Chapter 4.3. Sagebrush Rangelands and Greater Sage-grouse in Northeastern California

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Sagebrush Rangelands

Sagebrush (*Artemisia* species) habitat, an intricate, species-rich mosaic of different sagebrush species and a remarkably diverse assemblage of grasses, forbs, and other shrubs, once covered about 170 million acres (69 million ha) across the Western United States (fig. 4.3.1). Noss et al. (1995) note that sagebrush habitat is an imperiled ecosystem because of its degradation, fragmentation, or removal by humans (Connelly et al. 2011), including conversion to agriculture (Leonard et al. 2000) compounded by other factors such as invasion by nonnative annual grasses, encroachment by junipers and piñon pines, improper grazing, and climate change (Davies et al. 2011) that interact in complex ways (see Finch et al. 2015). Additional discussion about climate impacts on sagebrush rangelands can be found in Chapter 6.1 (Wright, this synthesis, *Ecological Disturbance in the Context of a Changing Climate: Implications for Land Management in Northeastern California*).

On the Lassen and Modoc National Forests, sagebrush rangelands provide habitat for obligate species (they only live in sagebrush ecosystems) and facultative species (they use sagebrush ecosystems as well as other ecosystems). Sagebrush-obligate species include pygmy rabbit (*Brachylagus idahoensis*), sagebrush vole (*Lemmiscus curtatus*), pronghorn (*Antilocapra americana*), sagebrush sparrow (*Artemisiospiza nevadensis*), sage thrasher (*Oreoscoptes montanus*), and northern sagebrush lizard (*Sceloporus graciosus graciosus*) (fig. 4.3.2). Noteworthy facultative species are sandhill crane (*Grus canadensis*), elk (*Cervus canadensis*), and mule deer (*Odocoileus hemionus*). Sagebrush rangelands also host a wide variety of invertebrates, including pollinating insects and monarch butterflies (*Danaus plexippus*). Many of these animals are

on the California list of Species of Greatest Conservation Need (Gonzales and Hoshi 2015). The pygmy rabbit, once rare in Lassen and Modoc Counties, now appears to be locally extinct (Larrucea and Brussard 2008).

Some conservationists have suggested that greater sage-grouse (*Centrocercus urophasianus*) serve as an "umbrella species" for conservation and restoration of sagebrush ecosystems because their status is an indicator of overall sagebrush ecosystem health. The assumption with this management philosophy is that other sagebrush-obligate species of concern will simultaneously benefit when the sagebrush ecosystem is managed for greater sage-grouse (Rowland et al. 2006). Carlisle et al. (2018) note, however, that while this may be appropriate at the landscape level, some treatments applied at the local level to benefit sage-grouse (e.g., enhance forb abundance by removing sagebrush) may reduce abundance of other sagebrush-obligate species at that local level.

Further, when managers are considering conservation and restoration efforts, they should look for opportunities where projects can meet multiple objectives simultaneously (see Dumroese et al. 2016). Indeed, managing sagebrush rangelands toward a rich mosaic of sagebrush, other sagebrush steppe shrubs, forbs, grasses, and wetland plants can enhance habitat for greater sage-grouse and other wildlife. For example, Copeland et al. (2014) documented that conservation measures for greater sage-grouse overlapped with migration corridors (about 70 percent), stopover locations (about 75 percent), and wintering areas (about 50 to 90 percent) of mule deer in Wyoming, yielding benefits to the herd. Such conservation efforts could also have strong monetary returns. For example, Horney (2010) notes that the decline in greater sage-grouse populations due to increases in juniper canopy cover coincides with loss of habitat and a dramatic decrease in the population of the local mule deer in Northeastern California, from 45,000 animals in the 1950s (160,000 according to Longhurst et al. 1952) to about 4,000 animals in 2008. Loft (1998) calculated, using hunter surveys, that between 1987 and 1997 deer hunting revenue dropped precipitously in Lassen ($5.4 million to $830,000) and Modoc ($4.7 million to $550,000) Counties.

The Decline of Greater Sage-grouse

An iconic symbol of sagebrush rangeland is the greater sage-grouse, and not surprisingly, populations of greater sage-grouse are declining in concert with the loss of

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Figure 4.3.1—Excellent sagebrush habitat in Lassen County supports species that only reside in sagebrush, as well as other species for which sagebrush can be an optional habitat (photo by Dawn M. Davis, used with permission).

quality sagebrush rangeland habitat across its range (see Chapter 3.2, Dumroese, this synthesis, *Rangeland in Northeastern California* for more discussion). Between 1965 and 1985 the population declined 70 percent across the range (Connelly et al. 2004) and the annual rate of decline of male birds (used as an estimate of population size) from 1965 through 2015 was about 2 percent, whereas the loss of leks was about 8 percent annually (Nielsen et al. 2015). This decline prompted the U.S. Department of the Interior, U.S. Fish and Wildlife Service (USFWS) to determine if the greater sage-grouse required protection under the Endangered Species Act of 1973; they concluded in 2005 that listing was not warranted. Challenged in court, the USFWS again reviewed status, and based on implementation of "science-based regulatory mechanisms in Federal and State plants [that] have substantially reduced risks to more than 90 percent of the

Figure 4.3.2—The northern sagebrush lizard requires sagebrush habitat for its livelihood (photo by Tony Kurz, used with permission).

species' modeled breeding habitats..." (https://www.fws.gov/greatersagegrouse/status.php) deemed listing was not warranted in 2015 (Federal Register 2015), but indicated the status of greater sage-grouse will be re-evaluated in 2020 (USDOI 2015). Despite these mechanisms and focused attention across public and private land ownerships, Garton et al. (2015) note little short-term success in stabilizing declining greater sage-grouse populations.

The same decline in greater sage-grouse populations is occurring in Northeastern California. Historically, greater sage-grouse were plentiful on the Modoc National Forest (hereafter the Modoc), despite this area being on the periphery of the species' range. Brown (1945) recounts seeing lines of hunters along the roads several miles in length easily shooting the low-flying, large birds, resulting in near extirpation of the species. A ban on hunting followed by revised bag limits was showing benefits by 1945, and Brown (1945) was optimistic about the species future, especially in the Devil's Garden area of the Modoc. Hunting was reinstated in the early 1950s, but from then until the early 1980s the estimated harvest of greater sage-grouse declined nearly 60 percent on the Lassen National Forest (hereafter the Lassen) and 86 percent on the Modoc (Horney 2010). The number of active leks (sparsely vegetated sites where males perform elaborate strutting to attract and mate with females) in the Devil's Garden Population Management Unit dropped from a high of 29 in 2000 to a single lek for the years 2001 to 2007, and on the Clear Lake National Wildlife Refuge that lies entirely within the Modoc, the number of male birds dropped from a high of about 60 in 1990 to an average of about 8 for the years 1999 to 2009 (Horney 2010).

Landscape Requirements

At the landscape level, modeling by Arkle et al. (2014) concluded that the probability of greater sage-grouse occupying a site was greatest when the cover of low (dwarf) sagebrush (*A. arbuscula, A. nova,* or *A. tripartita*) was 10 to 20 percent and that of Wyoming big sagebrush (*A. tridentata wyomingensis*) was 10 to 15 percent. Greater sage-grouse have been shown to prefer browsing on dwarf sagebrush, which has a lower monoterpene level than that Wyoming big sagebrush and requires less metabolic energy to digest, even when dwarf sagebrush is less abundant (Frye et al. 2013). While the taller stature of Wyoming big sagebrush does, however, provide superior nesting locations and escape cover, and can be associated with greater cover of forbs and grasses, greater sage-grouse readily and successfully use dwarf sagebrush habitat for nesting (Musil 2011).

Spatial Requirements and Annual Movements

Greater sage-grouse are, in general, wanderers, using vast areas of sagebrush habitat for courting, cover, and food in often complicated movements (Eng and Schladweiler 1972). For example, the annual migration of one greater sage-grouse population covers about 150 miles (240 km), and birds may roam 100 miles (160 km) in just 18 days (Smith 2013). In Northeastern California, birds may annually roam (straight-line distance) nearly 19 miles (30 km) (Davis et al. 2014). Such large distances generally correspond to large home ranges. Many studies have examined the home range of greater sage-grouse (e.g., Bruce et al. 2011; Davis et al. 2014; Hagen 1999; Leonard et al. 2000; Schroeder et al. 1999; Stonehouse et al. 2015), but different methodologies, numbers of observations, sites, elevations, seasons, quality of habitat, study objectives, and so on hamper the ability to compare results beyond general trends.

Traditionally, populations of greater sage-grouse have been classified as either migratory or nonmigratory (resident). Migratory populations move more than 10 km between distinct seasonal ranges (i.e., breeding, summer, autumn, winter) to complete their life histories, whereas the seasonal movement of resident populations overlaps within the same area (Connelly et al. 2000). Smith (2013) found that greater sage-grouse migrated about 150 miles (240 km) from winter ranges in Montana to summer ranges in Saskatchewan, whereas Leonard et al. (2000) noted annual migrations in Southeastern Idaho of about 68 miles (110 km). In Lassen County in Northeastern California, Davis et al. (2014) studied birds from 4 lek complexes (13 leks total) and found they moved an average of about 17 miles (27 km), although birds from one complex appeared to be more resident, never moving more than 6 miles (10 km) between seasonal ranges. Fedy et al. (2012), however, challenge this notion of migration. In Wyoming, they found that within populations, birds use different strategies, with some migrating long distances (more than 31 miles [50 km]) while others remained relatively sedentary. Across a range of Wyoming sites (populations), about 40 percent of each population had little inter-seasonal movement, and thus classifying a population as migratory or not may be inappropriate, and counterproductive to conservation, given

that individual birds display different strategies to fulfill their annual life history. It is noteworthy that Davis et al. (2014) also noted high variability in the annual movement of individual greater sage-grouse in Lassen County.

Davis and others (2014) examined habitat requirements and annual movement of greater sage-grouse within the population occurring on the Buffalo-Skedaddle Population Management Unit, adjacent to the Lassen. Using the minimum convex polygon (MCP) approach, which uses connected straight lines to define a perimeter enclosing all sightings of the species, they estimated the home range for the population was about 840,150 acres (340,000 ha). This simple method often overestimates home range size because the perimeter, in an effort to encompass all sightings, may include large areas not actually used, or used infrequently, by the species (Boulanger and White 1990). Given this drawback, Davis and others (2014) also determined the annual 95 percent fixed kernel home range size (the area where the birds were observed 95 percent of the time) was 185,300 acres (75,000 ha) and the 50 percent core-area size, where birds spent 50 percent of their time, was 20,000 acres (8,100 ha). Although Davis et al. (2014) caution that these values may underestimate home range size, these values fall within the results (6,600 to 276,400 ha [16,310 to 683,000 acres]) observed by others (Connelly et al. 1988, 2004; Leonard et al. 2000). Further, Davis et al. (2014) found that the winter home range (95 percent fixed kernel) for the Buffalo-Skedaddle population was only about 13,350 acres (5,400 ha) whereas the average home range (95 percent fixed kernel) for the remainder of the year was about 117,375 acres (47,620 ha). Population of greater sage-grouse in Southeastern Idaho (Leonard et al. 2000) and Central Montana (Wallestad 1975) also showed small winter ranges. Davis et al. (2014) found that the home range size for individual birds in Lassen County was highly variable (1,235 to 176,430 acres [500 to 71,300 ha]).

Within the home range of the population, individual greater sage-grouse can travel long distances and have different home ranges depending on sex, age, and lek of capture. In Northeastern California, Davis et al. (2014) found that females had a larger, average home range (28,660 acres, range = 12,355 to 176,185 acres [11,600 ha, range = 5,000 to 71,300 ha]) than did adult males (14,580 acres, range = 1,235 to 44,480 acres [5,900 ha, range = 5,000 to 18,000 ha]), the latter being more sedentary than yearling males (26,200 acres [10,600 ha]). Within home ranges, wet meadows are an important habitat; see Chapter 6.1, Wright, this synthesis, *Ecological Disturbance in the Context of a Changing Climate: Implications for Land Management in Northeastern California*, for more discussion.

While understanding average home range size for populations of greater sage-grouse is important, Fedy et al. (2012) urge caution in focusing conservation solely on core areas used by greater sage-grouse because of the long distances birds travel during a year in search of seasonal habitat requirements (that is, food, cover). The risk of focusing solely on core area is that such an approach may not adequately include all of the annual needs for the species (Aldridge and Boyce 2007; Doherty et al. 2010; Fedy et al. 2012).

Gene Flow and Augmentation

A concern with ever-increasing fragmentation of sagebrush rangelands and declining greater sage-grouse populations, especially at the periphery of the species' range, is that genetic diversity will decline as increasingly smaller populations become progressively isolated; this can lead to local extinction (Crist et al. 2017; Frankham 2005). Wisdom et al. (2011) concluded that greater sage-grouse in Northeastern California and on the periphery of the species' range were at greater risk for extinction than populations more centrally located with the species' range. Loss of genetic diversity can begin a chronic decline in the population because of a reduction in fitness, less disease resistance, and an impaired ability to react to disturbances (see Davis et al. 2015).

Recent attention in Lassen County has looked at habitat requirements of greater sage-grouse (Davis et al. 2014) and whether or not declining populations on this extreme western end of the range were genetically stable (Davis 2012; Davis et al. 2015). Sampling birds from 13 leks across 4 lek complexes, Davis et al. (2015) found genetic diversity was similar to that of populations with the species' core range and without differentiation among the leks (all leks had diverse genetics). Davis et al. (2015) suggest that the sage-grouse in Northeastern California are maintaining these high levels of genetic diversity by breeding among adjacent leks and/or from sage-grouse populations in Northern Nevada; such inter-population gene flow is the most likely scenario for greater sage-grouse (Oyler-McCance et al. 2005). Indeed, recent work (Cross et al. 2018; Row et al. 2018) notes that greater sage-grouse in Northeastern California have

genetic connectivity with birds in Oregon and potential connectivity with birds as far away as Southwestern Idaho. Davis et al. (2015) caution, however, that gene flow disrupted by fragmentation, resulting in reduced genetic diversity, may not become apparent for many generations; thus, Northeastern California birds may already be isolated from Nevada but the isolation is too soon to be detected. Finally, they note that within leks, breeding males and females were mostly unrelated and most likely it is the females moving long distances that aids gene flow and maintenance of genetic diversity.

For very small, isolated populations, genetic diversity could be augmented through introduction of greater sage-grouse from distant populations. In a review of 56 attempted translocations, Reese and Connelly (1997) found rather dismal results (less than 10 percent success). Attempts in Utah (Duvuvuei 2013; Gruber 2012), including one with long-term data (Baxter et al. 2008, 2009, 2013) have proven more successful, with acceptable survival and reproduction when placed in suitable habitat. On the Clear Lake National Wildlife Refuge located within the Modoc, Bell and George (2012) report good success with translocated greater sage-grouse. Hens moved during the breeding season and released at a lek quickly integrated into the local population and survival was similar to resident hens. Augmented with 59 hens, the number of males observed on the refuge lek increased from 5 in 2005 to 16 in 2011. Another approach, experimental in nature and somewhat controversial (see Wyoming Wildlife Federation 2017), is collection of eggs from wild nests, controlled rearing, and return of chicks to surrogate brooding hens (Thompson et al. 2015). The perceived advantages are: (1) reduced predation of eggs, (2) that "donor" hens may re-nest thus mitigating the potential effects on brood production within source populations, and (3) breeding age females are not moved to new locations; translocated birds, in addition to reducing the donor population, typically have lower survival than resident birds (Baxter et al. 2013; Duvuvuei 2013; Gruber 2012).

Seasonal Habitat Requirements

Leks

In early spring, male greater sage-grouse congregate on leks to court females. The lek itself generally occurs where sagebrush cover is minimal (less than 10 percent), such as open meadows, sparsely vegetated ridges, and even agricultural fields (Connelly et al. 2004; Ellis et al. 1989)

with generally flat and relatively smooth surfaces (Knick et al. 2013). Modeling the minimum ecological requirements for greater sage-grouse leks in the western portion of their range (including sites in Northeastern California) and using a 3.1-mile (5-km) radius, Knick et al. (2013) found that leks were present when:

- sagebrush-dominated landscape covered 79 percent of the area, compared to 28 percent of the historic leks no longer occupied;

- conifer forest covered less than 1 percent of the area; leks were absent when conifer cover was 40 percent or greater;

- surrounded by, on average, greater than 40 percent landscape cover of sagebrush;

- surrounded by, on average, less than 10 percent agriculture; leks were absent when agriculture exceeded 25 percent;

- densities of roads, powerlines, pipelines, and communication towers were low.

Nest-Site Habitat

A number of studies across the range of greater sage-grouse, including one from Lassen County, report the average distance females move from their lek of capture to their initial nest-site ranges from 1.3 miles (2.1 km) to 4.8 miles (7.8 km), with most studies reporting an average of about 3 miles (4.7 km), and a few studies showing a range of 0.1 to 19 miles (200 m to 30 km) (table 4.3.1). Lyon and Anderson (2003) note, however, that when leks are disturbed (in their study, well pads or roads), the distance from lek of capture to initial nest site nearly doubled, with 91 percent of the nests occurring within 1.9 miles (3 km) of the lek of capture compared to just 26 percent when leks were disturbed. Measuring the distance from lek of captured to females' initial nest sites in Northeastern California, Davis et al. (2014) found that 39 percent of the nests occurred within 1.9 miles (3 km) of the lek of capture, and 73 percent were within 3.1 miles (5 km), results similar to Holloran and Anderson (2005). Davis et al. (2014) also noted a success rate of 56 percent for nests within 3 miles of the lek; the success rate for nests beyond 3 miles was similar. Because of lek locations, some females may move long distances from their lek of capture to nest, with that nest location being much closer to a different lek. Females, especially successful females, show strong fidelity to nest sites (Davis et al. 2015; Fischer et al. 1993).

Table 4.3.1—Average distance female greater sage-grouse travel from leks to nesting sites.

Location	Author(s)	Average km (miles)	Range km (miles)
Northwestern Wyoming	Lyon and Anderson 2003	2.1 (1.3)	--
Southeastern Idaho	Fischer 1994	3.4 (2.1)	--
Colorado	Peterson 1980 (fide Schroeder et al. 1999)	4.0 (2.5)	--
Southeastern Idaho	Wakkinen et al. 1992	4.6 (2.9)	--
Southeastern Alberta	Aldridge and Brigham 2001	4.7 (2.9)	0.4 to 16 (0.2 to 9.9)
Northeastern California	Davis et al. 2014	4.7 (2.9)	--
Western / Central Wyoming	Holloran and Anderson 2005	4.7 (2.9)	0.2 to 27 (0.1 to 16.8)
Northcentral Montana	Moynahan et al. 2007	4.8 (3.0)	0.5 to 30 (0.3 to 18.6)
Southeastern Montana / Southwestern North Dakota	Herman-Brunson et al. 2007	4.9 (3.0)	--
Wyoming	Goebel 1980 (fide Schroeder et al. 1999)	6.2 (3.8)	--
Central Washington	Schroeder et al. 1999	7.8 (4.8)	--

Greater sage-grouse build their nests on the ground (fig. 4.3.3). Nests are predated by a variety of animals, some attracted by scent, for example, skunks (*Mephitidae*) and American badger (*Taxidea taxus*) and some by vision, for example, common raven (*Corvus corax*) and black-billed magpie (*Pica pica*). Coyotes (*Canis latrans*) do not appear to be important predators (Mezquida et al. 2006). Much research has been conducted to describe habitat features that reduce nest predation. Features such as grass height and cover; shrub species, height, and cover; and understory vegetation and cover have been examined, with studies showing positive, negative, and neutral results across these features at the nest level—these discrepancies may be due to differences in the local predator communities (see Coates and Delehanty 2010) and greater sage-grouse subsequently selecting nest sites in response to local predator pressure (Conover et al. 2010), with a preference toward greater concealment from visual (avian) predators (Connelly et al. 2004; Doherty et al. 2010; Kirol et al. 2012). At a landscape scale, recent work found that nesting locations had lower densities of avian predators than did random locations (Dinkins et al. 2012).

Of the predators, common ravens are receiving much attention because their populations are increasing dramatically across the Western United States (see Coates et al. 2014) and more common ravens increase predation levels (Coates and Delehanty 2010). The increase in common raven populations is thought to be associated

Figure 4.3.3—A female greater sage-grouse on a nest in Lassen County (photo by Dawn M. Davis, used with permission).

with anthropogenic disturbances that favor this species, such as provision of additional food sources (e.g., landfills) and electric / communication infrastructure that provides hunting perches and nesting sites (see Coates and Delehanty 2010; Coates et al. 2014; Dzialak et al. 2011; Harju et al. 2018; and references therein). In Wyoming, for every 0.6 miles (1 km) a nest was initiated closer to an overhead transmission line, the risk of nest and brood failure increased 12 and 38 percent, respectively (LeBeau et al. 2014). Knick et al. (2013) found that historic leks no longer active have much greater densities of powerlines and communication towers.

Data from a study in Elko County, Nevada, suggests that good nesting habitat has about 20 to 30 percent sagebrush cover and 40 percent or greater total shrub cover (Coates et al. 2010), similar to landscape-scale findings of Knick et al. (2013) and management guidelines proposed by Connelly et al. (2000). In addition to sagebrush canopy cover, grass height has long been identified as important; grasses are taller at nest sites compared to random locations (Hagen et al. 2007) and the occurrence of tall grass can, however, help mitigate decreased cover of sagebrush by obscuring nest sites (e.g., Davis et al. 2014; Kaczor et al. 2011). More recent research is, however, casting some doubt on the value of grass height as a factor in nest predation.

Height of grass and other herbaceous material changes rapidly during spring and this change in phenology coincides with greater sage-grouse nesting. Gibson et al. (2016b) asserts that collecting data without noting this transient nature in phenology may yield incorrect interpretations about vegetation height and brood success. Thus, recent work by Smith et al. (2018a), using data from previous studies in Idaho, Wyoming, and Montana that showed successful nests were associated with taller grass but adjusted for height for when nests were observed, found no difference in grass height between predated and nonpredated nests. Nonetheless, they do show that female greater sage-grouse preferred locating nests where grass was 4 to 8 inches (10 to 20 cm) tall. Gibson et al. (2016a), working in Central Nevada, found that female greater sage-grouse selected for nest sites associated with: (1) higher amounts of sagebrush and nonsagebrush cover heterogeneous in age (not dominated by uniform, tall shrubs); (2) more abundant, taller, and species-diverse forbs; and (3) taller live and residual grasses. This led Smith el al. (2018b) to conclude that the relationship between grass height and nest concealment is likely overstated, and thus strict guidelines for grass height should instead allow local managers flexibility (see Chapter 1 in Stiver et al. 2015), especially given that grass height showed more variability among growing seasons than among ranches following different grazing management plans.

In Lassen County on sites occupied by greater sage-grouse, sagebrush canopy cover is only about 10 percent (Davis et al. 2014), on the low end of the range for sagebrush communities (12 to 43 percent; Connelly et al. 2000). On this site, Davis (2012) found that grass height at the nest bowl significantly, and positively, influenced distribution of nest sites, whereas live sagebrush and shrub canopy cover, percent cover of grasses and bare ground, and nest

bowl shrub and forb height were not significant (fig. 4.3.4). About a third of the nests were located under big sagebrush (*Artemisia tridentata*), with others found beneath silver sagebrush (*A. cana*), little sagebrush (*A. arbuscular*), antelope bitterbrush (*Purshia tridentata*), greasewood (*Sarcobatus vermiculatus*), Douglas rabbitbrush (*Chrysothamnus viscidiflorus*), horsebrush (*Tetradymia* species), crested wheatgrass (*Agropyron cristatum*), bluebunch wheatgrass (*Pseudoroegneria spicata*), and basin wildrye (*Leymus cinereus*). Nest success was about 56 percent, similar to rates observed across the range of greater sage-grouse. Another study in Lassen County on a degraded site found that 59 percent of nests were under big sagebrush (Popham and Gutiérrez 2003) and that successful nests were further from the lek (2.2 vs. 1.2 miles [3.6 vs. 2.0 km]), occurred under taller shrubs (25 vs. 19 inches [65 vs. 50 cm]), and the height of visual obstruction was greater (15 vs. 13 inches [40 vs. 32 cm]).
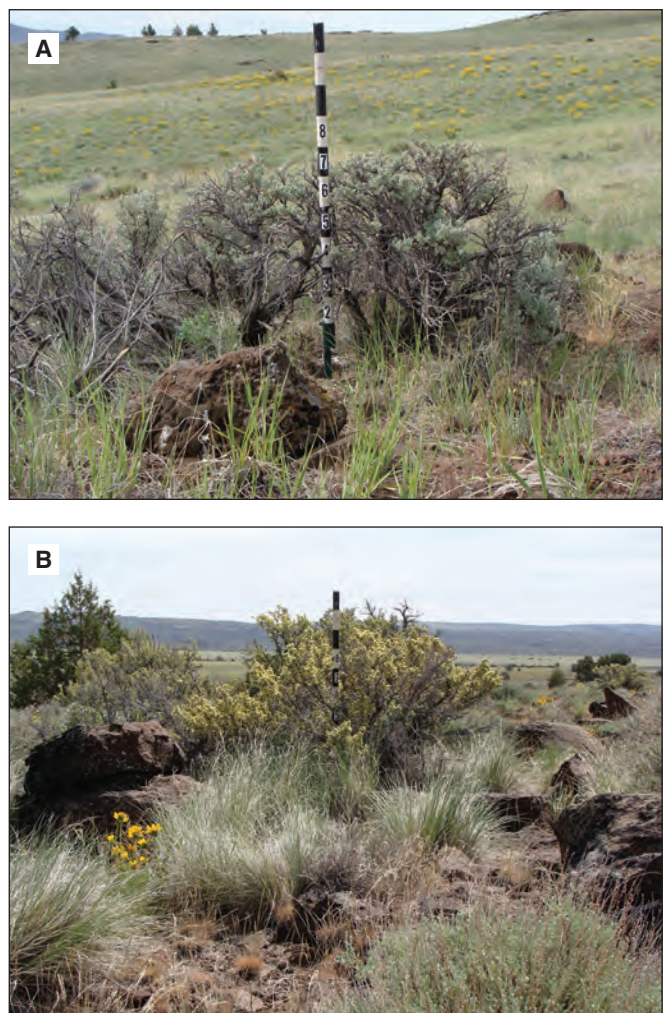

Figure 4.3.4—Examples of (A) unsuccessful and (B) successful greater sage-grouse nest sites in Lassen County (photo by Dawn M. Davis, used with permission).

Dietary Requirements

Spring

For pre-nesting hens, a variety of annual and perennial forbs constitute, by weight, about 18 to 50 percent of their diet (Barnett and Crawford 1994). In the Columbia Basin and Great Basin, *Lomatium* species are a significant portion of the diet of hens and chicks (Barnett 1992; Barnett and Crawford 1994; Ersch 2009); many other genera, including *Agoseris, Collomia, Crepis,* and *Phlox* are also consumed (see Dumroese et al. 2015, 2016). A large variety of annual invertebrates comprise 52 to 60 percent of the diet of very young chicks, with forb consumption increasing with age (Klebenow and Gray 1968; Peterson 1970). During the first week post-hatch in Southeastern Oregon, chicks consume ants (Hymenoptera: Formicidae), darkling beetles (Coleoptera: Tenebrionidae), scarab beetles (Coleoptera: Scarabaeidae), and various

caterpillars (Lepidoptera) (Ersch 2009). *Ericameria* and *Chrysothamnus* (rabbitbrush) support more caterpillars, a good protein source, during the spring than do mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) communities (Ersch 2009). Broods move to more open sagebrush canopy cover because, as canopy cover of sagebrush decreases, the abundance of grasses and forbs increases (Olson and Whitson 2002) as does the abundance of invertebrates hosted by the herbaceous plants (fig. 4.3.5).

Summer

During summer, greater sage-grouse search for forage areas rich in succulent forbs, including agricultural fields, sagebrush uplands, and moist drainages (Braun et al. 2005). Forbs comprise 50 percent or more of the juvenile and adult summer diets (Barnett 1992; Barnett and Crawford 1994; Connelly et al. 2000; Ersch 2009; Gregg et al. 2008; Klebenow and Gray 1968; Trueblood

Figure 4.3.5—During the spring, greater sage-grouse hens and chicks move to areas with more open sagebrush canopy because forbs and other herbaceous plants are more plentiful, such as this rangeland near Observation Point in eastern Lassen County. Greater sage-grouse consume a variety of forbs directly, and forbs also indirectly support greater sage-grouse by hosting numerous invertebrates that are essential to the diet of developing chicks (photo by Dawn M. Davis, used with permission).

1954; Wallestad et al. 1975). The suite of plants consumed during summer changes, reflecting species availability as the season progresses. Summer forbs can include milkvetch (*Astragalus*), lily (*Calochortus*), lupine (*Lupinus*), and aster (*Symphyotrichum*) (see Dumroese et al. 2015). Tall sagebrush (more than 15 inches [40 cm]) with adequate canopy cover (10 to 25 percent) are required for resting and escape (Braun et al. 2005).

Autumn

As native vegetation continues to dry out, greater sage-grouse move toward northerly aspects having more moisture to continue to support native forbs late into the season and consumption of sagebrush becomes more common (Braun et al. 2005). Autumn forbs can include buckwheat (*Eriogonum*), goldenrod (*Solidago*), and asters (*Symphyotrichum*) (see Dumroese et al. 2015). Birds, now gathering into larger flocks, begin to congregate in denser, taller stands of sagebrush (Braun et al. 2005).

Winter

Weather and snow conditions have a large impact on habitat use by greater sage-grouse. Flocks prefer areas with dense sagebrush (for cover) and where sagebrush extends 8 to 12 inches (20 to 30 cm) or more above the snow because more than 99 percent of their diet is sagebrush. Birds may also use windswept ridges and southerly aspects (Braun et al. 2005).

Impacts of Fire

Prescribed fire on Wyoming big sagebrush sites in Southeastern Idaho and Eastern Oregon yielded no benefit to greater sage-grouse in either the short- (1 to 3 year) or long- (up to 14 years) term for a variety of nesting and brooding metrics, even when 60 percent of the sagebrush was removed (Beck et al. 2009; Fischer et al. 1996; Rhodes et al. 2010). Similar results were found for wild- and prescribed-fire in mountain big sagebrush habitats in Southeastern Idaho (Nelle et al. 2000). Moreover, because of the slow recovery of sagebrush to a stature that supports nesting sites, prescribed fire may negatively impact nesting habitat (Nelle et al. 2000). In an examination of 211 plots across the Great Basin, Arkle et al. (2014) found few burned areas conducive to breeding (less than 10 percent), brood rearing (less than 6 percent), or use during critical winter months (less than 10 percent) because of a limited sagebrush overstory. Modeling by Pedersen et al. (2003) suggests that light, infrequent fires on sites in

Southeastern Idaho, where mountain big sagebrush was the predominate sagebrush species, have no effect on greater sage-grouse populations, whereas severe, frequent fires do, and that a combination of fire and sheep grazing on the season following fire would significantly decrease greater sage-grouse populations. Models by Coates et al. (2015) for the Great Basin, however, suggest that burning sagebrush near leks has a dampening effect on population growth, and in concert with the projected rates of burning and sagebrush recovery for the next 30 years, they predict steady and significant declines of greater sage-grouse in the Great Basin.

On sites within the Hart Mountain National Antelope Refuge, just northeast of the Modoc, and dominated by Wyoming big sagebrush, Pyle and Crawford (1996) found that spring prescribed fires generated more severe fires, that fires in both seasons greatly reduced shrub cover (similar to other studies), and that burning increased total forb cover and diversity. Unfortunately, response of greater sage-grouse to these changes in habitat was not measured. Similarly, Davis and Crawford (2014), working in Northwestern Nevada on the Sheldon National Wildlife Refuge, found that wildfire readily changed the mountain big sagebrush community structure from shrub-dominated to one dominated by native grasses and forbs 2 to 3 years post-burn. A decade later, little difference was noted in total forb cover, but sufficient shrub canopy had regenerated to provide suitable nesting cover. Moreover, abundance of arthropods, and in particular, ants, was unaffected by fire.

Wildfire in native rangeland can foster the invasion of invasive annual grasses, such as cheatgrass (*Bromus tectorum*). This starts a pernicious fire cycle, where the annual grasses burn more frequently than surrounding native rangeland (fig. 4.3.6). Each subsequent fire removes more of the perennial vegetation, chronically converting the shrub-bunchgrass communities required by greater sage-grouse into annual grasslands (D'Antonio and Vitousek 1992; Davison 1996). In Northwestern Nevada, however, Davis and Crawford (2014) report little change in the abundance of cheatgrass following wildfire on a mountain big sagebrush site where livestock grazing has been excluded since 1994.

Impacts of Energy Development and Vehicles

A robust literature concerning the impact of energy development on the sagebrush ecosystem has developed

Figure 4.3.6—Wildfire in sagebrush rangeland can destroy critical habitat required for obligate sagebrush species, as well as allow invasive species, such as cheatgrass, to become established. Often, invasion by cheatgrass changes the natural fire regime, leading to the establishment of vast monocultures of cheatgrass and loss of native flora and fauna diversity (photo by Amanda Shoaf, Forest Service).

during the past 2 decades, with particular focus on greater sage-grouse. Much of this work was done in Wyoming with natural gas production, but because common denominators of energy development, whether it be extracting oil, gas, or hot water (geothermal) from below ground, or operating windmills, are the need for a pad to operate from and supporting infrastructure (e.g., roads). Thus, the literature from natural gas extraction in Wyoming is pertinent to the Lassen and Modoc.

Energy development and transmission in sagebrush rangelands supporting greater sage-grouse has detrimental effects on the populations. Much of the recent energy development is in more pristine sagebrush communities supporting the greatest densities of greater sage-grouse and other sagebrush-obligate species (Bergquist et al. 2007; Crawford et al. 2004; Gilbert and Chalfou 2011; Kaiser 2006; Knick et al. 2003). Greater sage-grouse are affected by energy development and transmission because these activities fragment habitat, increase noise, benefit predators, and foster spread of nonnative, invasive plants. Waste-water holding ponds have potential to facilitate spread of West

Nile virus (Schrag et al. 2011), which can infect and rapidly kill greater sage-grouse, and has been detected across the West, including California (USGS 2006).

When well pads are installed near leks (0.25 to 0.5 miles [0.4 to 0.8 km]), the number of male birds in attendance during the breeding season drops dramatically (35 to 91 percent; Blickley et al. 2012a; Harju et al. 2010; Walker et al. 2007); the decrease in males also increases with increasing well-pad density (Harju et al. 2010). This decline can be acute (occurring during the first year; Walker et al. 2007) or more chronic (a delay in the decrease of males between the onset of development and measurable effects on leks; Harju et al. 2010). In one study, male attendance at leks dropped 29 percent when exposed to noise associated with natural gas drilling and 73 percent with noise from roadways (Blickley et al. 2012a) and males that remained on leks exposed to noise had higher levels of stress hormones (Blickley et al. 2012b). Using 30 years of data from Wyoming, Hess and Beck (2012) found unoccupied leks had 10 times more oil and gas wells in a 0.6-mile (1-km) radius than did occupied leks, and the

probability of a lek persisting dropped below 50 percent when well density was more than 2 per 247 acres (100 ha). Females were found to move further from leks disturbed by well-pad and road activity before initiating nests, nearly twice as far as females in areas without development (Lyon and Anderson 2003). During winter, greater sage-grouse are less likely to occupy habitat near wells (Doherty et al. 2008), even if that habitat is suitable and regardless of the activity levels at the wells (Matthew et al. 2015).

Wind energy development can affect greater sage-grouse, too. Zimmerling et al. (2013) estimate that every turbine is associated with 3 acres (1.2 ha) of habitat loss, and because each turbine requires a pad, the same issues observed with natural gas pads pertain, although traffic associated with turbines is much less than that for natural gas (4 vehicle visits per year for operation and maintenance versus 1,285 vehicle visits, respectively; see LeBeau et al. 2014 and Sawyer et al. 2009). This reduced disturbance may have less impact on the birds. However, work with open-country, gallinaceous species similar to greater sage-grouse (lesser prairie-chickens, *Tympanuchus pallidicinctus,* and greater prairie-chickens, *T. cupido*) found that birds avoided crossing under transmission lines, suggested that tall structures, including turbines, may inhibit use of suitable habitat near wind energy farms (Pruett et al. 2009). More recent work by LeBeau et al. (2017) suggests that habitat disturbance caused by wind farm infrastructure is more important than turbine height. They modeled that the resulting 2 percent habitat disturbance within 0.75 miles (1.2 km) of a string of 10 turbines caused by the actual turbine footprint and access road would decrease the selection of that habitat for brood-rearing and summer habitat by 60 percent.

As discussed above, electrical energy transmission lines provide hunting perches and nesting sites for avian predators of greater sage-grouse, and in particular, common ravens. Coates et al. (2014) found that the swath of habitat affected by common ravens using a transmission line supported by 65-foot (20-m) tall poles could be as much as 2.8 miles (4.5 km) wide, and LeBeau et al. (2014) found that nest and brood failure decreased with increasing distance from transmission lines.

In addition to the detrimental effects of motorized vehicle noise described above, vehicles can serve as vectors in the spread nonnative plant species. The magnitude of impact is influenced by level of road improvement, soil type, aspect, native vegetation type (i.e., forest or grassland),

and the nonnative species (Gelbard and Belnap 2003; Gelbard and Harrison 2003; Hansen and Clevenger 2005). The disturbed edges of roadways allow nonnative plant establishment. Although roadways in forests can facilitate spread of nonnative plants (e.g., Mortensen 2009), grasslands appear more susceptible to invasion (Hansen and Clevenger 2005). In semiarid grasslands, shrublands, and woodlands of Southern Utah, Gelbard and Belnap (2003) found that road type (paved, improved gravel surface, graded without gravel, four-wheel-drive track) was important, mainly because the zone of roadside disturbance increased with increasing development. The general trend was more weeds and less native plants in these disturbed zones. For example, the coverage of cheatgrass increased threefold when comparing four-wheel-drive tracks to paved roadways. This effect persisted past the disturbed zone; the number of nonnative species and their abundance 164 feet (50 m) outward from the edge of roadside disturbance was greater, and the richness of native species lower, along paved roads compared to four-wheel-drive tracks.

As described earlier, greater sage-grouse may act as "umbrella species" for other sagebrush-obligate species and species that can also thrive in the sagebrush ecosystem. Thus, it is likely that energy development may also have detrimental effects on other wildlife (Knick et al. 2003). Indeed, mule deer avoid natural gas wells, especially during winter (Sawyer et al. 2009) and Gilbert and Chalfoun (2011) noted well density decreased abundance of Brewer's sparrow (*Spizella breweri*), sage sparrow, and vesper sparrow (*Pooecetes gramineus*), but for horned larks (*Eremophila alpestris*), a species that prefers bare ground with little or no vegetation, their abundance increased. Sage thrashers (*Oreoscoptes montanus*), a sagebrush-obligate species, showed no response to energy development (fig. 4.3.7).

Impacts of Grazing

In a review of the literature, Beck and Mitchell (2000) found that livestock grazing can have direct and indirect impacts on sage-grouse habitat, and that these impacts can be positive or negative. Direct positive effects were associated with light grazing and rest-rotation grazing that encouraged forbs. Direct negative effects were associated with overgrazing that reduced forbs and high herd densities that physically disrupted nests. In Idaho, greater sage-grouse formed a new lek where domestic sheep had cleared an area. Indirect negative effects were associated with conversion of sagebrush to pure grass forage and

introduction of weeds because these lead to the loss of forb diversity and abundance. Recent work documented 25 years of habitat management on a study site and found that applying small-acreage sagebrush treatments that reduced shrub cover to release the forb understory sustained grazing and increased the number of birds counted on leks (Dahlgren et al. 2015). The authors note, however, that there is a limit to this conversion and the cumulative removal of sagebrush over time can negatively affect the availability of winter cover, resulting in winter mortality.

Determining and implementing a grazing management plan in concert with managing wildlife habitat requires an approach that combines plant community dynamics with habitat requirements with livestock use and their interactions (Vavra 2006). Detailed grazing management practices have been developed to foster compatibility between livestock and greater sage-grouse; these plans focus on annual management of forage to meet native plant growth requirements in order to either maintain a healthy sagebrush site or encourage progression to a more desired state (e.g., Cagney et al. 2010). Grazing has the most influence during nesting and early brood-rearing (Boyd et al. 2014); during this period maximum herbaceous cover and height is desired to decrease predation of nests and chicks. Similarly, Monroe et al. (2017) found that early grazing caused population decline, whereas sage-grouse populations responded positively to that same level of grazing after peak vegetation productivity. Moderate grazing can maintain habitat, sustained heavy grazing reduces forb abundance, and targeted grazing can decrease fine-fuel accumulation where annual invasive grasses are

Figure 4.3.7—Bird species react differently to disturbance caused by roads and well development. While abundance of Brewer's and sage sparrows decreased, abundance of sage thrashers (shown here) showed no response to energy development (photo by Tony Kurz, used with permission).

a concern. Pedersen et al. (2003), modeling fire and sheep grazing in mountain big sagebrush in Southeastern Idaho, found that any level of grazing decreased greater sage-grouse populations, and that grazing following burning could reduce populations by 14 percent (light grazing) to 40 percent (heavy grazing).

An indirect effect of grazing is greater sage-grouse mortality caused by collisions with fences; in Idaho about 0.4 strikes occurred per km (0.6 miles) of fence (Stevens et al. 2012a). For California, Stevens et al. (2013) predict that more than 10 percent of the area within 1.8 miles (3 km) of a lek could have more than 1 collision during a season. Prioritizing mitigation would probably affect 6 to 14 percent of the landscape (Stevens et al. 2013) and should focus on flat terrain having more than 0.6 miles (1 km) of fence per 247 acres (100 ha) within 1.2 miles (2 km) of active leks (Stevens et al. 2012a, 2013). Fences with wooden posts spaced less than 13 feet (4 m) apart reduced collisions (Stevens et al. 2012a) and placing reflective markers on fences reduced collisions about 57 to 83 percent (Stevens et al. 2012b; Van Lanen et al. 2017).

Impacts of Conifer Encroachment

As alluded to elsewhere (Moser, this synthesis, *Understanding and Managing the Dry Conifer Forests of Northeastern California*; Padgett, this synthesis, *Weeds, Wheels, Fire, and Juniper: Threats to Sagebrush Steppe*; earlier portions of this chapter) encroachment of juniper into new areas of the sagebrush steppe, as well as infill (increasing canopy closure of previously spare stands of trees) has ecological implications. Miller et al. (2001, 2005, 2008) report a 3- to 10-fold increase in distribution and a 10-fold increase in abundance, bringing the coverage of these species in the interior Western United States to more than 18 million ha (refer to the *Juniper Woodlands* section in Chapter 2.1, Moser, this synthesis, *Understanding and Managing the Dry Conifer Forests of Northeastern California* for more information on potential causes for this expansion). The transition of sites dominated by sagebrush, perennial grasses, and forbs to a piñon-juniper forestland follows a three-stage trajectory (Miller et al. 2005, 2013). Initially, few trees are established (phase 1, less than 10 percent cover). As the sagebrush canopy becomes codominant with the trees (phase 2, 10 to 30 percent cover), the herbaceous understory declines and once the trees dominate (phase 3, more than 30 percent), little to no herbaceous understory remains. Transition from sagebrush steppe to a conifer-

dominated landscape further fragments the sagebrush steppe ecosystem and pressures wildlife populations. For example, earlier in this chapter the precipitous decline of mule deer with increasing canopy of conifers in bitterbrush-dominated stands in Northeastern California was noted, a byproduct of the loss of herbaceous browse material. Similarly, conifer expansion is also thought to be detrimental to greater sage-grouse because the tree canopy decreases the herbaceous understory critical to sage-grouse brood success and the trees provide perches for avian predators of eggs (e.g., common ravens) and adult birds (e.g., hawks) (see Coates et al. 2017 and *Nest-Site Habitat* above). In Central Oregon during the breeding season, 75 percent of the greater sage-grouse were found in stands of *Artemisia arbuscula* (low sagebrush) having less than 5 percent juniper cover (Freese et al. 2016) and Baruch-Mordo et al. (2013) found that lek activity ceased with a juniper canopy cover of as little as 4 percent. More recent work by Coates et al. (2017) noted greater sage-

grouse avoided sites with canopy cover of 1.5 to 2 percent. Mapping by Falkowski et al. (2017) indicate nearly 40 percent of the greater sage-grouse range in California has more than the 4 percent threshold identified by Baruch-Mordo et al. (2013).

Recent science is demonstrating, however, that greater sage-grouse respond positively to conifer removal (fig. 4.3.8). In Northern Utah, Sandford et al. (2017) found that nest and brood success was greater for hens using habitat nearer areas where mechanical removal had occurred. Similarly, Severson et al. (2017) found that within a large, mostly mechanically treated area (34,000 ha [84,000 acres]) in Southeast Oregon just north of the Modoc (removal treatments from 2007 through 2014 with minimal fire; a portion of the nontreated, experiment control area was in Modoc County), removing conifers increased annual female and nest survival 6.6 and 18.8 percent, respectively, and they estimated a 25 percent increase in overall population growth compared to the nontreated

Figure 4.3.8—Removing juniper from sagebrush rangeland can benefit greater sage-grouse and other sagebrush-obligate species. Treating junipers while their densities are low and judiciously burning the slash to protect the remaining sagebrush allows forbs to rebound in abundance and retention of the woody canopy structure preferred by nesting greater sage-grouse (photo by Amanda Shoaf, Forest Service).

control areas. For the Severson et al. (2017) effort, individual stand-level treatments were 42 to 6,200 acres (17 to 2,500 ha) in size and cumulatively covered about 20 percent of the treated area (about 16,000 ac [6,500 ha]).

Although the abundance of perennial forbs was not consistently enhanced by a variety of conifer removal treatments, increases of 1.5- to 6-fold were observed (Bates et al. 2017). They conclude that mechanical removal and low disturbance fuel-reduction conifer treatments (essentially restricting burning to felled trees), especially in phase 1 and 2 conditions, may be best for greater sage-grouse in the short term. Compared to broadcast prescribed fires, these treatments yield a similar forb response while maintaining the critical shrub canopy required by the birds. Moreover, on phase 3 sites in Southeastern Oregon, conifer removal treatments followed by burning promoted cheatgrass; these sites had 4 to 16 times more cheatgrass than that found on phase 2 sites (Bates et al. 2013). Unfortunately, these treatments fail to remove young conifer seedlings and the seed bank, so follow-up treatments will be required. Boyd et al. (2017) note that prescribed, broadcast fire controls conifer regrowth about twice as long as mechanical felling, but reduction of the shrub canopy and the long-time horizon for it to regrow to a stature that supports greater sage-grouse (in excess of 20 to 30 years) may be prohibitive when quality habitat is needed to sustain the sage-grouse populations. Thus, they suggest restricting broadcast prescribed fire to late phase 2 and phase 3 areas where the forb/sagebrush component has already been so degraded that it currently fails to support greater sage-grouse. Doherty et al. (2018) used simulations to predict potential outcomes of juniper removal and suggest such an approach can assist land managers and stakeholders in better understanding biological returns on investment.

Removing all conifers, especially pre-European settlement junipers (i.e., those older than 150 years), may not be prudent as these trees have other functional traits. For example, these legacy trees can be important roost sites for bats. Trees with at least one cavity and proximity to water were more favored (Anthony 2016). Males preferred home ranges with low juniper canopy cover (less than 10 percent), whereas lactating females used woodlands with up to 20 percent canopy cover.

Severson et al. (2017) conclude that conifer removal may seem expensive but proactive management, that is, targeting areas where conifer encroachment is just

beginning (phase 1 sites), can yield positive benefits to overall ecosystem health (see Davies et al. 2011) as well as to ranch-level income (e.g., McClain 2012). They note that a $9 million investment on phase 1 sites having greater sage-grouse would, for example, treat all of Oregon. McClain (2012) modeled that for Southwestern Idaho sites, juniper encroachment from phase 1 to phase 2 would reduce livestock forage 37 percent and ranch income by 15 percent. Farzan et al. (2015) in modeling conifer removal scenarios in Lassen and Modoc Counties notes, however, that derived benefits will depend on goal prioritization at a landscape scale; prioritizing forage production provided little benefit to greater sage-grouse but targeting treatments to benefit the birds also derived forage benefits. See Chapter 3.2 (Dumroese, this synthesis, *Rangeland in Northeastern California*) for more information about prioritizing and restoring sagebrush steppe.

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