitat was on a sand dune that was devoid of vegetation. On the same study area, 90 percent of 21 leks observed by Locke (1992) were on oil pads, and 91 percent of 34 leks in the following spring were situated on oil pads. The remaining leks were in pasture. About one-half of the available oil pads were used as lek sites. Use of oil pads as lek sites was independent of surrounding habitat type(s) (that is, oil pads had an equal probability of being used as lek sites regardless of adjacent habitat type) (Locke, 1992).

Lek density and corresponding interlek distances may provide an index to habitat quality. Interlek distance was defined by Crawford (1974), Locke (1992), and Giesen (1994) as the distance between a lek and its nearest neighbor. Presumably, this definition holds for Crawford and Bolen (1976a) as well. Taylor (1979) and Applegate and Riley (1998) referred to an average distance between leks but did not specify how those means were calculated. In landscapes dominated by grassland, interlek distances were 0.84–3.2 kilometers (km), and lek densities were 0.18–0.97 leks per square kilometer (km^2) (Crawford, 1974; Crawford and Bolen, 1976a; Taylor, 1979; Locke, 1992; Giesen, 1994). On the Comanche National Grassland (primarily sand sagebrush and bunchgrasses) in Colorado, average lek density was 0.2 lek per km^2, and average distance between leks was 1.1 km (number of leks was not given) (Giesen, 1994). In Oklahoma, the number of active leks in a 41.4-km^2 study area varied from 18 to 40 leks over an 8-year period, but only 13 leks were active during all 7 years in which counts of displaying males were completed (Davison, 1940). In Texas, density of leks (estimated from interlek distances) varied with the proportion of the landscape within a 2,331-ha block that was cultivated (Crawford, 1974; Crawford and Bolen, 1976a). Lek densities were highest in landscapes with limited (5–37 percent) cultivated land compared to landscapes with more (>37 percent) cultivated land and landscapes with no cultivation. Mean distance between leks on sites with limited cultivation was 2.4 km (number of leks not given). Mean distance between leks on sites with no cultivated land was 3.2 km. In highly cultivated landscapes, average distance between leks was 5 km (Crawford, 1974). In another Texas study, mean interlek distance for 14 leks on a 5,200-ha study area was 1.3 km (Taylor, 1979). In New Mexico, mean interlek distance for 21 leks ranged from 0.8 km in 1 year to 1.0 km for 34 leks found the following year (Locke, 1992). In a second New Mexico study, Davis (2009) reported an average distance of 1.1 km between lek sites where 21 females were captured and the locations of their nests.

Jarnevich and others (2016) developed models to predict habitat suitability for Lesser Prairie-Chicken leks in the five occupied States and to explore relationships of occurrence with landscape characteristics and anthropogenic effects that may influence lek distribution. Two models were developed, one with and one without State as a factor. When State was included in the model, State was the most important predictor of habitat suitability, followed by the percentage of land cover consisting of vegetation classes that are known (that is, vegetation classified as shrubland, steppe, and savanna systems) or suspected (that is, vegetation classified as grassland systems) to be used by Lesser Prairie-Chickens within a 5-km diameter neighborhood around a lek. Without State as a factor, land cover was the most important predictor of relative habitat suitability for leks. In both models, habitat suitability increased with an increasing percentage of known or suspected land covers used by Lesser Prairie-Chickens within a 5,000-m area surrounding a lek (Jarnevich and others, 2016).

Lesser Prairie-Chicken populations are monitored by counting the numbers of displaying males present at leks (Garton and others, 2016). Several studies have examined the relationship between the numbers of displaying males (or trends in these numbers) and characteristics of the surrounding landscape (Crawford, 1974; Crawford and Bolen, 1976a; Cannon and Knopf, 1981; Leslie and others, 1999; Woodward and others, 2001; Gehrt and others, 2020). In western Kansas and eastern Colorado, the vegetation parameter that best predicted lek attendance within 100 m and 5 km of leks was the quadratic effect of VOR, indicating that male attendance was greatest when VOR at 75 percent obstruction was between 15 and 20 cm (Gehrt and others, 2020). Male lek attendance decreased 9 and 13.5 percent when VOR decreased from 15 to 10 cm at the 100- and 5-km scales, respectively. At both scales, lek attendance also decreased when VOR at 75 percent obstruction was >20 cm (Gehrt and others, 2020). In Oklahoma, Cannon and Knopf (1981) and Cannon and others (1982) examined the relationship between density of Lesser Prairie-Chickens (based on counts of displaying males at leks) and vegetation in four sand sagebrush study areas and four shinnery oak study areas, each 4,144 ha in size, using field and multispectral vegetation data. In the sand sagebrush areas, densities of displaying males were positively correlated with percentage of shrub cover, grass frequency (determined from cover types recorded at 2-m intervals), and shrub frequency. Densities were negatively correlated with percentage of grass cover (Cannon and Knopf, 1981; Cannon and others, 1982). In the shinnery oak areas, densities of displaying males were positively correlated with the percentage of grass and the percentage of area in grassland classes and negatively correlated with the percentage of shrub cover, shrub frequency, and the percentage of area in brushland classes (Cannon and Knopf, 1981; Cannon and others, 1982). No significant correlations were detected between remotely sensed cover classes and male Lesser Prairie-Chicken densities in the sand sagebrush study areas (Cannon and others, 1982). In Oklahoma, Texas, and New Mexico, annual rates of habitat change within 4.8 km (that is, a 7,238-ha surrounding area) of four leks with declining numbers of males averaged 1.14 percent, whereas annual rates of habitat change averaged 0.21 percent at eight leks with stable populations (Leslie and others, 1999). In another study in Oklahoma, Texas, and New Mexico, Woodward and others (2001) reported that the composition of landscapes within a 4.8-km radius of leks with declining Lesser Prairie-Chicken populations was characterized by greater rates of landscape change and greater loss of shrubland cover types. Specifically, landscapes in which populations declined contained less low-density mixed shrubland (that is, <15 percent sand sagebrush in mixed-grass prairie), less total low-density shrublands (that is, <15 percent sand sagebrush and shinnery oak) and less upland prairie shrubland (that is, native prairie with <15 percent shinnery oak and <15 percent mixed shrubs) than landscapes in which populations did not decline. Indices of total landscape change (defined as any change from one habitat to another [for example, native pasture to cropland]) were greater for landscapes in which Lesser Prairie-Chickens declined than for landscapes in which Lesser Prairie-Chicken populations were stable (Woodward and others, 2001). In landscapes with declining populations, 44 percent of the total area had changed from one cover type to another as compared to 8 percent of the area in landscapes where Lesser Prairie-Chickens did not decline (Woodward and others, 2001). Extensive grazing and conversion of native rangeland to center-pivot irrigated crop fields contributed to the loss of native mixed-grass prairie, including shrub-dominated habitats (Leslie and others, 1999; Woodward and others, 2001). In Texas, Crawford (1974) and Crawford and Bolen (1976a) evaluated the impact of land use and habitat on spring and autumn lek counts of male Lesser Prairie-Chickens within eight 2,331-ha blocks. Lesser Prairie-Chicken abundance within a block was positively associated with the percentage of rangeland within the block, the percentage of the landscape within the block that was deep sands range-site category (a category defined by the U.S. Department of Agriculture's Soil Conservation Service [now the Natural Resources Conservation Service] based on soil type and potential production of natural vegetation), and the percentage of cropland within the block that was in minimum-tillage agriculture (Crawford, 1974; Crawford and Bolen, 1976a).

Nesting Habitat

Lesser Prairie-Chicken hens nest in tall, residual grasses or under shrubs in native pastures and avoid shortgrass habitats and cultivated fields (Bent, 1963; Copelin, 1963; Jones, 1963a; Davis and others, 1979; Sell, 1979; Merchant, 1982; Wilson, 1982; Riley and others, 1992; Giesen, 1994). Lesser Prairie-Chickens prefer dense vegetation for nesting, such as that provided by shrubs and residual bunchgrasses >40 cm tall that provide >75 percent vertical screening in the first 33 cm above the ground and 50 percent overhead cover (Sell, 1979; Haukos and Smith, 1989; Giesen, 1994). In Kansas and Colorado, hens consistently selected nesting areas with VOR between 20 and 30 cm (Lautenbach, 2015). Shrubs, forbs, or residual grasses typically are taller and denser at nest sites than in the surrounding rangeland, and typically are taller and denser at successful nests than at unsuccessful nests (Van Pelt and others, 2013).

In a meta-analysis of nesting habitats of the Lesser Prairie-Chicken, Hagen and others (2013) summarized the mean estimates for vegetative characteristics at nest sites in sand sagebrush habitat: canopy cover of 59 percent (15 percent shrub, 37 percent grass, and 7 percent forb cover), 38 percent cover of bare ground, and a VOR of 27 cm. Mean grass, shrub, and forb height were 28, 43, and 22 cm, respectively. Mean estimates at nest sites in shinnery oak habitat included 36 percent canopy cover (21 percent shrub cover, 13 percent grass cover, and 2 percent forb cover), 21 percent bare ground cover, 48 percent litter cover, and a VOR of 39 cm. Mean grass and shrub heights were 36 and 34 cm, respectively.

In Colorado, 41 percent of 29 nests were under sand sagebrush plants, 38 percent were in bunchgrasses or under other species of shrubs, and 21 percent were under yucca plants (Giesen, 1994). Shrub, forb, and grass heights, and height-density of vegetation, were greater at nest sites than along the remainder of the 10-m transect crossing the nest site. Shrubs averaged 48 cm in height at the 26 nest sites where shrubs were present compared with 38 cm along transects. Mean height of forbs at 26 nest sites was 21 cm; forbs along transects averaged 16 cm. Grass was present at all nests and averaged 36 cm in height at nest sites and 27 cm along transects (Giesen, 1994). Height-density of vegetation averaged 32 cm at 29 nest sites and 20 cm along transects. At 29 nest sites, average sand sagebrush plant density and coverage were 3,471 plants per ha and 7.2 percent, respectively (Giesen, 1994).

In eastern Colorado and south-central and western Kansas, Lesser Prairie-Chickens selected nest microsites with 75 percent VOR at 20–35 cm tall (Lautenbach and others, 2019). Most (95.7 percent) of the 257 nests were in habitats with ≥10-cm and ≤40-cm VOR. On average, females placed nests in areas with 6–8 percent bare ground and avoided nesting in areas with greater bare ground cover. Survival of Lesser Prairie-Chicken nests was maximized when 75 percent VOR was 20–40 cm (Lautenbach and others, 2019). Bent (1963) described three nests in southwestern Kansas from the unpublished notes of Walter Colvin; two nests were beneath sagebrush plants, and one was under a tumbleweed (*Salsola* sp.) that was lodged between two clumps of grass. In another southwestern Kansas study, nest sites had greater grass height, higher VOR, and greater sand sagebrush density than random locations in the surrounding area (Pitman and others, 2005). Grass height, sagebrush density, and sagebrush height were important positive predictors of nest success. In a mixed-grass prairie in Kansas, Fields (2004) found Lesser and Greater prairie-chicken nests predominantly in medium- and tall-statured grasses, such as western wheatgrass, little bluestem, big bluestem (*Andropogon gerardii*), and switchgrass. Of seven nests in Oklahoma found by Copelin (1963), three were in little bluestem clumps, two were in clumps consisting of little bluestem and three-awn, one was in a clump consisting of little bluestem and sand bluestem, and one was in a clump of sand lovegrass. Shinnery oak, ranging in height from 31 to 38 cm, was present at five of those seven nest sites. Most of the successful nests were between clumps of residual grasses. Shrubs that sheltered nests did not exceed 38 cm in height (Copelin, 1963).

In Texas, 75 percent of eight nests were in habitats with level topography, few unstable sand dunes, and low shinnery oak abundance (Sell, 1979). Five nests were under sand sagebrush, two were under purple three-awn (*Aristida purpurea*), and one was under shinnery oak. An additional two nests were in habitats with large, unstable sand dunes; abundant and somewhat tall shinnery oak; and low grass coverage. Canopy coverage of sand sagebrush and structural-density measurements were significantly higher at nest sites than in surrounding habitat (no specific values were given for canopy cover or height-density). In northwestern Texas, 71 percent of 36 nests were associated with sand sagebrush, 19 percent were associated with little bluestem, 8 percent were associated with yucca, and 2 percent were associated with shinnery oak (Grisham and others, 2014). Compared to random points, nest sites had less bare ground cover, more grass cover, and more shrub cover. A nest-survival model indicated a 10 percent increase in nest survival for every 5 percent increase in VOR. In western Texas, Borsdorf (2013) reported that female Lesser Prairie-Chicken habitat use for nesting was slightly disproportionate to availability; females favored shinnery oak-dominated habitat with grassy areas. In another Texas study, 80 percent of 10 female Lesser Prairie-Chickens that were captured and released in areas that had been treated with tebuthiuron later nested in untreated shinnery oak (Haukos and Smith, 1989). More hens nested in untreated areas than expected based on the availability of untreated habitats. Vegetation was sampled at 13 nests; all nests were associated with residual grasses. Vegetation was dominated by purple three-awn at nine nest sites, little bluestem at three nest sites, and sand bluestem at one nest site. Vegetation-density estimates from four profile-board readings per nest averaged 61–80 percent obstruction in the first 33 cm above the ground, 6–20 percent from 34 to 66 cm above the ground, and <5 percent obstruction from 67 to 99 cm above the ground. Overhead cover at nest sites averaged 42 percent (Haukos and Smith, 1989). In northwestern Texas, radio-marked hens selected nest sites with higher VOR, higher percentage woody cover, and lower percentage bare ground than surrounding areas (Leonard, 2008). In the Southern High Plains of Texas and New Mexico, Grisham and others (2016a) monitored nest microclimates at 49 nests in mixed-grass prairie, 22 nests in shinnery oak, and 30 nests in shortgrass prairie. Microclimates were hotter and drier during incubation in shinnery oak prairies than in mixed-grass and shortgrass prairies. Nest survival was positively associated with VOR; the probability of daily nest survival decreased by 10 percent every one-half hour when the temperature was >34 degrees Celsius (°C) and the vapor pressure deficit was <−23-mm mercury during the day (Grisham and others, 2016a).

In New Mexico, Lesser Prairie-Chickens nested only in shinnery oak-tallgrass habitats and avoided honey mesquite-shortgrass habitats (Davis and others, 1979; Wisdom, 1980). Nesting success was positively associated with percent composition of sand bluestem, three-awn, and all species of grass combined within 3 m of nest sites. Nesting attempts were most successful when nests were placed directly under sand bluestem cover. Nesting hens selected shinnery oak and sand bluestem habitat, followed by three-awn and little bluestem habitat and shinnery oak and three-awn habitat. Hens selected nest sites with north or northeast aspects and abundant sand bluestem, shinnery oak, or dropseed (*Sporobolus* spp.) that was taller than the average vegetation height within 3 m of nest sites. As a result, nest sites were characterized by more litter and less bare ground than in the surrounding habitat. The percentage of litter cover was higher, and the percentage of bare ground was lower, within 3 m of nests in shinnery oak-tallgrass habitats than were found along field transects (Davis and others, 1979; Wisdom, 1980). Of 36 nests for which fate could be determined in that same study, 28 percent were successful (that is, one or more eggs hatched) (Riley and others, 1992). Nests in habitats of sand bluestem seemed to be more successful (67 percent of 6 nests were successful) than nests found in little bluestem (22 percent of 9 nests), three-awn (14 percent of 7 nests), sand sagebrush (20 percent of 5 nests), shinnery oak (0 percent of 4 nests), or broom-like ragwort (*Senecio spartioides*) (0 percent of 2 nests). One nest, which was successful, was found in silver bluestem (*Bothriochloa saccharoides*) habitat, and one of two nests found under yucca was successful. Sand bluestem provided better concealment for nesting hens than other species of grass. Mean height of vegetation above nest sites was significantly greater at successful nests (67 cm) than at unsuccessful nests (35 cm). In all shinnery oak habitats, shrub coverage was similar at successful and unsuccessful nests and ranged from 31.3 to 66.2 percent (Riley and others, 1992).

In other New Mexico studies, nesting hens selected habitats dominated by shinnery oak, purple three-awn, and bluestem grasses; habitats dominated by shinnery oak and interspersed with little bluestem and sand bluestem; and habitats vegetated by shinnery oak, three-awn, dropseed, and grama (*Bouteloua* spp.) (Merchant, 1982; Wilson, 1982). Nesting hens avoided weeping lovegrass (*Eragrostis curvula*); oldfields; and fallow, cultivated, or shortgrass habitats. Of 24 nests, 38 percent were under little bluestem, 25 percent were under yucca, 25 percent were under shinnery oak, 8 percent were under purple three-awn, and 4 percent were under sand sagebrush (Wilson, 1982). Mean heights of plants directly above nests were taller than plants within 3 m of nest sites. Mean basal coverage of all plants within 3 m of nests ranged from 6.7 to 8.8 percent, and canopy coverage of all vegetation ranged from 31.4 to 38.4 percent. Nests in grasses were more successful (80 percent of 5 nests) than those under shrubs (30 percent of 10 nests). Davis (2009) reported that 23 female Lesser Prairie-Chickens in the Milnesand Prairie Preserve in New Mexico used shinnery oak, broom snakeweed (*Gutierrezia sarothrae*), sand sagebrush, yucca, little bluestem, and three-awn as nesting cover, but nest success was not affected by the type of nesting cover. Nest sites had greater visual obstruction, shrub height, shrub cover, and litter cover, and lower forb cover and bare ground cover compared to areas surrounding the nest site (within 5 m) and randomly sampled sites (within 200 m). Compared to depredated nests, successful nests had greater visual obstruction and shrub cover and less bare ground cover (Davis, 2009). In New Mexico, Patten and others (2006) reported that 76 percent of 45 nests had shinnery oak as a component of the overstory cover, 22 percent had sand sagebrush, and 16 percent included yucca (percentages did not sum to 100 because the overstory included multiple species). Also in New Mexico, Patten and Kelly (2010) reported that females selected nest sites with markedly higher shrub cover (especially shinnery oak), canopy height, and higher vegetation density relative to availability. Shinnery oak mottes (that is, small thickets of tall shinnery oak) were considered important habitats for nesting and roosting Lesser Prairie-Chickens (Patten and Kelly, 2010). In another New Mexico study within shinnery oak habitat, Fritts and others (2016) reported that nest sites had less bare ground and greater angles of obstruction compared to random sites. The angle of obstruction was based on methods described by Kopp and others (1998) and was defined as a volume of air space within which a raptor would have an unobstructed line of flight to an exposed bird or nest. Native grasses (especially little bluestem) were often the dominant nest plants, along with shinnery oak, but the study could not conclusively link nest survival with grass or shrub cover (Fritts and others, 2016).

Brood-Rearing Habitat

Lesser Prairie-Chicken broods forage for invertebrates in areas with abundant bare ground and approximately 25 percent canopy coverage of shrubs, forbs, or grasses <30 cm in height (Jones, 1963a; Donaldson, 1969; Davis and others, 1979; Ahlborn, 1980; Riley and Davis, 1993). During hot weather, broods may use areas with taller vegetation (Copelin, 1963; Donaldson, 1969). In a meta-analysis of Lesser Prairie-Chicken brood-rearing sites, Hagen and others (2013) reported estimates of 35.8 percent canopy cover (8.2 percent shrub, 13.2 percent grass, and 14.4 percent forb) and 27-cm VOR at brood-rearing sites in sand sagebrush habitat, and a mean estimate of 39 percent canopy cover (20.2 percent shrub, 15.2 percent grass, and 3.6 percent forb), 36 percent bare ground, 27 cm VOR, 24 cm grass height, and 29 cm shrub height at brood-rearing sites in shinnery oak habitat. In Colorado and Kansas, broods consistently selected habitats with greater forb cover and less bare ground cover than expected at random across all study sites (Lautenbach, 2015). Also in Colorado and Kansas, Gehrt and others (2020) reported a linear relationship between available brooding habitat and distance from a lek. In Kansas, brood-use areas had higher invertebrate biomasses and greater VOR compared to nonuse areas (Hagen and others, 2005).

In Oklahoma, Donaldson (1969) observed eight Lesser Prairie-Chicken broods in shinnery oak habitats, two in sand sagebrush habitats, and two on unimproved roads. Six of those 12 broods were in phenoxy herbicide-treated shinnery oak, two were in untreated shinnery oak, and one each was in treated and untreated sand sagebrush. Broods used moderate-to-tall (specific vegetation heights were not given) plants for resting cover during the day. For feeding, they used low vegetation with an open aspect. Broods used taller vegetation, particularly thickets of shinnery oak, when temperatures exceeded 32 °C than when temperatures were lower (Donaldson, 1969). In another Oklahoma study, Copelin (1963) found 27 broods in 2–30 m diameter thickets of 1–6 m tall shinnery oaks and one brood in low-growing oaks. In a third Oklahoma study, Jones (1963b) observed 28 Lesser Prairie-Chicken broods over three breeding seasons. The broods used grasslands interspersed with 0.8–2.0 m tall shrubs. Composition of perennial plants in brood ranges was 7.8 percent sand dropseed, 22.8 percent sand sagebrush, 17.2 percent skunkbush sumac (*Rhus aromatica*), 15.7 percent western ragweed, and <3 percent other perennial plants (Jones, 1963a).

In a New Mexico study, encounters of unmarked broods along transects suggested that hens with broods preferred shinnery oak and bluestem habitat and shinnery oak and three-awn habitat (that is, sandhills) over cultivated fields, fallow fields, shinnery oak and mixed-grass habitat, shortgrass and broom snakeweed habitat, weeping lovegrass habitat, or oldfield habitat (Ahlborn, 1980). Results from radio locations of hens with broods indicated a preference for shinnery oak and mixed-grass habitat and shinnery oak and three-awn habitat, and the species used other habitats less than expected. Sites used by broods were characterized by about 25 percent canopy coverage of vegetation (Ahlborn, 1980). In southeastern New Mexico, Bell and others (2010) evaluated the structural attributes of shrubland communities in providing thermal refugia and protective cover for Lesser Prairie-Chicken broods; broods selected locations based on shinnery oak dominance. When temperatures were warmer (>26.4 °C), broods selected taller plant heights and more overhead cover than vegetation available at random. At cooler temperatures (<26.4 °C), broods selected warmer sites dominated by shinnery oak. Broods preferred grazed and ungrazed areas that had not been treated with the herbicide tebuthiuron (Bell and others, 2010).

In eastern New Mexico, encounters of unmarked broods varied from 0.10 to 0.18 per km of transect across three shinnery oak-tallgrass habitat types (Davis and others, 1979). Detection rates of radio-marked hens with broods were similar. No broods were detected in honey mesquite-shortgrass habitats. Percentage basal composition was determined from transects at brood-foraging sites and along haphazardly placed transects scattered throughout each habitat type. Percentage basal composition of grasses and shrubs at brood-foraging sites suggested that broods used areas with lower grass abundance and greater shrub abundance than generally was available in the habitat type. In shinnery oak-sand bluestem habitats, 13 brood-foraging sites had 62 percent grass and 38 percent shrub coverage compared with 65.3 percent grass and 34.7 percent shrub coverage along 30 transects in that habitat type. In three-awn and little bluestem habitat, 19 brood-foraging sites were characterized by 52.7 percent grass and 47.3 percent shrub coverage compared with 65.3 percent grass and 34.7 percent shrub coverage along 60 transects in that habitat type (Davis and others, 1979). Results of comparisons between brood-foraging sites and the overall habitat in shinnery oak and three-awn habitats were similar to those for three-awn and little bluestem habitat. In shinnery oak and three-awn habitat, 47 brood-foraging sites were characterized by 43.6 percent basal composition of grass and 56.4 percent basal composition of shrubs compared with 48 percent basal composition of grass and 52 percent basal composition of shrubs along 32 transects in that habitat type. Percentage total ground cover composed of plants at 13 brood-foraging sites in shinnery oak and sand bluestem habitat averaged 8.4 percent, whereas along transects in that habitat type, total ground cover averaged 18.8 percent (Davis and others, 1979). In three-awn and little bluestem habitat and shinnery oak and three-awn habitat, plant cover at brood-foraging sites was significantly greater than was available on average in those habitat types. At 19 brood-foraging sites dominated by three-awn, little bluestem, and shinnery oak, plant cover averaged 14.6 percent compared to 11.7 percent along 60 transects in that habitat. At 47 brood sites in shinnery oak and three-awn habitat, plant coverage averaged 14 percent; plant coverage along 32 transects averaged 9.2 percent. Remaining percentages of ground cover were composed of litter and bare ground (Davis and others, 1979).

In another New Mexico study, brood-foraging sites generally were on bare ground in low sandhills and in areas dominated by shinnery oak (Riley and Davis, 1993). Three-awn and shinnery oak were the most common species at 12 brood-foraging sites, but species composition of vegetation varied widely. Live plant material and litter completely covered the ground at one-third of the foraging sites, whereas bare ground was prevalent at the remaining two-thirds of the sites. Grass species at foraging sites included three-awn, Hall's panicgrass (*Panicum hallii*), dropseed, sand bluestem, big bluestem, false buffalograss (*Munroa squarrosa*), hairy grama (*Bouteloua hirsuta*), and thin paspalum. Shrub species at foraging sites included shinnery oak, yucca, and sand sagebrush. Dominant forbs at brood-foraging sites included annual eriogonum (*Eriogonum annuum*), spurge (*Euphorbia* sp.), western ragweed, and crotons (*Croton* spp.) (Riley and Davis, 1993).

Foraging Habitat

Throughout the year in Oklahoma, Lesser Prairie-Chickens foraged mostly in grass habitats, especially those consisting of mixed-grass species 25–80 cm in height (Jones, 1963a). Important food items were seeds of sixweeks fescue (*Vulpia octoflora*) and fragrant sumac. During spring, Lesser Prairie-Chickens primarily foraged among shrubs <80 cm tall. During summer, they foraged among grasses and forbs 25–80 cm tall, whereas during autumn, they foraged among grasses 25–80 cm tall. During winter, Lesser Prairie-Chickens primarily were found in habitats consisting of grasses >80 cm tall (Jones, 1963a). In another Oklahoma study, Lesser Prairie-Chickens used wheat, western ragweed, and blue grama for foraging throughout the year (Donaldson, 1969). Lesser Prairie-Chickens occasionally were seen on bare ground, presumably obtaining grit.

In New Mexico, Lesser Prairie-Chickens foraged nearly exclusively in shinnery oak-tallgrass prairie habitats during autumn and winter (Davis and others, 1979; Riley and others, 1993). Vegetation at foraging sites was dominated by grass and shinnery oak, with shinnery oak being more prevalent at winter sites than at autumn sites (Davis and others, 1979). Autumn foraging sites contained more grass and fewer shrubs than did winter sites. Vegetation at 22 autumn foraging sites consisted of 63 percent grasses and 37 percent shrubs, whereas vegetation at 50 winter foraging sites consisted of 59 percent grasses and 41 percent shrubs, primarily shinnery oak. Dominant grass species were sand bluestem, little bluestem, dropseed, three-awn, hairy grama, and Hall's panicgrass. Forbs were scarce at autumn and winter foraging sites and were not sampled (Riley and others, 1993). Total ground coverage at foraging locations differed between autumn and winter (Davis and others, 1979). At 23 autumn foraging locations, total ground coverage was 37.4 percent litter, 37.4 percent bare ground, and 25.2 percent live plants. At 51 winter foraging locations, total ground coverage was 46.0 percent litter, 44.3 percent bare ground, and 9.7 percent live plants. At adult foraging sites, total ground coverage composed of plants ranged from 10.5 to 12.7 percent. Lesser Prairie-Chicken foraging habitats were similar to the overall habitat type (Davis and others, 1979). In another New Mexico study, vegetation at Lesser Prairie-Chicken kill sites during fall hunting season included shinnery oak, bluestem grasses, sand sagebrush, sunflower, honey mesquite, plum (*Prunus* spp.), yucca, dropseed, black grama (*Bouteloua eriopoda*), blue grama, and sideoats grama (Lee, 1950).

Harvested sorghum (*Sorghum* spp.), corn (*Zea mays*), and other grain fields often are used as winter foraging areas (Lee, 1950; Schwilling, 1955; Bent, 1963; Copelin, 1963; Jones, 1963a; Donaldson, 1969; Campbell, 1972; Crawford, 1974; Ahlborn, 1980; Merchant, 1982; Wilson, 1982; Litton and others, 1994; Cable, 1996; Hagen and Giesen, 2020). Sorghum, corn, and other grain fields adjacent to native pastures also commonly are used as foraging areas from late autumn through early spring (Davison, 1940; Lee, 1950; Schwilling, 1955; Bent, 1963; Copelin, 1963; Hoffman, 1963; Jackson and DeArment, 1963; Jones, 1963a; Donaldson, 1969; Crawford, 1974; Ahlborn, 1980; Merchant, 1982; Litton and others, 1994; Applegate and Riley, 1998; Jamison, 2000; Hagen and Giesen, 2020). In Oklahoma, use of cultivated food plots and grain fields by Lesser Prairie-Chickens may have been affected by the abundance of natural foods (that is, shinnery oak mast, grass seed, and forb seed) in grasslands and by the amount of snow cover that affected accessibility of food (Copelin, 1963). During one winter, land managers reported that 56 percent of 16 grain food plots were used by Lesser Prairie-Chickens. During the next winter, only one of these 16 plots was used. Of 12 food plots maintained in Lesser Prairie-Chicken range during the following winter, 75 percent were used by Lesser Prairie-Chickens. During the next winter, all four of the plots that remained were used (Copelin, 1963). In another Oklahoma study, Lesser Prairie-Chickens foraged in sorghum fields where they were available (Jones, 1963a). Of 130 Lesser Prairie-Chickens flushed during winter, 59 percent were in sorghum fields, 23 percent were in mid-grass vegetation types, and 18 percent were in shrub communities.

Water Use

Lesser Prairie-Chickens will drink surface water where it is available, particularly during dry periods (Copelin, 1963; Crawford and Bolen, 1973; Crawford, 1974; Candelaria, 1979; Davis and others, 1979; Sell, 1979; Robinson and others, 2016b). Necessary water generally is obtained through foods, and surface water is not considered a limiting resource because populations of Lesser Prairie-Chickens persisted in areas without readily available surface water before settlement (Hagen and Giesen, 2020). In western Kansas, Robinson and others (2016b) used hydrogen isotopes (deuterium) to determine if female Lesser Prairie-Chickens used and incorporated free water during egg formation; egg shells had deuterium values similar to free water in the year of a severe drought, but values were dissimilar in the year with lessened drought severity. In Oklahoma, Copelin (1963) noted use of ponds and water tanks at windmills during September. In western Texas, Boal and Pirius (2012) reported that nearly 100 percent of the locations of 23 radio-marked Lesser Prairie-Chickens were within 3.2 km of a water source. In another Texas study, Lesser Prairie-Chickens were observed drinking surface water from late April through June and again in August (Sell, 1979). Males were observed drinking water near lek sites, and females regularly were observed at stock tanks early in the nesting season. In northwestern Texas, hens nested closer to stock tanks than would be expected at random, and 87 percent of female visits to stock tanks were between April and June (Grisham and others, 2014). In western Texas, Lesser Prairie-Chickens were observed drinking water at earthen and ground-level metal stock tanks during March and April (Crawford and Bolen, 1973; Crawford, 1974). In New Mexico, Davis and others (1979) captured female Lesser Prairie-Chickens using mist nets at livestock-watering facilities near leks during a dry spring; the researchers had greater success capturing hens at livestock-watering facilities than at leks.

Climate

Climate may affect abundance, survival, or productivity of Lesser Prairie-Chickens. McDonald and others (2014) developed a statistically robust survey and analysis to estimate Lesser-Prairie Chicken population size and trends at leks during 2 years across the species' occupied range. Results from the survey indicated a 50-percent reduction in abundance between the 2 years; the authors surmised that extreme drought conditions in the southern Great Plains in the first year of the survey likely contributed to the population decrease in the second year of the survey. Wilsey and others (2019) compiled bird observation data and covariates of climate and habitat to project climate vulnerability scores under scenarios in which global mean temperature increases 1.5, 2, or 3 ºC. Lesser Prairie-Chickens ranked low in vulnerability during the breeding season under the 1.5 and 2 ºC scenarios and ranked moderate in vulnerability under the 3 ºC scenario. During the winter, Lesser Prairie-Chickens ranked neutral in vulnerability under the 1.5 ºC scenario and ranked low in vulnerability under the 2 and 3 ºC scenarios. On the Comanche National Grassland in southeastern Colorado, Giesen (2000) determined that the amount of annual precipitation was strongly correlated with the number of displaying males counted 2 years later; the author surmised that the increase in herbaceous vegetation during years of greater moisture provided more residual nesting cover the following year and was expressed as an increase in displaying males 2 years after the year of increased precipitation. In mixed-grass prairies in Kansas, radio-marked female Lesser Prairie-Chickens minimized thermal stress during the summer (June–September) by selecting areas with cooler, more humid, midday conditions (Lautenbach, 2017). In Kansas, Ross and others (2016b) reported that male Lesser Prairie-Chicken abundance on leks responded positively to short-term increases in the Palmer Drought Severity Index (PDSI) from the spring of the preceding year and responded negatively to years with hot, dry summers (that is, low PDSI). Ross and others (2016b) hypothesized that the positive effect of high spring PDSI on male Lesser Prairie-Chicken abundance on leks the following breeding season reflected the effects of precipitation on vegetation in the early growing season, with increased precipitation providing favorable growing conditions for cool-season grasses and forbs. Lesser Prairie-Chicken abundance on leks exhibited minimal response to variation in the El Niño Southern Oscillation or the Pacific Decadal Oscillation (Ross and others, 2016b). In northwestern, southwestern, and south-central Kansas, Ross and others (2018) reported that the PDSI had no measurable effects on adult survival or mean number of offspring per female but population growth rate declined following severe drought. The declines in Lesser Prairie-Chicken populations in response to drought were likely because of decreases in chick and juvenile survival rather than emigration outside of the study area. In northwestern Kansas and eastern Colorado, Sullins and others (2018) determined that Lesser Prairie-Chickens were 1.7 times more likely to use CRP grasslands in regions that received 40 cm compared to 70 cm of average annual precipitation and during years of greater drought intensity. Using information synthesized from the literature across the species' geographical range, Earl and Fuhlendorf (2016) reported that individual characteristics (sex, age class) and geographic variables (latitude, ecoregion) were better at predicting vital rates (clutch size, nest success, subadult/adult season survival) than climate variables (temperature, precipitation, drought). In Oklahoma and New Mexico, survival of radio-marked Lesser Prairie-Chickens was higher in microhabitat that was cooler, more humid, and less exposed to wind (Patten and others, 2005a). In Texas, the presence of incubating hens at nests was critical in regulating thermal and humidity conditions at nests; incubating hens were able to maintain a slightly constant nest temperature (31.2 °C) and nest humidity (56.8 percent) during the incubation process (Boal and others, 2014b). Boal and others (2014b) observed multiple nest abandonments in 1 year when temperatures exceeded 37 °C for 5 consecutive days in the last week of May and witnessed three nest abandonments in another year when temperatures around the nests exceeded 50 °C. Boal and others (2014b) concluded that the species' ability to compensate for climate trends of hotter, drier air may be limited by their tolerance levels for increased temperatures and decreased humidity. In the Texas Southern High Plains, where environmental conditions are hotter and drier than in the northern portion of the species' range, Grisham and Boal (2015) reported that drought positively affected survival of radio-marked females because females did not incubate eggs during drought conditions and thus were less vulnerable to predation. In contrast, drought negatively affected male mortality and survival later in the breeding season because males had rigorous lekking activities through late May combined with a lack of food and cover later in the breeding season (Grisham and Boal, 2015).

Area Requirements and Landscape Associations

Male territory sizes within leks vary with density and dominance status of males on a given lek. Territories have varied in size from 3.6 m (Copelin, 1963) to >7 m in diameter (Hjorth, 1970, in Hagen and Giesen, 2020). Davis and others (1979) suggested that areas at least 0.1 ha in size were required for leks. In Texas, oil pads used as lek sites were approximately 0.16 ha (Taylor, 1979).

The size of home ranges used by male and female Lesser Prairie-Chickens may vary with time of year and location, and across studies. In Colorado, spring and summer home ranges of male Lesser Prairie-Chickens averaged 211 ha (Hagen and Giesen, 2020). In Kansas, median monthly home ranges of males (determined for >2 birds for 25 months) varied from 12 to 140 ha in April and May, from 77 to 144 ha during June through September, and from 229 to 409 ha during October through November (Jamison, 2000). In Texas, mean monthly range sizes of females varied from 3 to 72 ha from May through October (Sell, 1979) and from 35 to 495 ha from November through February (Taylor and Guthery, 1980a). In another Texas study, average home-range sizes during the nonbreeding season (September–February) were 503.5 ha for six females and 489.1 ha for 17 males (Pirius and others, 2013). In the Texas Panhandle, Toole (2005) reported that the average area occupied by all Lesser Prairie-Chickens trapped at a given lek was 1,508 ha and varied from 152 ha (sample size number [n]=1 radio-marked bird) to 3,679 ha (n=13 radio-marked birds), and the average distance between leks was 3.5 km. In western Texas, females had larger home-range sizes during the breeding season than males (Borsdorf, 2013). The home-range estimates, using three different estimators, ranged from 173.2 to 306 ha for males and 415.1 to 671.4 ha for females. The mean home-range size for five males was 277.1 ha, with a core-range size of 73.0 ha. Their combined home-range space was 721.0 ha, with 36.2 percent of the combined home-range area overlapping among males. The combined core-range space for these five males was 245.0 ha, with 29.8 percent of the combined core area overlapping among males (Borsdorf, 2013). In another Texas study, mean monthly ranges varied in size from 50 to 1,945 ha between November and February (Taylor and Guthery, 1980a). In New Mexico, mean size of female Lesser Prairie-Chicken ranges varied from 62.7 to 231.0 ha during the prenesting period, from 8.5 to 92.0 ha during the nesting period, and from 66.4 to 240.0 ha during the postnesting period (sample sizes ranged from 7 to 40 individuals across time periods and studies) (Candelaria, 1979; Merchant, 1982; Riley and others, 1994). The average size of areas used by hens with broods in New Mexico ranged from 47 to 118.9 ha (sample sizes ranged from three to five individuals) (Candelaria, 1979; Ahlborn, 1980; Merchant, 1982). Mean size of postnesting ranges for 19 hens without broods was 73.4 ha (Candelaria, 1979).

Hagen and Elmore (2016) indicated that the Lesser Prairie-Chicken is an area-sensitive species that requires large landscapes of relatively unfragmented habitat, but limited data are available on the minimum size of grassland patch required by Lesser Prairie-Chickens. Hagen and others (2016) reported that Lesser Prairie-Chicken occupancy throughout the species' range was positively related to increased mean patch size of native land cover in the landscape and to the percentage of land enrolled in prescribed grazing (that is, managing the harvest of vegetation with grazing to achieve specific ecological, economic, and management benefits) at a large scale (225 km^2) and in the CRP at a small scale (56 km^2). In a preliminary analysis to evaluate apparent avoidance of anthropogenic features (oil and gas wells, transmission lines, roads, buildings, and wind turbines) throughout the species' range, Bartuszevige and Daniels (2016) found that lek presence was related to the percentage of the landscape that was not impacted by anthropogenic features at multiple scales (3,000 and 5,000 m); this relationship seemed to extend to the largest buffer area of 10,000 m (31,416 ha). The percentage of the landscape that was in native prairie and CRP grasslands also was an important factor for predicting lek presence (Bartuszevige and Daniels, 2016). In eastern Colorado and western Kansas, Gehrt and others (2020) reported that Lesser Prairie-Chicken abundance on leks increased with the proportion of grassland in the surrounding landscape. Also in Colorado and Kansas, Sullins and others (2018) indicated that Lesser Prairie-Chickens were about eight times more likely to use CRP in 5,000-ha landscapes that were 70 percent grassland compared to 20 percent grassland. In western Kansas, larger (≥300 ha) pastures had greater use by nonbreeding female Lesser Prairie Chickens because of interactions between stocking density and the amount and quality of forage available; the increase in habitat heterogeneity in larger pastures likely ensured the presence of desired microhabitat or plant community composition used by female Lesser Prairie-Chickens (Kraft, 2016). In a second study in western Kansas, Ross and others (2016a) reported that a threshold exists for Lesser Prairie-Chickens in response to the gradient of cropland to grassland in the landscape; Lesser Prairie-Chicken abundance initially increased in response to more cropland on the landscape but then declined after the threshold of 9.6 percent cropland on the landscape. In southwestern Kansas, male Lesser Prairie-Chickens avoided CRP and tallgrass habitats, but those habitats were in small patches and may have been avoided because of their small sizes (Jamison, 2000). Also in Kansas, Jarnevich and Laubhan (2011) developed models that predict the probability of lek occurrence across the landscape used by Lesser Prairie-Chickens; lek habitat suitability was positively correlated with increasing grassland and CRP land in the landscape. In Texas, the largest Lesser Prairie-Chicken populations were in landscapes that consisted of 63–95 percent native pasture, with the remainder planted to sorghum (Crawford, 1974; Crawford and Bolen, 1976a).

In Kansas, Robinson and others (2018) reported that survival was greater for female Lesser Prairie-Chickens with home ranges that had greater patch richness (that is, the number of different patch types within each home range) and in areas with 30 percent cropland and 57 percent grassland. Patten and others (2005b) concluded that greater fragmentation, which was defined as any discontinuity in habitat (for example, by fences and roads), in Oklahoma than in New Mexico resulted in increased mortality rates of hens and selected for increased reproductive effort in Oklahoma. Female Lesser Prairie-Chickens laid larger clutches and nested fewer years but made more nesting attempts within a year in Oklahoma compared to females in New Mexico. Fuhlendorf and others (2002) examined multiscale effects of landscape structure and change on population trends of 10 Lesser Prairie-Chicken leks in the southern Great Plains of Oklahoma and Texas. Landscapes with declining Lesser Prairie-Chicken populations had a greater percentage of cropland and tree cover and greater overall landscape changes at broader spatial scales (3.4 and 4.8 km). The percentage of land cover consisting of cropland was, on average, 2.5 times greater on landscapes with declining populations compared to landscapes with sustained populations of Lesser Prairie-Chickens. At smaller spatial scales (1.2, 1.7, and 2.4 km), increased changes in edge density were higher for landscapes with declining Lesser Prairie-Chicken populations. Mean changes in the largest patch index also were found to be higher on landscapes with declining Lesser Prairie-Chicken populations, independent of scale. Fuhlendorf and others (2002) concluded that Lesser Prairie-Chicken populations are particularly vulnerable to fragmentation of native grasslands and shrublands and that isolated populations may require more stable landscapes than populations that are not isolated.

Lesser Prairie-Chickens remain close to their lek sites during the breeding season. In Kansas, Pitman and others (2006) captured and radio-marked 184 hens; the mean and median distances between their nest sites and the leks at which they were captured were 3.1 and 1.4 km, respectively. In western Texas, Pirius and others (2013) reported that 23 radio-marked Lesser Prairie-Chickens remained within 3.2 km of the lek at which they were captured. In western Texas, Borsdorf (2013) reported that 99.6 percent of the locations of 37 radio-marked male Lesser Prairie-Chickens were within 3.2 km from the lek at which they were captured. For females, 85.4 percent of locations were within 3.2 km from lek of capture, and 10.3 percent were within 3.2 and 4.8 km from lek of capture.

Movements by Lesser Prairie-Chickens may vary with moisture conditions, time of year, and across studies. Lesser Prairie-Chickens generally travelled greater distances over larger areas during drought conditions than when moisture conditions were near average or above average (Copelin, 1963; Ahlborn, 1980; Merchant, 1982). Maximum long-distance movements of 26, 40, and 71.4 km have been reported by Jamison (2000), Pitman and others (2006), and Earl and others (2016), respectively. In New Mexico, daily movements of 40 prenesting females were 390 m per day within an average range of 231 ha (Riley and others 1994). Twelve nesting hens moved 250 m per day within average ranges of 92 ha, and three hens with broods moved an average of 280 m per day within 119-ha ranges. Movements of 19 females without broods was 220 m per day within 73-ha ranges.

Brood Parasitism by Cowbirds and Other Species

No studies have documented brood parasitism of Lesser Prairie-Chicken nests by Brown-headed Cowbirds (*Molothrus ater*) (Shaffer and others, 2019). Lesser Prairie-Chickens are not suitable hosts for Brown-headed Cowbirds because young grouse are precocial and nidifugous, leaving the nest within 24 hours after hatching; however, other upland gamebird species have laid eggs in Lesser Prairie-Chicken nests. In a study in southwestern Kansas, Ring-necked Pheasants (*Phasianus colchicus*) parasitized three of 75 Lesser Prairie-Chicken nests (Jamison, 2000; Hagen and others, 2002). In another Kansas study, Pitman and others (2006) found 209 Lesser Prairie-Chicken nests. Four of the 209 prairie-chicken nests contained prairie-chicken eggs and Ring-necked Pheasant eggs; one prairie-chicken nest contained 10 prairie-chicken eggs and a Northern Bobwhite (*Colinus virginianus*) egg; and one prairie-chicken nest contained three prairie-chicken eggs, a Ring-necked Pheasant egg, and a Northern Bobwhite egg. Mote and others (1999) reported that Ring-necked Pheasants also have been observed harassing male Lesser Prairie-Chickens on their leks.

There are no records of Greater Prairie-Chickens laying eggs in Lesser Prairie-Chicken nests or vice versa; however, hybridization between Lesser and Greater prairie-chickens has been reported in a zone of sympatry in the northern portion of the Lesser Prairie-Chicken's range in Kansas (Bain and Farley, 2002; Fields, 2004; McDonald and others, 2012; Oyler-McCance and others, 2016). McDonald and others (2012) estimated that hybrids represent <1 percent of the Lesser Prairie-Chicken population.

Breeding-Season Phenology and Site Fidelity

Male Lesser Prairie-Chickens primarily display on leks from mid-February to mid-June, although males may be associated with leks throughout the year (Schwilling, 1955; Copelin, 1963; Campbell, 1972; Crawford and Bolen, 1975; Candelaria, 1979; Davis and others, 1979; Cable, 1996; Jamison, 2000; Hagen and Giesen, 2020). Displays are most intense at sunrise (Copelin, 1963), and more males are present during the morning display period than during evening (Crawford and Bolen, 1975). Display activity, hen visitation, and copulations peak from early to mid-April (Davison, 1940; Crawford and Bolen, 1975; Candelaria, 1979; Davis and others, 1979). Males generally exhibit high fidelity to leks between years (Campbell, 1972; Hagen and Giesen, 2020), but 21 percent of 48 males that were marked and recaptured in Kansas had moved 0.42–4.41 km to leks other than the one where they initially were captured (Jamison, 2000).

Nests are initiated between mid-April and mid-June, with most clutches hatching in late May or early June (Schwilling, 1955; Bent, 1963; Ahlborn, 1980; Merchant, 1982; Cable, 1996; Jamison, 2000; Patten and others, 2005b; Davis, 2009; Hagen and Giesen, 2020). In Oklahoma and New Mexico, the median clutch initiation dates were May 22 and May 12, respectively (Patten and others, 2005b). In western Kansas, 95 percent of 209 nests were initiated and completed between May 5 and July 2; the average incubation length was 26.7 days (Pitman and others, 2005). In northwest Texas, the mean incubation length was 28 days for 16 Lesser Prairie-Chicken nests (Grisham and others, 2014).

Some Lesser Prairie-Chicken hens initiate second and third nests when earlier clutches are destroyed or fail (Candelaria, 1979; Merchant, 1982; Giesen, 1994; Riley and others, 1994; Patten and others, 2005b; Lautenbach, 2015). In a 2-year study in Colorado and Kansas, average clutch size for 185 nests was 10.4–10.6 eggs for first nest attempts and 7.3–7.8 for renesting attempts (Lautenbach, 2015). In Kansas, an average of 31 percent of Lesser Prairie-Chicken hens renested after nest failure, with renesting attempts having smaller average clutch sizes (7.6 eggs) compared to first nests (12.0 eggs) (Pitman and others, 2006). The probability of renesting decreased by 16.2 percent for every incubation day that passed during the initial nesting attempt. In another

Kansas study, 25 percent of 19 radio-tracked Lesser Prairie-Chicken broods survived to 60 days posthatch; nest survival decreased for nests initiated later in the season (Fields, 2004). Patten and others (2005b) reported that hens nested fewer years in Oklahoma but more often within a year than hens in New Mexico; Lesser Prairie-Chicken hens in Oklahoma made more nesting attempts per year in Oklahoma (average of 1.55 attempts per year) than in New Mexico (average of 1.07 attempts per year).

Clutch sizes may differ between habitats and portions of the species' range. In Kansas, Oklahoma, and Texas, the average clutch size in mixed-grass prairies was about two eggs larger than average clutches in shinnery oak prairie (Wolfe and others, 2016). Patten and others (2006) reported that the average clutch size was higher for Lesser Prairie-Chicken hens in Oklahoma (10.83 and 10.88 eggs per clutch for adults and yearlings, respectively) than for hens in New Mexico (9.29 and 7.67 eggs for adults and yearlings, respectively). In east-central New Mexico, clutch size for 16 nests ranged from 6 to 12 eggs (Davis, 2009).

Lesser Prairie-Chickens are not known to raise more than one brood per year (Hagen and Giesen, 2020). Double-broodedness in Lesser Prairie-Chickens is likely curtailed by time constraints on breeding because of the cessation of male displays in early summer and the long time period required to raise chicks to independence (about 60 days).

Species' Response to Management

Fire and grazing are the main management practices that affect vegetation structure and composition on native prairies and shrublands in the Lesser Prairie-Chicken range (Bidwell and others, 2003). The frequency, size, and pattern of burning or grazing, and their interaction, are important considerations to meet the year-round habitat requirements and restore habitat for the species (Bidwell and others, 2003; Lautenbach, 2017). In shinnery oak grasslands, spring burning may result in an increased number of displaying males and relocation of leks to recently burned areas (Cannon and Knopf, 1979). In Oklahoma, burning was conducted in a shinnery oak-bluestem pasture and a weeping lovegrass pasture during April (Cannon and Knopf, 1979). The shinnery oak-bluestem pasture had not been grazed for the previous 9 months and residual vegetation was 60–100 cm tall. Burning removed the residual vegetation. Before burning, two active leks in the shinnery oak-bluestem pasture were used by 14 and 12 males. After burning, prairie-chickens remained at the first lek and increased from 14 to 21 males. Prairie-chickens abandoned the second lek, which occurred in an area that was not burned (Cannon and Knopf, 1979). Two new leks were established after the fire; one of the new leks was established at a historical lek site in the burned lovegrass pasture, and the other was established at a new site in the burned shinnery oak-bluestem pasture. The two new leks were used by 12 and 6 males, respectively. Following the burns, the number of displaying males on the study area increased from a preburn total of 26 males to a postburn total of 39 males (Cannon and Knopf, 1979). A 2-year study on the effects of fire on vegetation in shinnery oak habitat of Oklahoma suggested that controlled burning could benefit Lesser Prairie-Chickens by providing foraging areas; however, the immediate effects of fire on nesting cover were negative, particularly when burns were conducted in spring (Boyd, 1999; Boyd and Bidwell, 2001). One year postburn, the coverage of grasses used for nesting was lower in burned (46–57 percent) than in unburned plots (64 percent), although the percentage cover was similar among burning seasons (Boyd and Bidwell, 2001). Percentage of bare ground was higher in burned (49–64 percent) than in unburned plots (6.4 percent). Visual obstruction in May and January decreased with burning in all seasons (fall, winter, and spring). Mean canopy coverage of shrubs used for nesting was lower in burned plots (31–59 percent) than in control plots (74 percent). Two years postburn, canopy coverage of nesting grasses rebounded to 67.2 percent and height-density increased to >80 percent in burned plots, while measurements of these variables remained unchanged in control plots (Boyd, 1999). Frequency of occurrence of forbs was greater in burned plots (46–52 percent) than in control plots (16 percent) 2 years postburn, but canopy coverage of forbs was <4 percent. The fire breaks around burned plots often were revegetated with a continuous coverage of forbs that supported larger insect populations than did undisturbed areas (Boyd, 1999; Boyd and Bidwell, 2001).

Managers often use a combination of burning and grazing as a tool in grassland management. Patch-burn grazing (or pyric herbivory) is a management strategy in which only a portion of the landscape is burned annually, and livestock preferentially graze on these burned areas, generating heterogeneity in vegetation structure and composition (Fuhlendorf and Engle, 2001; Starns and others, 2020). Patch-burn grazing mimics the historical grazing patterns of native grazers and thus has the potential to create a favorable mosaic of habitat patches and habitat structure across the landscape for Lesser Prairie-Chickens, while at the same time maintaining high nutritional value for domestic livestock (Fuhlendorf and Engle, 2001). Starns and others (2020) assessed the differences in vegetation structure created by patch-burn grazing compared to fire-only treatments to determine whether patch-burn grazing increased habitat heterogeneity for Lesser and Greater prairie-chickens during their distinct life history stages. Compared to the fire-only treatment, patch-burn grazing improved vegetation characteristics reported as critical to Lesser and Greater prairie-chicken reproduction, including providing more forb cover, reducing vegetation height and biomass, extending the length of time bare ground was present after fires, and maintaining adequate canopy cover (Starns and others, 2020). In mixed-grass prairies in Kansas, Lautenbach (2017) evaluated habitat selection of Lesser Prairie-Chickens relative to landscape mosaics of vegetation patches generated through patch-burn grazing. Radio-marked female Lesser Prairie-Chickens used all patch types created in the patch-burn grazing mosaic, based on their different needs during each life-cycle stage (Lautenbach, 2017). Females selected greater time-since-fire patches (>2 years postfire) for nesting, 2-year postfire patches during the spring lekking season, 1- and 2-year postfire patches during the summer brooding period, and 1-year postfire units during the nonbreeding season. Lautenbach (2017) did not observe any nesting attempts within year-of-fire patches.

The predominant driver of grassland condition in the Lesser Prairie-Chicken's range is livestock grazing (Kraft, 2016). Grazing systems with light-to-moderate grazing pressure that create a mosaic of grassland patches are preferred by Lesser Prairie-Chickens over intensive systems that reduce grass and shrub cover (Applegate and Riley, 1998). Degradation of nesting habitat as a result of overgrazing (that is, grazing continuously at high intensities) has been implicated in the declines of some Lesser Prairie-Chicken populations and may serve as an impediment to the species' recovery (Taylor and Guthery, 1980b; Cable, 1996; Leslie and others, 1999; Mote and others, 1999; Bailey and others, 2000; Kraft, 2016). Heavy grazing pressure may result in the conversion of the original plant community to a shortgrass-dominated habitat or in a shortage of the tall, residual cover that is required for successful nesting (Hoffman, 1963; Jackson and DeArment, 1963; Davis and others, 1979; Litton and others, 1994). In Colorado, Giesen (1994) indicated that nest success of Lesser Prairie-Chickens may have been negatively impacted by excessive grazing. In areas of heavy grazing, Lesser Prairie-Chicken hens tend to nest under shrubs; nests under shrubs often are less successful than nests under bunchgrasses (Sell, 1979; Merchant, 1982; Riley and others, 1992; Giesen, 1994). In western Kansas, nonbreeding female Lesser Prairie-Chickens selected grasslands with light-to-moderate grazing pressure (0.25–1.0 animal unit month [AUM] per ha) during years of average or above-average rainfall, but the probability of female prairie-chicken use declined as grazing pressure increased above 1.5 AUMs per ha and as rainfall decreased (Kraft, 2016). In rangelands lacking sand sagebrush cover, female use declined as grazing pressure increased above 1.0 AUM per ha; in rangelands that included sand sagebrush, female use declined as grazing pressure increased above 2.0 AUMs per ha. The probability of female Lesser Prairie-Chicken use decreased as the number of grazing days increased. As grazing pressure increased from 0 to 1.2 AUMs per ha, daily nest survival of Lesser Prairie-Chickens declined (Kraft, 2016). In Oklahoma, Copelin (1963) noted that Lesser Prairie-Chickens used moderately grazed pastures more frequently than heavily grazed pastures; moderately grazed grasslands leave clumps of grass throughout the year for spring nesting. In Texas, Haukos and Smith (1989) reported that 8 of 10 Lesser Prairie-Chicken nests were in areas that were not grazed or treated with tebuthiuron; the authors concluded that heavy grazing pressure (heavy grazing was not defined) in combination with chemical treatment of shinnery oak may reduce overhead nesting cover for Lesser Prairie-Chickens. In northwestern Texas, Leonard (2008) reported that 11 of 12 Lesser Prairie-Chicken nests were in ungrazed habitats with high levels of visual obstruction, and radio-marked hens used ungrazed grasslands that were not treated with herbicides significantly more than all other habitats (that is, CRP, cropland, grazed grassland treated with herbicides, and grazed grassland not treated with herbicides).

In New Mexico, survival of Lesser Prairie-Chicken nests did not differ among four combinations of treatments with a short-duration, rotational-grazing system (that is, grazed once during the dormant season in January and February and once during the growing season in July) and a herbicide application (tebuthiuron applied at 0.60 kilogram [kg] per ha) that were being used to restore shinnery oak-grassland communities (Grisham, 2012; Grisham and others, 2014). In another New Mexico study, Lesser Prairie-Chickens used lightly grazed habitats during drought years but used more heavily grazed habitats in years of near-average precipitation (Merchant, 1982). In Milnesand Prairie Preserve in New Mexico, Fritts and others (2018) reported that adaptive grazing (that is, alteration of grazing pressure based on vegetation biomass; herds were rotated through pastures with the goal of achieving a 50 percent utilization of available forage) positively influenced Lesser Prairie-Chicken abundance at leks before a severe drought in 2011 but had no effect on Lesser Prairie-Chicken abundance postdrought; Lesser Prairie-Chicken abundance was seven times greater predrought than postdrought. Grazing had a positive influence on Lesser Prairie-Chicken survival and recruitment predrought. As the number of cow days per hectare (that is, the number of cattle in the pasture multiplied by the number of days the cows were in a specific pasture divided by the pasture size) increased by one before the drought, both survival and recruitment increased by about 0.8 (Fritts and others, 2018). In another New Mexico study, Hunt and Best (2004) reported that 18.6 percent of 27 lek abandonments by Lesser Prairie-Chickens were associated with overgrazing.

Haying is uncommon in grasslands typically occupied by Lesser Prairie-Chickens, but poorly timed haying may be detrimental to Lesser Prairie-Chicken nesting and winter survival (Bidwell and others, 2003). Bidwell and others (2003) indicated that haying before July 1 destroyed nests or killed young chicks. Haying after July 10 missed the optimum combination of forage protein and production for livestock. Late haying also did not allow enough time for vegetation regrowth to maintain adequate nesting cover and plant vigor for the next growing season (Bidwell and others, 2003).

Sorghum, corn, and other cultivated fields may provide foraging areas for Lesser Prairie-Chickens in fall, winter, and early spring, especially those fields adjacent to rangelands that are managed by grazing to ensure residual cover (Davison, 1940; Lee, 1950; Schwilling, 1955; Bent, 1963; Copelin, 1963; Hoffman, 1963; Jackson and DeArment, 1963; Jones, 1963a; Donaldson, 1969; Crawford, 1974; Ahlborn, 1980;

Merchant, 1982; Litton and others, 1994; Applegate and Riley, 1998; Jamison, 2000; Bidwell and others, 2003; Hagen and Giesen, 2020). In Texas, the percentage of minimum-tillage agriculture was one of three land-use or habitat variables considered to be of greatest importance in determining numbers of Lesser Prairie-Chickens (Crawford, 1974; Crawford and Bolen, 1976a). Maximum numbers of Lesser Prairie-Chickens were found in areas in which 5–37 percent of the landscape was planted to sorghum using minimum-tillage techniques (Crawford, 1974). In another Texas study, numbers of Lesser Prairie-Chickens declined over a 10-year period, then stabilized at about one-third the level of initial counts (Jackson and DeArment, 1963). Declines were attributed to the use of combine harvesters instead of in-field shocking to harvest sorghum (and concomitant reduction in winter food), treatment of extensive areas with shrub-specific herbicide, drought, and harsh winter conditions.

Conservation Reserve Program grasslands are important habitats for Lesser Prairie-Chickens as they provide habitat diversity and connectivity, contribute to increased grassland patch size, promote range expansion, and mitigate for grassland loss. CRP grasslands planted to a diverse mixture of mid- and tall-statured species of native grasses and forbs that resemble historical mixed-grass and tallgrass prairies may provide suitable habitat for Lesser Prairie-Chickens (Hagen and others, 2004; Rodgers, 2016; Spencer and others, 2017). Lesser Prairie-Chickens seemed to prefer CRP fields dominated by little bluestem interspersed with sideoats grama that achieved heights of about 45 cm over CRP stands dominated solely by tallgrass species that were taller and denser. Ripper and others (2008) reported that CRP fields in Kansas consistently displayed a high forb component and tall average grass height, two habitat attributes that are considered important factors in the species' range expansion and population stability (Ripper and others, 2008). In west-central Kansas, Fields (2004) reported that nesting hens (Greater and Lesser prairie-chickens combined) used grass CRP fields (that is, CRP fields seeded with just grass species) and interseeded CRP fields (that is, grass CRP fields interseeded with forbs) more than expected based on availability. Greater use of interseeded and grass CRP fields was attributed to greater abundance of invertebrates and cover provided by these two habitats. Nesting hens used cropland, rangeland, and forb CRP fields (that is, CRP fields seeded with both grass and forbs) less than expected. Hens with broods used cropland less than expected but showed no selection for any of the other habitat types (Fields, 2004). Litton and others (1994) suggested that CRP fields seeded to warm-season bunch grasses, native legumes, and shrubs would benefit Lesser Prairie-Chickens in Texas; however, no data were provided on use of such habitats. Historically, CRP grasslands in Texas were established as monocultures of weeping lovegrass, yellow bluestem (*Bothriochloa ischaemum*), or kleingrass (*Panicum coloratum*) that provide little brood-rearing or winter cover (Sullivan and others, 2000). Sullivan and others (2000) suggested that the establishment of CRP grasslands in the Texas Panhandle have not been detrimental to Lesser Prairie-Chickens, even though the vegetative structure in those fields did not provide optimal habitat for the species. In a 2-year study in the Rolling Plains of the Texas Panhandle, Toole (2005) did not observe any of the 69 radio-marked Lesser Prairie-Chickens using nearby CRP fields, which were tall, dense stands of nearly impenetrable weeping lovegrass that lacked adequate nesting and brood-rearing cover, forbs, and sufficient invertebrate production for survival and reproduction. In the Southern High Plains of Texas, radio-marked male and female Lesser Prairie-Chickens selected CRP fields seeded to nonnative grasses (weeping lovegrass and Old World bluestem species [*Bothriochloa* spp.]) and CRP fields seeded to native grasses and forbs (Indiangrass, little bluestem, switchgrass, green sprangletop [*Leptochloa dubia*], sideoats grama, blue grama) but avoided rowcrop agriculture and native shortgrass prairies (Harryman and others, 2019).

In Baca County in southeastern Colorado, about one-third of the former cropland was enrolled in the CRP between 1985 and 2000; no leks were found in CRP fields, but anecdotal evidence suggested that some CRP fields were used for roosting (Giesen, 2000). In eastern Colorado and northwestern Kansas, nest densities were about three times higher in CRP grasslands planted to tallgrass vegetation (6.0 nests per 10 km^2) than in grazed mixed-grass and shortgrass prairies (1.7 nests per 10 km^2); 85 percent of radio-marked females with broods that survived to 7 days moved their young from CRP grasslands to other cover types (Sullins and others, 2018). Nest survival, adult survival during breeding, and nonbreeding-season survival did not differ between radio-marked Lesser Prairie-Chickens that used CRP grasslands and those that did not use CRP grasslands (Sullins and others, 2018). In Kansas, converting cropland to perennial grassland cover in the CRP helped mitigate for grassland loss (Spencer and others, 2017), and Lesser Prairie-Chicken populations responded positively to habitat provided by CRP grasslands (Rodgers and Hoffman, 2005). The establishment of CRP grasslands may have contributed to a northward expansion of the species' range (Rodgers and Hoffman, 2005; Oyler-McCance and others, 2016). By the late 1990s, Lesser Prairie-Chickens were found in the northern portion of their historical range (that is, north of the Arkansas River in Kansas) (Rodgers, 2000); most of the 101 leks in 1999 and 2000 were in, or within 3.2 km of, CRP fields seeded to native grasses (R.D. Rodgers, Kansas Department of Wildlife and Parks, Hays, Kansas, written commun. [n.d.]). Species composition of seeding mixes used in CRP fields in Kansas varied considerably. In Kansas, Spencer and others (2017) documented that, since 1986, grasslands became more connected and less fragmented because of an increase in the area of CRP grasslands in the landscape, but Lesser Prairie-Chicken abundance and their overall occupied range declined; the researchers suggested that factors other than available grassland (for example, long-term changes in climate, extreme weather, declining habitat quality) are the primary drivers of Lesser

Prairie-Chicken population trends in Kansas. In New Mexico, Bailey and Williams (2000) suggested that the conversion of cropland to CRP grasslands may have negatively affected Lesser Prairie-Chicken populations by decreasing winter food sources in cultivated fields, although there was no direct evidence to support this assertion.

In contrast to CRP grasslands, which provide potential habitat for population expansion, a large-scale increase in the coverage of trees (mainly eastern redcedar [*Juniperus virginiana*] and mesquite) is considered one of the primary factors associated with the loss of Lesser Prairie-Chicken populations in the species' current range (Fuhlendorf and others, 2002, 2017; Hunt and Best, 2010; Falkowski and others, 2017; Hagen and others, 2019). The Lesser Prairie-Chicken tends to avoid areas with extensive tree cover (Lautenbach and others, 2017). More than 273,000 ha of occupied Lesser Prairie-Chicken habitat are impacted by encroachment by eastern redcedar, with 65 percent of this area having low-density cover (<10 percent canopy cover) of redcedar (Lesser Prairie-Chicken Initiative, 2016). In northwestern Oklahoma and northern Texas, Fuhlendorf and others (2002) reported that tree cover was significantly greater in landscapes with declining Lesser Prairie-Chicken populations than in landscapes with sustained populations. In mixed-grass prairies in south-central Kansas, female Lesser Prairie-Chickens avoided grasslands where trees were present (Lautenbach, 2015; Lautenbach and others, 2017). Females were 40 times more likely to use treeless habitats than habitats with 5 trees per ha and were 19 times more likely to use habitats 100 m from the nearest tree than habitats 0 m from the nearest tree. Nest survival was not affected at densities of <2 trees per ha, but nest survival could not be tested at >2 trees per ha because no nests were detected at higher tree densities. In the Southern High Plains of New Mexico, Hagen and others (2019) modeled the probability that a Lesser Prairie-Chicken lek would remain active relative to coverage and distribution of honey mesquite on the landscape; Lesser Prairie-Chickens avoided areas with even a low density (1–9 percent canopy cover) of mesquite and with uniformly distributed mesquite.

Despite their aversion to increasing coverage of trees, Lesser Prairie-Chicken habitat is characterized by dryland shrubs, particularly shinnery oak and sand sagebrush (Patten and others, 2005a). Livestock producers apply herbicides to shinnery oak and sand sagebrush, which are considered poor forage for livestock (Hunt and Best, 2004), and shinnery oak blooms are poisonous to livestock (Peterson and Boyd, 1998). Traditional management to control shinnery oak and sand sagebrush in the Lesser Prairie-Chicken range has emphasized chemical control with herbicides. The effects of shrub-specific herbicides on Lesser Prairie-Chickens are mixed and probably are affected by interactions with grazing pressure and resulting herbaceous cover (Fritts and others, 2016). Tebuthiuron treatment of shinnery oak rangelands has had both beneficial and detrimental effects on Lesser Prairie-Chicken populations (Leonard, 2008). An interspersion of different habitat types can be obtained by applying herbicide treatments that kill shrubs and allow an increase in grass coverage, provided that grass coverage is not reduced by heavy grazing (Donaldson, 1966, 1969; Doerr and Guthery, 1983; Olawsky, 1987; Olawsky and Smith, 1991). In Texas, Haukos and Smith (1989) captured and radio-marked 10 female Lesser Prairie-Chickens in tebuthiuron-treated areas. Eight of those 10 hens nested in untreated shinnery oak; more hens nested in untreated areas than expected based on the availability of untreated habitat. In western Texas and eastern New Mexico, Olawsky (1987) noted that more flocks of Lesser Prairie-Chickens were encountered (actual number of flocks encountered was not given) in tebuthiuron-treated plots (15 percent of the flocks) than in untreated shinnery oak (10 percent of the flocks). Lesser Prairie-Chicken densities during summer were estimated at 0.25 and 0.20 birds per ha on treated and untreated areas, respectively. During winter, Lesser Prairie-Chicken densities were estimated at 0.53 bird per ha in treated areas and 0.34 bird per ha in untreated areas; however, no statistically significant differences were detected in Lesser Prairie-Chicken flock sizes or densities between tebuthiuron-treated and untreated shinnery oak pastures (Olawsky, 1987; Olawsky and Smith, 1991). In Texas and New Mexico, Boal and others (2014b) examined four combinations of herbicide (tebuthiuron) and grazing treatments, including treated with tebuthiuron and not grazed, treated with tebuthiuron and grazed, not treated with tebuthiuron and grazed, and a control of not treated and not grazed. No clear pattern of nest-site selection was detected for treatment types in shinnery oak and sand sagebrush habitats among hens associated with individual leks. When hens from all leks were pooled, Boal and others (2014b) reported that nesting Lesser Prairie-Chickens selected control plots for nesting more than plots that were grazed, treated with tebuthiuron, or were both grazed and treated with tebuthiuron. The probability of nests surviving the incubation period was 0.57 and did not vary among treatment types (Boal and others, 2014b). In New Mexico, Fritts and others (2016) concluded that a tebuthiuron application rate of 0.6 kg per ha, short-duration grazing (that is, removing 25 percent of herbaceous material per dormant season and growing season), and a combination of these management techniques were not detrimental to Lesser Prairie-Chicken nest-site selection or nest survival. In eastern New Mexico, Johnson and others (2004) evaluated habitat use and nest-site selection by female Lesser Prairie-Chickens in tebuthiuron-treated and untreated pastures within vegetation types dominated by shinnery oak. Hens were detected more often in untreated pastures. Thirteen of 14 Lesser Prairie-Chicken nests were in untreated pastures, and all nests were in sites that had a substantial (>35 percent) shinnery oak component (Johnson and others, 2004). In shinnery oak habitats in southeastern New Mexico, Bell and others (2010) studied habitat use of Lesser Prairie-Chicken hens and broods to evaluate the effects of land-management practices on brood-rearing habitats.

Broods (n=24) preferred areas that were ungrazed and not treated with the herbicide tebuthiuron across the entire study area. Within an herbicide-treated pasture, 71 percent of the locations of four broods were in ungrazed sites that were not treated with tebuthiuron, although these areas represented only 32 percent of the available habitat (Bell and others, 2010).

In a sagebrush mixed-grass prairie in northwestern Oklahoma, Thacker and others (2012) examined the changes in habitat structure and food resource availability for Lesser Prairie-Chickens after application of the herbicide 2,4–Dichlorophenoxyacetic acid (2,4–D). In pastures that were recently treated (0–3 years) with 2,4–D, grass basal cover increased by 4 percent, but there was no increase in annual or perennial forbs, forb richness, forb density, or grasshopper (Acrididae) density. Sagebrush cover declined from 26 percent in untreated pastures to 10 percent in pastures treated 20 years earlier, and sagebrush density declined from 0.57 plant per square meter (m^2) in untreated pastures to 0.20 plants per m^2 in pastures treated 20 years earlier. Thacker and others (2012) concluded that loss of protective cover may persist for more than 20 years after treatment with 2,4–D, and that 2,4–D may have limited use as a habitat management tool. In another Oklahoma study, Donaldson (1969) observed more Lesser Prairie-Chickens in herbicide-treated areas than in untreated areas. Shinnery oak and sand sagebrush habitats were treated between mid-May and mid-July with two aerial applications of phenoxy herbicides (2,4,5–Trichlorophenoxyacetic acid [2,4,5–T] and 2,4–D, respectively) at the rate of 0.56 kg per ha. More Lesser Prairie-Chickens were flushed in 1,280 ha of shinnery oak habitat (255 adults and 78 juveniles) than in 1,024 ha of sand sagebrush habitat (113 adults and 31 juveniles) during the 2-year study. Numbers of males per lek were higher in herbicide-treated than untreated shinnery oak habitats, and no leks were found in untreated sand sagebrush areas. A mean of 19.9 males per lek and 17.0 males per lek were observed at 14 leks in treated areas in 2 consecutive years, respectively. In contrast, 3.8 and 2.6 males per lek were seen at 6 leks in untreated areas during those same years (Donaldson, 1969). Donaldson (1966) suggested that the habitat components used by Lesser Prairie-Chickens during summer were present in treated and untreated habitats; however, the time since herbicide application was not specified in Donaldson's (1966, 1969) study.

Collisions with livestock fences are a major source of Lesser Prairie-Chicken mortality (Wolfe and others, 2007). In highly fragmented landscapes, higher fence densities may increase collision risk to Lesser Prairie-Chickens or increase in avian and mammalian predators in Lesser Prairie-Chicken habitats by providing perches for predatory birds and travel corridors for generalist predators (Wolfe and others, 2007, 2016; Haukos and Zavaleta, 2016; Robinson and others, 2016a; Spencer and others, 2017). In Colorado and Kansas, 7.2 percent of 69 hen mortalities during the breeding season were attributed to agricultural equipment or collisions with fences (Plumb, 2015). In Kansas, mortality risk of radio-marked female Lesser Prairie-Chickens increased as distance to fences increased (Robinson and others, 2018). In Oklahoma and New Mexico, 33.1 percent of 260 mortalities of radio-collared Lesser Prairie-Chickens were the result of fence collisions (Wolfe and others, 2007). The percentage of deaths from fence collisions was significantly higher in Oklahoma (99.8 percent of 128 mortalities) than in New Mexico (26.5 percent of 132 mortalities). Females were more susceptible to collisions than males, and adults were more likely to die from collisions than were young birds (Wolfe and others, 2007). Patten and others (2005b) determined that 32 percent of 100 Lesser Prairie-Chicken deaths in Oklahoma and 13.3 percent of 98 deaths in New Mexico were attributed to collisions with fences.

Lesser Prairie-Chickens tend to avoid tall structures, roads, buildings, and oil and gas wells (Robel and others, 2004; Pitman and others, 2005; Pruett and others, 2009; Hagen and others, 2011; Boal and Haukos, 2016; Wolfe and others, 2016; Plumb and others, 2019; Sullins and others, 2019). Hagen (2010) conducted a meta-analysis on the impacts of energy development and associated infrastructure on prairie grouse distribution and demography and identified potential mechanisms for population-level responses. Hagen (2010) indicated that there was a moderate-to-large effect for prairie grouse displacement by anthropogenic features in landscapes impacted by energy development and subsequently reduced demographic rates. Powerlines and roads had the largest displacement effects. Demographic rates (for example, brood survival, nest initiation rate, nest success) were lower in developed areas for all biological seasons, with the largest effect on annual survival (Hagen, 2010). In Colorado and Kansas, Sullins and others (2019) developed models to evaluate relationships with anthropogenic structures and grassland composition; the models indicated that the probability of use by Lesser Prairie-Chickens decreased in 2-km radius (that is, 12.6 km^2) landscapes that had >2 vertical features (for example, oil wells or trees), >2 oil wells, >8 km of county roads, or >0.15 km of major roads or transmission lines. In southwestern Kansas, Robel and others (2004) estimated that habitat use for nesting and brood rearing was negatively affected as much as 1.6 km from human-made structures. In another Kansas study, Jarnevich and Laubhan (2011) used species distribution models with environmental and energy-development parameters to predict the probability of Lesser Prairie-Chicken lek occurrence. The resulting models indicated that the footprint of energy development negatively affected lek habitat suitability; leks closest to anthropogenic features (highways, electric transmission lines, and oil and gas wells) were associated with lower habitat suitability. In the mixed-grass and shortgrass ecoregions of Kansas, Plumb and others (2019) investigated the effects of anthropogenic structures on locations of home ranges and nests of Lesser Prairie-Chickens. When pooled across ecoregions, radio-marked Lesser Prairie-Chickens displayed behavioral avoidance of powerlines, roads, and oil wells within their home ranges. The home ranges of radio-marked female Lesser Prairie-Chickens were farther from powerlines and roads than would be expected at random. The probability of home-range placement increased 1.66 and 1.54 times as the distance increased from 0 to 3 km from roads and powerlines, respectively. Distance to oil and gas well locations was not an important predictor of home-range placement. Distance to powerlines was the only significant predictor of nest placement, with females placing nests farther from powerlines than expected at random. The probability of nest placement increased 2.19 times as the distance from a powerline increased from 0 to 3 km. In northwestern Kansas, Lipp (2016) reported behavioral avoidance of suitable habitat by nesting Lesser Prairie-Chickens because of anthropogenic noise produced from oil and gas pumpjack motors; sound constrained Lesser Prairie-Chicken habitat selection but did not significantly influence nest success or nest survival. In southwestern Kansas, suitable habitat near developments (wellheads, buildings, improved roads, transmission lines, and center-pivot irrigation fields) was avoided (Pitman and others, 2005). Suitable habitat near unimproved roads was not avoided. Prairie-chickens maintained a minimum distance of 80 m from wellheads and a minimum distance of 1,000 m from buildings; however, the distance to development was not a substantial predictor of apparent nest success. In the same area in Kansas, Hagen and others (2011) found centers of use (that is, home ranges) of Lesser Prairie-Chickens were farther from anthropogenic features (oil wells, buildings, roads, powerlines) than would be expected at random. In northwestern Texas, 85 percent of 36 Lesser Prairie-Chicken nests were >0.5 km from all anthropogenic features (buildings, pumpjacks, utility towers, stock tanks, and improved roads) except for unimproved roads (Grisham and others, 2014). In another Texas study, displaying males abandoned one lek after an elevated road was built across it (Crawford and Bolen, 1976b). In New Mexico, oil and gas exploration and development eliminated use of two leks and disrupted use on a third lek over a 3-year period (Candelaria, 1979; Davis and others, 1979).

Little is known about avoidance of wind-energy facilities by Lesser Prairie-Chickens (Wolfe and others, 2016), but Pruett and others (2009) speculated that the effects may be similar to other tall human-made structures (for example, powerlines, oil wells). In southern Kansas, LeBeau and others (2020) reported that radio-marked male and female Lesser Prairie-Chickens selected habitats regardless of the presence of wind-energy infrastructure during the nesting, breeding, and nonbreeding seasons; nest survival and annual adult survival were not negatively affected by wind-energy infrastructure during the 3-year study. LeBeau and others (2020) suggested that the placement of wind turbines in previously altered habitats may have contributed to the lack of negative impacts during their study.

Wild-trapped birds have been translocated to reintroduce or supplement Lesser Prairie-Chicken populations in areas where they had been extirpated, areas where populations were low, or areas outside of their known historical range (Snyder, 1967; Snyder and others, 1999; Horton, 2000; Rodgers, 2016; Hagen and Giesen, 2020). These efforts have had limited success. Snyder (1967) reported that translocations failed in New Mexico in the 1930s and 1940s. In Colorado, Lesser Prairie-Chickens were transplanted at least 10 times into the species' known historical range or transplanted in locations outside of their known historical range (Hagen and Giesen, 2020). For example, Colorado released 155 birds during a 6-year reintroduction attempt. Birds were released during spring into a landscape of native grassland and cropland, but the reintroduction was not successful (Snyder and others, 1999). In Oklahoma, about 300 birds transplanted in the 1930s failed to establish a population, but 200 birds transplanted in the 1940s were successful in establishing a population (mostly in the former range of the Greater Prairie-Chicken) (Horton, 2000). In Texas, 46 Lesser Prairie-Chickens were translocated in spring in 2 years to supplement an existing population in native habitat, but these efforts also were unsuccessful (Snyder and others, 1999). In southeastern New Mexico, McWilliams (2013) used decoys and audio playbacks of displaying Lesser Prairie-Chickens to attract conspecifics to 32 abandoned leks that were uninhabited in previous years. Lesser Prairie-Chickens responded (for example, approaching speakers, attaining searching posture, vocalizing) to the audio playbacks within 3–4 days at three of the 32 abandoned leks. McWilliams (2013) also deployed decoys of displaying conspecifics and playbacks of audio recordings at 10 active leks; the average number of Lesser Prairie-Chickens attending the leks (16 males per lek) did not change, but the Lesser Prairie-Chickens responded to audio playbacks by increasing their activity (for example, vigorous displaying, interactions among individuals, and inquisitive behaviors). Birds on active leks without decoys or playbacks displayed an average of >165 minutes per day, whereas birds on leks with decoys and playbacks displayed an average of >231 minutes per day.

Management Recommendations from the Literature

The Lesser Prairie-Chicken is an area-sensitive species that requires large landscapes of relatively unfragmented habitat (Hagan and Elmore, 2016). Conversion of native grasslands to rowcrop agriculture is considered a primary factor in the decline of Lesser Prairie-Chicken populations (Hagen and others, 2004; Boal and Haukos, 2016; Rodgers, 2016; Van Pelt and others, 2016; Robinson and others, 2018; Plumb and others, 2019). Robinson and others (2018) suggested that further conversion of grassland landscapes that are occupied by Lesser Prairie-Chickens should be avoided to reduce habitat loss and fragmentation thresholds that could affect annual survival. To benefit Lesser Prairie-Chickens, several authors have recommended protecting, maintaining, or restoring large (at least 1,024 ha) tracts of native shinnery oak-tallgrass or sand sagebrush grasslands (Copelin, 1963; Jones, 1963a; Crawford, 1974; Crawford and Bolen, 1976a; Davis and others, 1979; Ahlborn, 1980; Wilson, 1982; Applegate and Riley, 1998; Leslie and others, 1999; Wildlife Habitat Management Institute, 1999; Horton, 2000; Jamison, 2000; Jensen and others, 2000; Hagen and others, 2004). In west Texas, Crawford and Bolen (1976a) concluded that landscapes managed for Lesser Prairie-Chickens should be maintained with a minimum of 63 percent native shinnery oak rangeland to support stable populations of Lesser Prairie-Chickens. Hagen (2010) concluded that regional or range-wide strategies (for example, Doherty and others, 2011; Naugle and others, 2011) that protect large landscapes and the highest-quality habitats for prairie grouse are needed to increase the likelihood of persistence of prairie grouse populations. One range-wide conservation plan (Van Pelt and others, 2016) for the Lesser Prairie-Chicken recommended targeting areas that average 10,000 ha in which to focus habitat enhancement, maintenance, conservation, and protection. The Wildlife Habitat Management Institute (1999) suggested that complexes of breeding habitat patches totaling 10,000 ha may provide optimal conditions to maintain Lesser Prairie-Chicken populations, but grassland areas as small as 500 ha may be adequate to maintain breeding populations. Toole (2005) suggested that 15,000 ha was the minimum area required to sustain a viable Lesser Prairie-Chicken population in the Rolling Plains of Texas. Copelin (1963) indicated that Lesser Prairie-Chickens require broad, open expanses of prairie that are >1,024 ha, and Sell (1979) indicated that management areas should encompass at least 2,000 ha of grassland. Based on the proximity of radio-marked Lesser Prairie-Chickens to leks, Taylor and Guthery (1980a) recommended that areas managed for Lesser Prairie-Chickens in Texas should be at least 3,200 ha, with an optimal size of at least 7,200 ha. Kraft (2016) recommended that pastures within the species' occupied range should be at least 300 ha in size to maximize environmental heterogeneity and allow for lower stocking densities.

Conservation efforts that focus on restoring Lesser Prairie-Chicken habitat may help offset annual fluctuations in precipitation and projected changes in climate (Ross and others, 2016b). During drought periods, large grasslands may be important for supporting viable Lesser Prairie-Chicken populations (Merchant, 1982) and may provide broader ranges of microclimates and resources (Fritts and others, 2018). Ross and others (2016a, 2018) reported that the resilience of the Lesser Prairie-Chicken to withstand extreme drought conditions likely decreases as the amount of cropland in a region increases; habitat improvements that reduce the cropland- grassland ratio below 1:10 would likely increase adult, chick, and juvenile survival and buffer the population against the harmful effects of severe drought. To ensure available nesting habitat across the range of environmental variation, Lautenbach and others (2019) provided management strategies to improve vegetation structure on the landscape, including patch-burn grazing, maximizing pasture size (>400 ha), reducing stocking rates (<0.4 animal unit per ha), implementing low-to-moderate grazing deferments (60–100 days), resting pastures, and planting of CRP grasslands in close proximity to leks. Implementing these management strategies to create vegetation structure with 2.0–4.0 decimeters of 75 percent VOR will increase predator and thermal refugia, may increase the availability of selected nest habitats, and likely will improve nest survival (Lautenbach and others, 2019). Grisham and others (2016a) indicated that species' productivity may decrease with changes in spring phenology and warmer, more arid conditions; the authors suggested that the Lesser Prairie-Chicken would benefit from improving and maintaining VOR (3.7–4.4 decimeters; Hagen and others, 2013; Fritts and others, 2016) for nesting activities and implementing management practices (for example, prescribed fire, grazing, tree removal, herbicide application) that promote cooler, more humid nest microclimates.

Given that Lesser Prairie-Chickens are year-round residents that generally occupy the same areas during the breeding and nonbreeding seasons, conservation planning, habitat management, and efforts to estimate habitat availability typically focus on areas in which leks are located (Boal and Haukos, 2016). Pitman and others (2006) suggested that providing secure nesting habitat within 1 km of lek sites is an important strategy for managing Lesser Prairie-Chicken populations, because >80 percent of female Lesser Prairie-Chickens in Kansas nested within 1 km of a lek site and nested an average distance of 712 m from the previous year's nest site. Maintaining shrub-dominated habitats within 4.8 km of lek sites provides important nesting habitat for the species (Leslie and others, 1999; Woodward and others, 2001). In western Texas, Borsdorf (2013) suggested that sand-shinnery oak grassland habitat within 4.8 km of leks should receive highest conservation priority, given its importance for breeding-season activities for post-lekking males and nesting and brood-rearing females. Over 98 percent of overwintering male and female Lesser Prairie-Chickens in the northeastern Texas Panhandle remained within 2.4 km of a lek and selected habitats with <15 percent canopy shrub cover (Kukal, 2010). Kukal (2010) recommended managing rangelands within 5.0 km of leks for overwintering Lesser Prairie-Chickens and prioritizing areas within 2.4 km of leks in the northeast Texas Panhandle. Applegate and Riley (1998) suggested that areas managed for Lesser Prairie-Chickens should include ≥6 leks (but preferably should include ≥10 leks) and that interlek distances should be ≤1.9 km. Suitable lek display sites can be created in areas where suitable lek sites are limited by eradicating shrubs in 0.1–0.5 ha patches or by installing caliche pads (that is, a cemented soil layer formed when soluble salts are precipitated from evaporating water) (Davis and others, 1979; Sell, 1979; Taylor, 1979).

Maintaining high-quality nesting habitat will be beneficial to nesting Lesser Prairie-Chickens. In general, such habitat includes dense shrubs and residual bunchgrasses >40 cm tall that provide >75 percent vertical screening in the first 33 cm above the ground and 50 percent overhead cover (Sell, 1979; Haukos and Smith, 1989; Giesen, 1994). In sand sagebrush habitats, Hagen and others (2013) recommended maintaining a canopy cover >60 percent, which would include forbs, shrubs, and grasses >25 cm in the western portion of the species' range and >40 cm in the eastern portion of the species' range. Hagen and others (2013) also recommended >35 percent forb canopy cover and shrubs >36 cm in height. In shinnery oak habitats, sand bluestem ≥50 cm in height provides suitable nesting cover (Davis and others, 1979; Riley and others, 1992). Predator removal efforts may enhance nesting success of imperiled populations in small patches of habitat (Schroeder and Baydack, 2001). In a Kansas study, 50 prairie-chicken nests (Lesser and Greater prairie-chickens combined) were monitored over 2 years, and 94 percent of nest failures were attributed to depredation events (Fields, 2004).

Optimal brood habitat includes approximately 25 percent canopy of shrubs, forbs, or grasses that are 24–30 cm tall (Davis and others, 1979; Ahlborn, 1980; Riley and Davis, 1993). Hagen and others (2005, 2013) recommended increased herbaceous cover (27–40 percent) to provide sufficient invertebrate availability for foraging broods. In shinnery oak habitats, Hagen and others (2005, 2013) recommended that vegetation should be dominated by three-awn and shinnery oak with about 60 percent bare ground, and that optimal vegetation cover should consist of about 43–60 percent grasses, 24–43 percent shrubs (primarily shinnery oak), and 13–26 percent forbs.

Prescribed and natural fires can create the low, sparse vegetative structure that is preferred for lekking but may reduce overhead and horizontal cover necessary for nesting habitat and thermal cover (Boyd and Bidwell, 2001; Dahlgren and others, 2016; Grisham and others, 2016b). In idle grasslands that have not been disturbed (for example, CRP fields) or in grasslands with woody plant invasion, however, Dahlgren and others (2016) indicated that fire can be a cost-efficient tool for improving nesting and brood-rearing habitats. Bidwell and others (2003) emphasized the importance of maintaining unburned areas of dense grass within 1,600 m of historic leks. Boyd and Bidwell (2001) suggested that (1) shinnery oak mottes should be protected by disking fire breaks around the mottes to minimize fire impacts on thermal and escape cover, (2) patches with different time-since-fire intervals should be interspersed to minimize the effects of fire on habitat across the landscape, (3) burning should occur in seasons other than in spring, and (4) annual burning of large areas should be avoided to conserve residual nesting cover. Burning in mesic shinnery oak habitats will increase forb and invertebrate densities for foraging adults and broods. Litton and others (1994) and Snyder (1996) cautioned against burning in areas of loose, sandy soils because the lack of precipitation and revegetation increases the potential for wind erosion.

Fields and others (2006) suggested that the timing of prescribed fires should be carefully planned to avoid influencing vegetation cover or causing disturbances during nesting or brood rearing. Some nesting habitats may require as many as 3 years following a fire to provide adequate nest concealment (Boyd and Bidwell, 2001). Cannon and Knopf (1979) recommended early spring burns on recently abandoned shinnery oak-bluestem pastures to help improve nesting conditions in subsequent breeding seasons and to reestablish Lesser Prairie-Chickens in parts of the species' former range. Burning in any season will remove the previous year's growth and nesting habitat, but late summer, fall, and winter burns typically promote a higher proportion of forbs and improve brood habitat by removing litter and increasing bare ground, thus improving availability of seed and insects (Bidwell and others, 2003). Applegate and Riley (1998) suggested burning 20–30 percent of pasture area in late winter or early spring every 3 or 4 years. Bidwell and others (2003) suggested that burning 20–30 percent of the management unit each year will allow the entire area to be burned within the desired 3- to 5-year interval and still maintain quality nesting habitat; burning >50 percent of the management unit in 1 year may not leave sufficient escape and nesting cover. Fields (2004) recommended prescribed fires and other management techniques (interseeding, grazing, mowing, or strip disking) to increase forb abundance and enhance invertebrate biomass for foraging broods.

Bidwell and others (2003) indicated that a combination of fire and grazing at the landscape level may provide the best potential to reverse the decline of Lesser Prairie-Chickens. This management practice involves burning 15–30 percent of an area each year and allowing cattle free access to burned and unburned patches. Patch-burning increases landscape heterogeneity, structural diversity, and grassland bird diversity without negatively affecting production of livestock (Bidwell and others, 2003). Lautenbach (2017) suggested implementing prescribed fire in a patch-burn grazing system with a 4–6-year burn interval in the eastern portion of the species' range. Starns and others (2020) suggested using patch-burning (that is, pyric herbivory) as a land-management strategy to maximize vegetation heterogeneity for lekking, nesting, and brooding cover within proximity (spatially and temporally) of each other.

Most Lesser Prairie-Chickens occur on rangeland that is grazed by cattle or other herbivores (Elmore and others, 2018). Although grazing may benefit Lesser Prairie-Chickens, the direct impacts of livestock grazing on Lesser Prairie-Chicken populations have not been well studied (Elmore and Dahlgren, 2016). Given that native prairies evolved with periodic grazing, livestock stocking rates that are light to moderate are considered optimal for Lesser Prairie-Chickens (Copelin, 1963; Hoffman, 1963; Donaldson, 1969; Applegate and Riley, 1998; Bidwell and others, 2003; Elmore and others, 2018) and will ensure that some residual nesting cover will be available following dry years (Merchant, 1982; Giesen, 2000). Several researchers have recommended avoiding heavy grazing or long-term high-intensity grazing because these grazing practices result in reduced nesting cover or conversion of the plant community to shortgrass habitat (Hoffman, 1963; Jackson and DeArment, 1963; Jones, 1963a; Crawford, 1974; Merchant, 1982; Wilson, 1982; Haukos and Smith, 1989; Litton and others, 1994; Giesen, 2000; Dahlgren and others, 2016). However, grazing can be used as a tool to maintain heterogeneity in vegetation structure (Grisham and others, 2016b). Hagen and others (2004) recommended managing grazing to maintain adequate height (≥25 cm) and density of grasses and forbs. Giesen (1994) recommended that livestock grazing should maintain sufficient residual cover of tall (>40 cm) bunchgrasses and sand sagebrush within 1.8 km of leks to provide adequate nesting cover. Sand bluestem and little bluestem composition can be increased in shinnery oak-tallgrass habitats by reducing grazing pressure (Davis and others, 1979; Ahlborn, 1980; Wilson, 1982; Litton and others, 1994). Livestock exclosures can be used to protect some areas from grazing (Jones, 1963a). Pitman and others (2005) suggested that grazing should be maintained at a level that provides >25 cm grass height during the spring nesting season.

Bidwell and others (2003) indicated that the optimal grazing management plan for Lesser Prairie-Chickens is one that maintains prairie in middle-to-late stages of plant succession (native tall grasses, forbs, and legumes) interspersed with early stages of plant succession (native annual forbs). Although continuous or season-long grazing at a moderate stocking rate will provide a mosaic of heavily grazed, moderately grazed, lightly grazed, and ungrazed patches within a grazing unit, the same patches (for example, those near water and riparian areas) will be selectively grazed each year by livestock and eventually will be driven to poor condition. Short-duration grazing (that is, grazing with multiple paddocks with frequent moves of livestock) results in a decline of structural and compositional diversity and a more uniform height of the plant community and thus reduces habitat quality for Lesser Prairie-Chickens, as well as livestock weight gains and net profits, compared to continuous stocking (Bidwell and others, 2003). Deferred-grazing systems (that is, systems that postpone grazing until grassland plants have matured) or rest-rotation grazing systems (systems that involve multiple pastures through which livestock are rotated) may create suitable interspersion of different vegetation heights (Applegate and Riley, 1998). To provide increased variability in vegetation structure for Lesser Prairie-Chickens while also preventing pastures from experiencing long-term degradation, Derner and others (2009) recommended multipasture rotation systems, with moderate stocking rates, to shift from equal grazing across pastures to a system where some pastures are intensively grazed while other pastures remain rested or lightly grazed. Grisham and others (2016b) recommended an adaptive grazing strategy in shinnery oak prairie that creates a mosaic of vegetation; this strategy adjusts stocking rates and grazing systems to maintain middle-to-late stages of plant succession interspersed with early stages of plant succession. Fritts and others (2018) suggested that Lesser Prairie-Chickens likely will benefit from habitat management that remains adaptive with continuous monitoring to ensure that adequate habitat, including microhabitat, is available, particularly during altered weather conditions; specific adaptive measures associated with grazing that will benefit Lesser Prairie-Chickens on the Southern High Plains include removing cattle during and immediately following severe drought, resting pastures between grazing events, and restocking livestock at decreased levels following rainfall events in early spring.

Bidwell and others (2003) suggested that haying of native prairies should occur between July 1 and 10 to reduce mortality to nests and chicks and, at the same time, maintain adequate cover and plant vigor for next year's growth. To minimize mortality of broods, Bidwell and others (2003) emphasized that haying operations should begin in the center of a grassland and proceed outward.

Minimum-tillage practices in cultivated fields that border native grasslands may provide maximum availability of waste grains for winter forage (Crawford, 1974; Crawford and Bolen, 1976a; Ahlborn, 1980; Applegate and Riley, 1998). Although planting food plots may provide winter food for Lesser Prairie-Chickens (Copelin, 1963; Donaldson, 1969; Crawford, 1974; Applegate and Riley, 1998), most populations probably have access to cultivated fields and are limited more by the amount of available nesting cover than by winter food supplies (Taylor and Guthery, 1980b; Hagen and others, 2004). Cultivation of grasslands surrounding leks and disturbance of lek sites may result in lek abandonment (Crawford, 1974; Crawford and Bolen, 1976b; Davis and others, 1979).

About 94 percent of the current range of the Lesser Prairie-Chicken is in private ownership; private land management is mainly affected by incentive programs driven by government policies (Elmore and Dahlgren, 2016). Several authors have advocated for government programs that provide incentives for the development or restoration of Lesser Prairie-Chicken habitat on private lands (Wildlife Habitat Management Institute, 1999; Bailey and Williams, 2000; Horton, 2000; Sullivan and others, 2000; Dahlgren and others, 2016; Elmore and Dahlgren, 2016). These include programs administered by the U.S. Department of Agriculture (for example, CRP, Environmental Quality Incentives Program, Wildlife Habitat Incentives Program, Natural Resources Conservation Service Lesser Prairie-Chicken Initiative), the U.S. Fish and Wildlife Service (for example, Partners for Fish and Wildlife, Candidate Conservation Agreements with Assurances, Safe Harbor Agreements), and State natural resource agencies (for example, Texas Parks and Wildlife Department's Landowner Incentive Program). Beginning in 2008, private landowners in the five States with Lesser Prairie-Chicken populations could enroll in continuous CRP designated in the State Acres for Wildlife Enhancement (also known as SAFE) initiative to address State and regional high priority objectives for the Lesser Prairie-Chicken (Elmore and Dahlgren, 2016). The State goals included maintaining and enhancing populations, restoring mixed-grass prairies and short- and mid-grass sand sagebrush prairies, and increasing connectivity of existing habitat. To guide conservation and recovery efforts of Lesser Prairie-Chicken populations, Hagen and others (2016) emphasized the importance of maintaining connectivity between ecoregions (for example, Sand Sagebrush Prairie Ecoregion and Mixed-Grass Prairie Ecoregion) and their associated core areas.

CRP grasslands may provide suitable habitat for Lesser Prairie-Chickens throughout the year (Litton and others, 1994; Cable, 1996; Leslie and others, 1999; Giesen, 2000; Jamison, 2000; Rodgers, 2000; Rodgers and Hoffman, 2005; Harryman and others, 2019). In northwestern Kansas and eastern Colorado, Sullins and others (2019) recommended tree removal and CRP enrollment to benefit Lesser Prairie-Chicken conservation; spatially incentivized CRP enrollment has the potential to provide 4,189 km^2 of additional grassland habitat. Lesser Prairie-Chickens may benefit from CRP fields seeded to native tallgrass and mixed-grass prairie species (Litton and others, 1994; Applegate and Riley, 1998). Seeding mixes that result in CRP stands dominated by little bluestem seem to provide suitable habitat for Lesser Prairie-Chickens in Kansas (R.D. Rodgers, written comm. [n.d.]; Rodgers and Hoffman, 2005). CRP fields planted to a single nonnative grass species, such as yellow bluestem, provide little value to Lesser Prairie-Chickens (Bidwell and others, 2003). In Texas, newer CRP guidelines encourage the use of seeding mixtures that include forbs; incorporating forbs into CRP plantings may improve their value to Lesser Prairie-Chickens (Sullivan and others, 2000). Bidwell and others (2003) recommended planting a mix of native grasses and forbs or incorporating native forbs and shrubs (for example, sand sagebrush) into warm-season CRP plantings at the time of enrollment. Sullivan and others (2000) suggested that CRP fields should be managed in a manner that mimics the structure of native rangeland. A large-scale survey of 1,019 CRP fields in Colorado, Kansas, Oklahoma, New Mexico, and Texas was completed in 2007 to help guide management of Lesser Prairie-Chicken habitat (Ripper and others, 2008). Recommendations for CRP fields included increasing forb cover in Colorado. Other recommendations included increased management focus on Conservation Practice (CP)10 (already established grass or vegetative cover) and CP2 (permanent native grasses) fields in Colorado, New Mexico, and northwest Texas; CP2 fields in northeast Texas; and CP2, CP25 (rare and declining habitat restoration), and CP10 fields in Oklahoma. To maximize the benefits of the CRP to Lesser Prairie-Chickens, Sullins and others (2018) suggested concentrating CRP incentives in areas that receive <55 cm of average annual precipitation and in 50-km^2 landscapes that would surpass a 65 percent threshold of grasslands with the addition of CRP grasslands. Harryman and others (2019) recommended using CRP grasslands to complement management and conservation efforts in the Sand Shinnery Oak Prairie Ecoregion in Texas; strategic placement of new CRP grasslands adjacent to fields already occupied by Lesser Prairie-Chickens will increase grassland patch size and may reduce landscape fragmentation. Bidwell and others (2003) noted that grasses in older CRP grasslands may become too dense and less favorable to prairie-chickens, and the authors recommended periodic burning and grazing of CRP grasslands.

Tree invasions and tree plantings are among the greatest threats to Lesser Prairie-Chicken populations (Fuhlendorf and others, 2002, 2017; Bidwell and others, 2003; Hunt and Best, 2010; Falkowski and others, 2017; Hagen and others, 2019). Prescribed fires or other significant ecological disturbances (for example, mechanical or chemical tree removal) can be used to prevent tree encroachment, maintain productivity and vegetation composition of native grasslands and shrublands, and increase habitat occupancy by Lesser Prairie-Chickens (Lautenbach, 2015; Elmore and Dahlgren, 2016; Lautenbach and others, 2017). Elmore and others (2018) recommended burning prairie on a 7-year rotation to suppress the invasion of eastern redcedar. Elmore and others (2018) further recommended mechanical removal of trees through cutting, pushing with a bulldozer, chaining, or grinding when eastern redcedar stands become too mature (>2.1 m tall) or when the grass fuel load is insufficient (due to shallow soils or high stocking rates) to maintain a fire intensity that is great enough to remove the trees. Bidwell and others (2003) recommended removing all upland trees from areas used by Lesser Prairie-Chickens, including field windbreaks and living snow fences, because Lesser Prairie-Chickens avoid trees and because trees provide perches for predatory birds and habitat for generalist predators. In the southern portion of the species' range, researchers have found that Lesser Prairie-Chickens avoid habitats that have been encroached by mesquite and may abandon leks near areas with mesquite (Davis and others, 1979; Wisdom, 1980; Hunt and Best, 2010; Hagen and others, 2019). To increase available habitat for Lesser Prairie-Chickens and reduce the threat of habitat loss, Boggie and others (2017) recommended treating and removing honey mesquite from areas with the lowest mesquite canopy cover classes (1–15 percent). To restore habitat and increase connectivity and habitat availability, Boggie and others (2017) also recommended targeting areas with higher mesquite canopy cover classes (16–50 percent) in the occupied range. Falkowski and others (2017) and Miller and others (2017) emphasized the importance of careful targeting and proactive removal of conifer and mesquite trees during earlier phases of tree invasion to minimize ground disturbance and to retain shrub and herbaceous communities. In the Southern High Plains of New Mexico, Hagen and others (2019) suggested that removal of trees from areas with a low density of honey mesquite provides the most cost-effective first step in addressing mesquite invasion in prairie ecosystems.

The preferred habitat of Lesser Prairie-Chickens is native prairie intermixed with shrub cover (Bidwell and others, 2003). Shinnery oak and sand sagebrush rangeland can be managed (for example, burned) periodically to maintain proper shrub height and canopy (for example, maintaining nesting habitat with >50 percent of an area consisting of native grass and shrub cover above a height of 38 cm) as these native shrubs resprout quickly following a disturbance (Boyd and Bidwell, 2001). Shrub management can have positive or negative impacts on Lesser Prairie-Chickens, but eradication of shrubs is not recommended, especially in the western portion of the species' range (Elmore and Dahlgren, 2016). Patten and others (2005a) cautioned that land managers applying herbicides to remove shrubs should understand the potentially negative effects of reduced shrub cover on adult survivorship of Lesser Prairie-Chickens. Widespread control of shinnery oak or sand sagebrush may be detrimental to habitat quality for Lesser Prairie-Chickens (Haukos and Smith, 1989; Gunter and others, 2012; Van Pelt and others, 2013). Lesser Prairie-Chickens respond differently to the basic vegetative components of shinnery oak and sand sagebrush rangelands (Davis and others, 1979; Cannon and Knopf, 1981; Cannon and others, 1982; Merchant, 1982). Cannon and Knopf (1981) indicated that management strategies in shinnery oak habitats should emphasize grass cover, whereas management strategies in sand sagebrush should emphasize shrub cover, particularly in areas where taller species of grass have been reduced by overgrazing (Cannon and Knopf, 1981; Cannon and others, 1982; Giesen, 1994).

Although minimizing the use of herbicides in habitats used by Lesser Prairie-Chickens has been suggested (Applegate and Riley, 1998; Bidwell and others, 2003), application of some herbicides (for example, tebuthiuron or phenoxy) has been used to reduce cover of dense, continuous stands of shinnery oak and may allow an increase in coverage of grasses used by Lesser Prairie-Chickens for nesting as long as heavy grazing does not remove this cover (Copelin, 1963; Donaldson, 1969; Ahlborn, 1980; Haukos and Smith, 1989; Grisham and others, 2014; Boal and Haukos, 2016). K.M. Giesen (Colorado Division of Wildlife, Fort Collins, Colorado, written commun. [n.d.]) cautioned that the effects of herbicide treatment may not become evident until 3 or more years following the herbicide applications as the treated shrubs fall and decay. Patten and others (2006) concluded that tebuthiuron had a complex, positive-negative relationship with Lesser Prairie-Chicken fledgling production; tebuthiuron reduced shrub cover and oak density, which is an important component of nest concealment, but the herbicide also increased grass cover. Grass cover is an important component of nest cover, but it has a negative effect on fledgling production. Haukos (2011) concluded that that the timing and application rate of herbicides have different effects on vegetation composition and structure and suggested that the goal of tebuthiuron treatments should be to create vegetation heterogeneity with a codominant community of shrubs and native grasses interspersed in patchy mosaics. Hagen and others (2004) recommended minimizing the use of herbicides except to control invasive nonnative species; however, if herbicide treatments are needed, Hagen and others (2004) further recommended that the herbicide treatments should not reduce sand sagebrush or shinnery oak to <25 percent of the canopy within 1 year after the treatment. A mosaic of treated and untreated areas will provide an interspersion of habitats dominated by grasses that are suitable for nesting cover and areas dominated by shrubs that are suitable for brood-rearing, foraging, and protective cover for adults in autumn and winter (Donaldson, 1969; Ahlborn, 1980; Doerr and Guthery, 1983; Olawsky, 1987; Olawsky and Smith, 1991; Riley and others, 1993; Litton and others, 1994). Applying tebuthiuron in strips or blocks at rates of 0.2–0.6 kg per ha will create a mosaic of habitats (Doerr and Guthery, 1983; Olawsky, 1987). Boal and others (2014b) concluded that reduced application rates of herbicide and short-duration grazing treatments were not detrimental to nesting Lesser Prairie-Chickens, and that populations of Lesser Prairie-Chickens in shrub-dominated ecosystems may benefit from the resulting increase in habitat heterogeneity. Thacker and others (2012) cautioned against using the herbicide 2,4–D in Lesser Prairie-Chicken habitats to control shrubs where nesting cover is limited because of the long-term loss of protective cover and habitat structure. In Oklahoma, Gunter and others (2012) found an increase in the carrying capacity of cattle in response to sagebrush control and suggested that increased sagebrush control might provide an economic incentive for ranchers but also could limit the ecological services provided by sagebrush habitat because of loss of protective cover for wildlife. Fritts and others (2016) cautioned that intensified management (herbicide treatments, grazing, or a combination of herbicides and grazing) that increases bare ground to ≥35 percent or reduces overhead cover may negatively affect Lesser Prairie-Chicken nesting habitat and nest survival. Litton and others (1994) indicated that shinnery oak mottes that produce mast crops should be preserved and excluded from herbicide applications. Annual chemical brush treatment on large areas may reduce Lesser Prairie-Chicken populations (Jackson and DeArment, 1963; Litton and others, 1994). Litton and others (1994) suggested that shrubs should be treated in contour strips on a 6–8-year rotation to provide suitable interspersion of nesting and brood-rearing habitats while reducing wind erosion of sandy soils.

Removing unnecessary fences may be a viable option in some areas to ensure fewer collision mortalities of Lesser Prairie-Chickens, but fence removal is costly, time consuming, and would only slightly reduce fence densities on the landscape given that fences are vital to producers to contain their livestock (Wolfe and others, 2007, 2009). Although rotational grazing systems occasionally are recommended (for example, Applegate and Riley, 1998) as a management tool to improve nesting cover for Lesser Prairie-Chickens, Wolfe and others (2007) recommended against crossfencing of pastures and cell-type grazing systems because short-duration, high-intensity livestock grazing may result in greater exposure to fences and higher fence-collision mortality. In Oklahoma and Texas, Wolfe and others (2009) evaluated vinyl markers on wire strands to reduce prairie-chicken collisions. Fence marking greatly reduced collision mortalities, and Wolfe and others (2009) concluded that fence marking may be an important conservation tool for this species. To reduce collisions with perimeter fences in rangeland, Wolfe and others (2007) recommended decreasing fence height by about 10 percent (that is, 96–110 cm) from the typical height of 107–122 cm used for perimeter fences. In Kansas and Colorado, however, Robinson and others (2016a) found minimal evidence of mortality because of collisions with fences and recommended focusing resources on other limiting factors, such as improving habitat quality. Robinson and others (2016a) further recommended that land managers should seek strategies that maintain low fence densities in areas (for example, Oklahoma) that have higher risk of collision with fences. Additional information on fence collisions and recommendations to reduce fence-related grouse mortalities can be found in Stevens (2012), Stevens and others (2009, 2011, 2012a, 2012b, 2013), and Stevens and Dennis (2013).

Davis and others (1979) and Locke (1992) discouraged petroleum exploration and development in or near nesting areas of Lesser Prairie-Chickens. Although petroleum development may create areas that are suitable for leks, lek sites generally are not limiting (Candelaria, 1979; Davis and others, 1979). The disturbance associated with production of petroleum may disrupt lek activity or result in lek abandonment, as well as destroy nearby nesting habitat (Candelaria, 1979; Davis and others, 1979). To reduce continued habitat degradation throughout the species' range, Plumb and others (2019) recommended reducing or eliminating anthropogenic developments (for example, powerlines, oil wells, and roads) in quality Lesser Prairie-Chicken habitat and concentrating new developments in areas that already are altered and avoided by Lesser Prairie-Chickens. Lipp (2016) indicated that the keys to reducing the effects of oil and gas development on Lesser Prairie-Chickens and other grassland birds are to reduce the sound produced by pumpjacks (for example, by building walls around pumpjacks or using mufflers on pumpjacks) and to reduce the visibility of infrastructure (for example, by clustering pumpjacks in developed areas).

In response to concerns regarding possible impacts (for example, noise, habitat disruption [natural habitat that is incapable of supporting its native species], disturbance, fragmentation, increased predator access) of wind-energy facilities on prairie grouse, the U.S. Fish and Wildlife Service (Manville, 2004) recommended avoiding placement of wind turbines within 8 km of known leks for prairie grouse. Hagen and others (2004) recommended that wind-energy facilities or other large vertical structures should be positioned at least 2 km from known or potentially occupied Lesser Prairie-Chicken habitats. Moreover, if these structures must be placed in known Lesser Prairie-Chicken habitats, Hagen and others (2004) recommended that the wind-turbine structures be placed along habitat edges or clustered with other disturbances. To minimize impacts to local populations of Lesser Prairie-Chickens, LeBeau and others (2020) suggested placing wind infrastructure in previously disturbed landscapes. LeBeau and others (2020) reported that wind-turbine placement of 1.2 km did not act as a barrier to Lesser Prairie-Chicken movements between wind turbines.

Snyder and others (1999) evaluated data on prairie grouse translocations throughout the United States. Results from a logistic regression analysis suggested that soft releases (that is, a release technique that allows birds to walk out of a holding pen) of large numbers of birds (>100) over several years would maximize the probability of successful prairie grouse translocation attempts (Snyder and others, 1999). Audio playbacks and decoys may be used to attract conspecifics to abandoned leks or may be used to facilitate reintroduction or translocation of Lesser Prairie-Chickens into areas with suitable habitat (McWilliams, 2013).

Although Lesser Prairie-Chickens occupy an arid landscape, the value of human-made water sources as a management or conservation tool for Lesser Prairie-Chickens is unknown (Boal and others, 2014a; Grisham and others, 2016b), but these water sources may be important during drought (Haukos and Zavaleta, 2016; Robinson and others, 2016b). Davis and others (1979) warned that increasing the distribution of livestock-watering facilities may result in increased grazing pressure near those facilities, and Applegate and Riley (1998) suggested that well-distributed water sources would decrease the interspersion of different vegetation heights preferred by Lesser Prairie-Chickens. Boal and others (2014a) assessed the use of two commercially available wildlife water guzzlers by Lesser Prairie-Chickens. Lesser Prairie-Chickens used the guzzlers primarily during the lekking and nesting period (March–May) and the brood-rearing period (June–July), and use was primarily by males. Both designs were used, but Lesser Prairie-Chickens showed significantly greater use of the design that had a wider water trough and a ramp built into the tank cover compared to the design that had a longer, narrower trough extending from the tank. Boal and others (2014a) suggested giving more attention on this topic, given that natural moisture may become more limiting and the physiological needs of the Lesser Prairie-Chickens may become greater in a rapidly changing landscape and climate.

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Table D1. Measured values of vegetation structure and composition in Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*) breeding habitat by study. The parenthetical descriptors following authorship and year in the "Study" column indicate that the vegetation measurements were taken in locations or under conditions specified in the descriptor; no descriptor implies that measurements were taken within the general study area.

[cm, centimeter; %, percent; --, no data; CRP, Conservation Reserve Program; >, greater than; spp., species]

Study	State or province	Habitat	Management practice or treatment	Vegetation height (cm)	Vegetation height-density (cm)	Grass cover (%)	Forb cover (%)	Shrub cover (%)	Bare ground cover (%)	Litter cover (%)	Litter depth (cm)
Ahlborn, 1980 (broods)	New Mexico	Multiple	Grazing	30	--	47–60	13–26	24–39	--	--	--
Bell and others, 2010 (broods)	New Mexico	Multiple	Multiple	73.9[a]	--	--	--	--	--	--	--
Borsdorf, 2013 (roosts)	Texas	Sand shinnery oak (*Quercus havardii*) grassland	Multiple	20	42.4[b]	4	1	4.5	60.9	29.8	--
Copelin, 1963 (nests)	Oklahoma	Multiple	--	31–38[c]	--	--	--	--	--	--	--
Copelin, 1963 (broods)	Oklahoma	Multiple	--	120–600[c]	--	--	--	--	--	--	--
Davis, 2009[d] (successful nests)	New Mexico	Sand shinnery oak grassland	Grazing	41.3[c]	51[b]	12.6	1.8	44.0	4.6	65.7	--
Davis, 2009[d] (unsuccessful nests)	New Mexico	Sand shinnery oak grassland	Grazing	39.5[c]	40[b]	17.1	2.1	37.5	8.1	51.5	--
Davis and others, 1979[e] (leks)	New Mexico	Multiple	Grazing	0–10.2	--	--	--	--	--	--	--
Davis and others, 1979[e] (nests)	New Mexico	Multiple	Grazing	33.8–63.8	--	6.4–13.2	0.3–1.1	3.2–5.9	24.9–35.2	52.9–57.6	--
Davis and others, 1979[e] (brood foraging sites)	New Mexico	Multiple	Grazing	24.4–27.9	--	43.6–62	--	38–56.4	--	--	--
Davis and others, 1979[e] (adult foraging sites)	New Mexico	Multiple	Grazing	18.3–24.1	--	42.0–59.3	--	40.7–58.0	--	--	--
Fields, 2004[f] (nests)	Kansas	Tame grassland (CRP)	Interseeded	42.0	28.2[b]	75.9	4.9	0	18.1	--	--
Gehrt and others, 2020[e] (leks)	Kansas	Multiple	--	5.4–40.6	0–8.6[b]	20.1–89.0	0.2–30.3	0–13.1	2.5–57.8	1.8–40.4	0.02–2.4
Giesen, 1994[d] (nests)	Colorado	Multiple	Grazing	51	32[b]	29.4	1.4	7.2[g]	69.5	--	--
Grisham and others, 2014 (nests)	Texas	Sand shinnery oak grassland	Grazing	--	17[b]	21.7	5.2	38.6	7.3	26.7	--
Hagen and others, 2005 (broods)	Kansas	Sand sagebrush (*Artemisia filifolia*) prairie	--	--	28.1[b]	13.0	14.1	8.9	--	--	--

Table D1. Measured values of vegetation structure and composition in Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*) breeding habitat by study. The parenthetical descriptors following authorship and year in the "Study" column indicate that the vegetation measurements were taken in locations or under conditions specified in the descriptor; no descriptor implies that measurements were taken within the general study area.—Continued

[cm, centimeter; %, percent; --, no data; CRP, Conservation Reserve Program; >, greater than; spp., species]

Study	State or province	Habitat	Management practice or treatment	Vegetation height (cm)	Vegetation height-density (cm)	Grass cover (%)	Forb cover (%)	Shrub cover (%)	Bare ground cover (%)	Litter cover (%)	Litter depth (cm)
Haukos and Smith, 1989 (nests)	Texas	Sand shinnery oak grassland	Multiple	45	70[b]	--	--	--	--	--	--
Jones, 1963a (leks)	Oklahoma	Sand sagebrush grassland	--	10	--	43	--	--	--	--	--
Jones, 1963a (nests)	Oklahoma	Sand sagebrush grassland	--	45	--	55	--	17	--	--	--
Jones, 1963a (broods)	Oklahoma	Sand sagebrush grassland	--	80–200	--	--	15[h]	--	--	--	--
Lautenbach, 2015[i] (nests)	Kansas	Multiple	Grazed	--	19.8[b]	57.6	13.3	3.5	4.3	24.5	2.7
Lautenbach and others, 2019 (nests)	Kansas	Mixed-grass prairie	Grazed	--	--	54.0	21.0	1.3	8.3	15.7	--
Lautenbach and others, 2019 (nests)	Kansas, Colorado	Multiple	Multiple	--	--	63.9	7.5	2.0	6.9	23.7	--
Patten and others, 2006; Patten and Kelly, 2010 (nests)	New Mexico	Sand shinnery oak grassland	Grazed, sprayed	63.8[a]	--	47.3	--	53.8	--	--	--
Pitman and others, 2005 (nests)	Kansas	Sand sagebrush prairie	Grazed	16.3, 19.2, 43.8[j]	24.0[b]	37.2	8.4	15.2[k]	37.8	--	--
Riley and others, 1992 (successful nests)	New Mexico	Mixed-grass prairie	--	66.6	--	23.8–64.0	3.1–10.0	32.5–66.2	--	--	--
Riley and others, 1992 (unsuccessful nests)	New Mexico	Mixed-grass prairie	--	34.9	--	37.9–49.6	7.4–19.1	31.3–54.7	--	--	--
Riley and Davis, 1993 (broods)	New Mexico	Mixed-grass prairie	--	25	--	42.8	14.6	42.6	63.1	--	--
Sullins and others, 2018	Kansas	Mixed-grass prairie, shortgrass prairie	Grazed	17.1[l]	--	59.2	8.1	1.8	15.4	19.4	1.2
Sullins and others, 2018	Kansas	Tame grassland (CRP)	Hayed warm-season	32.3[l]	--	64.5	7.0	0.01	8.0	23.1	2.7
Taylor, 1979 (leks)	Texas	Shinnery oak/sand sagebrush grassland	Multiple	10–20[m]	--	--	--	--	--	--	--

Table D1. Measured values of vegetation structure and composition in Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*) breeding habitat by study. The parenthetical descriptors following authorship and year in the "Study" column indicate that the vegetation measurements were taken in locations or under conditions specified in the descriptor; no descriptor implies that measurements were taken within the general study area.—Continued

[cm, centimeter; %, percent; --, no data; CRP, Conservation Reserve Program; >, greater than; spp., species]

Study	State or province	Habitat	Management practice or treatment	Vegetation height (cm)	Vegetation height-density (cm)	Grass cover (%)	Forb cover (%)	Shrub cover (%)	Bare ground cover (%)	Litter cover (%)	Litter depth (cm)
Wilson, 1982 (nests)[e,n]	New Mexico	Multiple	--	42–52	--	3.1–13.2	--	21.4–28.3	39–49.1	44.2–52.3	--
Wisdom, 1980[o] (nests)	New Mexico	Shinnery oak grassland	Grazed	33.8–63.8[a]	--	28.5–77.7	0–14.3	22.2–57.1	38.3–59.1	31.7–42.9	--

[a]Canopy height.

[b]Visual obstruction reading (Robel and others, 1970).

[c]Height of shrubs.

[d]The sum of the percentages is >100%, based on the line-intercept method of Canfield (1941).

[e]Range across habitat types.

[f]Values represent averages for grassland CRP (23 nests), interseeded CRP (19 nests), rangeland (16 nests), and cropland (2 nests).

[g]Sand sagebrush cover.

[h]Western ragweed (*Ambrosia psilostachya*) cover.

[i]Values represent averages across four study sites.

[j]Forb, grass, and sagebrush (*Artemisia* spp.) height, respectively.

[k]Sagebrush cover.

[l]Grass height.

[m]Shinnery oak height.

[n]The sum of the percentages is >100%, based on the line-point method of Heady and others (1959).

[o]Values represent range of values across three habitat subtypes.

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Publishing support provided by the
Rolla Publishing Service Center

Jamison and others—**The Effects of Management Practices on Grassland Birds—Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*)**—Professional Paper 1842–D

ISSN 2330-7102 (online)
https://doi.org/10.3133/pp1842D