The Effects of Management Practices on Grassland Birds—Burrowing Owl (*Athene cunicularia hypugaea*)

Chapter P of

The Effects of Management Practices on Grassland Birds

Professional Paper 1842–P
Version 1.1, May 2023

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

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By Jill A. Shaffer,[1] Lawrence D. Igl,[1] Douglas H. Johnson,[1] Marriah L. Sondreal,[1] Christopher M. Goldade,[1,2] Paul A. Rabie,[1,3] Jason P. Thiele,[1,4] 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[1,5]

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square centimeter (cm^2)	0.001076	square foot (ft^2)
hectare (ha)	2.471	acre
hectare (ha)	0.003861	square mile (mi^2)
	Mass	
microgram (µg)	0.00000003527	ounce (oz)
milligram (mg)	0.00003527	ounce (oz)
kilogram (kg)	2.205	pound (lb)

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

$$°F = (1.8 \times °C) + 32.$$

Abbreviations

ABS	artificial burrow system
DDE	dichlorodiphenyldichloroethylene
NCA	Morley Nelson Snake River Birds of Prey National Conservation Area
n.d.	no date
sp.	species (an unspecified species within the genus)
spp.	species (applies to two or more species within the genus)
ssp.	subspecies

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The Effects of Management Practices on Grassland Birds—Burrowing Owl (*Athene cunicularia hypugaea*)

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Capsule Statement

Keys to Burrowing Owl (*Athene cunicularia hypugaea*) management include providing areas of short, sparse vegetation and maintaining populations of prey species and of burrowing mammals to ensure availability of burrows as nest sites. In particular, the conservation of black-tailed prairie dog (*Cynomys ludovicianus*) and Richardson's ground squirrel (*Urocitellus richardsonii*) colonies is vital to the preservation of Burrowing Owls on the Great Plains. Burrowing Owls have been reported to use habitats with less than (<) 31 centimeters (cm) average vegetation height, 5–12 cm visual obstruction reading, 12–36 percent grass cover, 29–45 percent forb cover, 1–11 percent shrub cover, 11–58 percent bare ground, and 6–27 percent litter cover. The descriptions of key vegetation characteristics are provided in table P1 (after the "References" section). Vernacular and scientific names of plants and animals follow the Integrated Taxonomic Information System (https://www.itis.gov).

Burrowing Owl. Illustration by Christopher M. Goldade, U.S. Geological Survey.

Breeding Range

Two subspecies of Burrowing Owl breed in Canada and the United States: the Western Burrowing Owl (*Athene cunicularia hypugaea*) and the Florida Burrowing Owl (*Athene cunicularia floridana*) (Poulin and others, 2020). This account focuses on the Western Burrowing Owl. Western Burrowing Owls breed from southern Alberta to southwestern Saskatchewan; south through east-central Washington, central Oregon, and southern California; and east to eastern North Dakota, west-central Kansas, and Texas (Klute and others, 2003; National Geographic Society, 2011; Poulin and others, 2020). Populations in the northern part of this range are migratory. The relative densities of Burrowing Owls in the United States and southern Canada, based on North American Breeding Bird Survey data (Sauer and others, 2014), are shown in figure P1 (not all geographic places mentioned in report are shown on figure).

Suitable Habitat

Burrowing Owls use a variety of habitats, generally preferring well-drained, level to gently sloping areas with sparse

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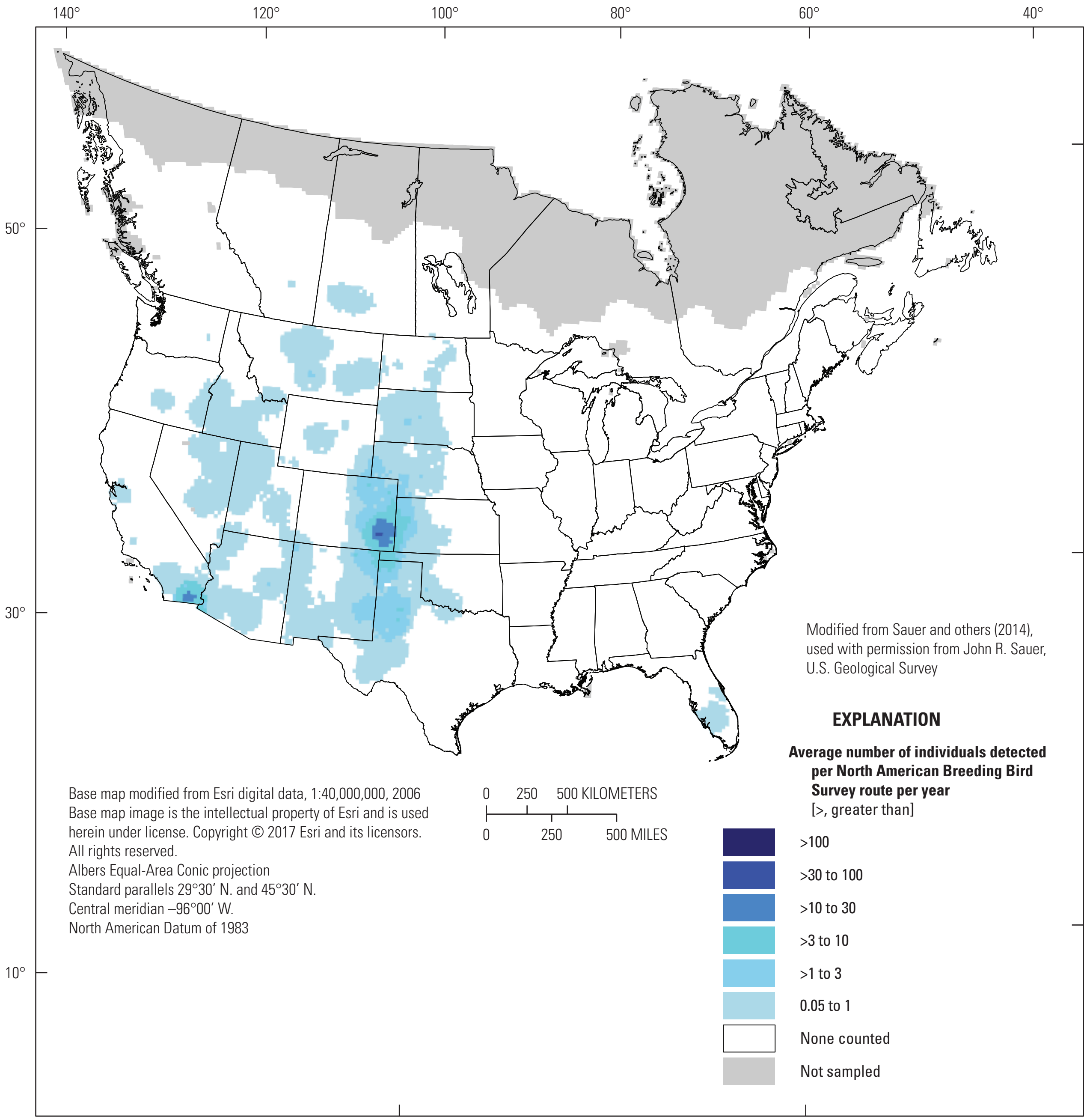

Figure P1. The breeding distribution of the Burrowing Owl (*Athene cunicularia*) in the United States and southern Canada, based on North American Breeding Bird Survey (BBS) data, 2008–12. The BBS abundance map provides only an approximation of breeding range edges.

vegetation and bare ground and containing available burrows created by fossorial mammals and, in some portions of their range, desert tortoises (*Gopherus* species [spp.]) (Crowe and Longshore, 2010, 2013; Conway, 2018; Poulin and others, 2020). Characteristic breeding habitat varies geographically. Burrowing Owls occupy shrubsteppe and sagebrush (*Artemisia* spp.) habitats throughout the Columbia Basin (Rich, 1984; Holmes and others, 2003); desert grasslands and scrub habitat, water-delivery canals within agricultural lands, and urban areas in the Sonoran Desert (Rosenberg and Haley, 2004; Beebe and others, 2014), Chihuahuan Desert (Botelho and Arrowood, 1998; Berardelli and others, 2010; Griffin and others, 2017), and Mojave Desert (Crowe and Longshore, 2010, 2013); and native and tame grasslands throughout the Great Plains (Poulin and others, 2020). The species has adapted to human-created habitats and landscapes, including golf courses (Thomsen, 1971; Smith and others, 2005), road and railway rights-of-way (Hall, 1961; Richards, 1972; Martin, 1973; Wedgwood, 1976), airports (Coulombe, 1971; Thomsen, 1971; Fisher and others, 2007), university campuses

(Botelho and Arrowood, 1998), towns and cities (Conway and others, 2006; Berardelli and others, 2010), and military installations (Arrowood and others, 2001; Gervais and others, 2003; Holmes and others, 2003). Because Burrowing Owls occupy such a diversity of habitats, the "Suitable Habitat" section first will describe the species' breeding habitats within the sagebrush and shrubsteppe ecosystems of the Columbia Basin of Washington, Oregon, and Idaho; followed by the desert grasslands and shrublands of California, Nevada, Arizona, and New Mexico; and end with descriptions for the Great Plains grasslands, including the mixed-grass, tallgrass, and shortgrass prairies from Canada to Texas.

Columbia Basin and Southwestern Desert Grasslands

Numbers of Burrowing Owl throughout the Columbia Basin and Sonoran and Chihuahuan deserts have expanded with the species' successful adaption to agricultural and urban habitats. In south-central Washington, Conway and others (2006) reported that landscapes dominated by agriculture (that is, irrigated cropland and pastures) and urban development (that is, urban, suburban, and industrial land uses) likely harbored the highest densities of Burrowing Owls in the State, even compared to populations in native sagebrush or shrubsteppe. Moulton and others (2006) and Bartok and Conway (2010) suggested that increased prey availability and diversity, suitable burrowing substrates, and adequate burrows in agricultural areas have attributed to the population growth of Burrowing Owls. Conway and others (2006) documented that nest density, nest success, number of fledglings per nesting attempt, and reuse of nest burrows were higher in agricultural landscapes than in urban landscapes, and that there was no difference between landscapes for clutch size and number of fledglings per successful nest; however, they also documented that natal recruitment and annual adult return rates were lower in agricultural landscapes. This latter finding suggested that agricultural areas could include "sink" populations (that is, populations within which death rates exceed birth rates; Pulliam, 1988). Within the urban areas, Smith and others (2005) compared Burrowing Owl nest productivity between artificial and natural burrows on and off golf courses and found that annual fecundity was lower on golf courses than off golf courses. In Idaho, Moulton and others (2006) compared availability of nest burrows within agricultural and nonagricultural habitats, where the former was defined as nests within 1 kilometer (km) of an irrigated agricultural field (nests could be in native vegetation surrounding and between agricultural fields) and the latter was defined as nests that were greater than (>) 3 km from irrigated fields and were typically native shrublands and grasslands highly invaded by nonnative vegetation and with no agricultural lands nearby. Availability of nest burrows did not differ between habitat types, and owl occupancy rates of artificial burrows were greater near agriculture. In another Idaho study, Belthoff and King (2002) found that owls nesting closer to irrigated fields had greater productivity (that is, the maximum number of fledging-age young at the burrow entrance) than nests farther away. In California, DeSante and others (2004) found that the highest remaining densities of Western Burrowing Owl throughout the species' North American range exist within the Imperial Valley, where conversion of the Sonoran Desert grasslands to irrigated agricultural operations has increased owl populations. In the Chihuahuan Desert of southern New Mexico, Berardelli and others (2010) reported that Burrowing Owl nest success was higher in grasslands compared to urban areas, although the number of young fledged per successful nest was higher in urban areas and mean fledging success per nest was similar.

Burrow Types

Burrowing Owls occupy the burrows of several species of fossorial mammals, which vary regionally. In the Columbia Basin and desert grasslands, these mammals include California ground squirrel (*Otospermophilus beecheyi*), spotted ground squirrel (*Xerospermophilus spilosoma*), round-tailed ground squirrel (*Xerospermophilus tereticaudus*), Townsend's ground squirrel (*Urocitellus townsendii*), rock squirrel (*Otospermophilus variegatus*), Douglas's squirrel (*Tamiasciurus douglasii*), Botta's pocket gopher (*Thomomys bottae*), Gunnison's prairie dog (*Cynomys gunnisoni*), black-tailed prairie dog, yellow-bellied marmot (*Marmota flaviventris*), common muskrat (*Ondatra zibethicus*), Ord's kangaroo rat (*Dipodomys ordii*), cottontail rabbits (*Sylvilagus* spp.), jackrabbits (*Lepus* spp.), and American badger (*Taxidea taxus*) (Stoner, 1932; Coulombe, 1971; Platt, 1971; Martin, 1973; Gleason and Johnson, 1985; Green and Anthony, 1989; Botelho and Arrowood, 1998; Arrowood and others, 2001; Rosenberg and Haley, 2004; Conway and others, 2006; Berardelli and others, 2010; Griffin and others, 2017). Conway (2018) provided a map that compares the distribution of the Burrowing Owl to the distributions of those fossorial mammals and tortoises upon which the owl depends for burrows, as well as a description of the hierarchy of the use of fossorial mammal burrows by Burrowing Owls in areas where species of burrowing mammal overlap. Burrowing Owls also occupy natural cavities created by lava flows; burrows in rock outcrops; naturally occurring crevices (Gleason and Johnson, 1985; Rich, 1986; Botelho and Arrowood, 1998); holes created by water seepage (Rosenberg and Haley, 2004); and erosion holes that form around cable housings and concrete culverts, slabs, canals, walls, light posts, cable covers, and building foundations (Botelho and Arrowood, 1996; Gervais and others, 2003; Beebe and others, 2014; Griffin and others, 2017; Smallwood and Morrison, 2018). The species has been found in piles of hay hollowed out by rabbits (Stoner, 1933). The species readily uses artificial nest burrows (also known as artificial burrow systems [ABSs]) (Collins and Landry, 1977; Henny and Blus, 1981; Smith and others, 2005; Smith and Belthoff 2001b). In the Mojave Desert in New Mexico, Burrowing Owls used burrows excavated by desert tortoises (*Gopherus agassizii*) and kit foxes (*Vulpes macrotis*) (Crowe and Longshore, 2010, 2013).

Vegetation Structure and Composition

Burrowing Owl breeding habitat throughout western States commonly contains some degree of anthropogenic development as well as vegetation composition consisting of native, tame, and domesticated commercial plant species (Rich, 1984; Rosenberg and Haley, 2004; Moulton and others, 2006). In Washington, Conway and others (2006) evaluated land use near nest burrows at two study areas. At one study area, most nest burrows were near agricultural fields, and 60 percent of the nest burrows had >50 percent of the area within 100 meters (m) consisting of agriculture. At the second study area, 57 percent of nests had some form of urban or industrial development within 100 m of the nest burrow, and 64 percent had native shrubsteppe. In north-central Oregon, Burrowing Owls nested in grazed shrubsteppe heavily invaded by non-native species (Green and Anthony, 1989; Holmes and others, 2003). Burrowing Owls in north-central Oregon nested in 100 percent (actual number not given) of the available American badger excavations in areas dominated by broom snakeweed (*Gutierrezia sarothrae*) (Green and Anthony, 1989). Owl nests also were found in open areas of short vegetation dominated by antelope bitterbrush (*Purshia tridentata*) or cheatgrass (downy brome [*Bromus tectorum*]). The species did not nest in habitats dominated by rabbitbrush (*Ericameria* species [sp.]) or bunchgrasses; these plants were too structurally unstable to be used as perches, and the average effective vegetation height of >20 cm restricted horizontal visibility for owls. Within the Morley Nelson Snake River Birds of Prey National Conservation Area (NCA) of south-central Idaho, Rich (1984) and Belthoff and King (2002) described the vegetation around Burrowing Owl nests as most commonly consisting of cheatgrass, tumble mustard (*Sisymbrium altissimum*), and crested wheatgrass (*Agropyron cristatum*). The area within 50 m of nest sites was characterized by bare ground, forb, rock, and cheatgrass; coverage of cheatgrass was greater at nest sites than at nonnest sites (Rich, 1986). Also within the NCA, Moulton and others (2006) reported that Burrowing Owls nested near shrubsteppe heavily invaded by cheatgrass, as well as near agricultural fields of alfalfa (*Medicago sativa*), common beet (*Beta vulgaris* subspecies [ssp.] *vulgaris*), and mint (*Mentha* spp.). Lehman and others (1998) reported that Burrowing Owls nested in shrubsteppe rangelands within the NCA, but specific vegetation characteristics or plant species were not described. In the Curlew Valley of southern Idaho and northern Utah, Burrowing Owls inhabited grazed sagebrush interspersed with plantings of crested wheatgrass (Platt, 1971). In an agricultural area of southeastern Idaho, seven of nine nests were adjacent to alfalfa fields; locations of the remaining two nests were not given (Gleason, 1978). Burrowing Owls that place nests near edges of agricultural fields in Idaho may have access to areas with higher insect populations and therefore may be closer to potential foraging areas (Rich, 1986).

As with populations in the Columbia Basin, Burrowing Owl densities in desert grassland ecoregions are highest within anthropogenic habitats (Rosenberg and Haley, 2004). On the Oakland, California, airport, Burrowing Owls nested within annual grasses, mustard (*Brassica* spp.), and coyotebrush (*Baccharis* spp.) (Thomsen, 1971). Within conservation areas at Moffett Federal Airfield, California, Burrowing Owls nested within open, grassy areas along inactive runways, selecting areas of tame grassland dominated by weeds, or in tame grasses on an adjacent golf course (Fisher and others, 2007). In the San Francisco urban environment, Trulio and Chromczak (2007) monitored 257 owl burrows in urban sites and 99 owl burrows in parkland environments (that is, managed for wildlife or human recreation); the number of nest burrows in urban areas declined 34 percent during a 6-year period, whereas the number of nest burrows in parkland environments remained constant. Nest success, number of young, and productivity (that is, the maximum number of young observed at a nest) did not differ between urban and parkland environments. On a naval air base in the San Joaquin Valley of central California, Burrowing Owls nested in burrows surrounded by fields of cotton (upland cotton [*Gossypium hirsutum*], Creole cotton [*Gossypium barbadense*]), alfalfa, garden tomatoes (*Solanum lycopersicum*), and corn (*Zea mays*), as well as along runway easements and taxiways and in unmowed grassy areas (Gervais and others, 2003). In the southern Joaquin Valley, within the largest remaining grasslands in California, Burrowing Owls nested within grasslands consisting of tame grasses such as fescue (*Vulpia* sp.), brome (*Bromus* sp.), filaree (*Erodium cicutarium*), and oats (*Avena* sp.), with remnant patches of native vegetation such as desert saltbush (*Atriplex polycarpa*), spinescale saltbush (*Atriplex spinifera*), nodding tussockgrass (*Nassella cernua*), iodinebush (*Allenrolfea occidentalis*), and big bluegrass (*Poa secunda* ssp. *secunda*) (Rosier and others, 2006). In the Imperial Valley of southern California, Burrowing Owls nested along water-delivery ditches and canals and along earthen drains near agricultural fields managed for sorghum (*Sorghum bicolor*), Bermudagrass (*Cynodon dactylon*), Kleingrass (*Panicum coloratum*), alfalfa, garden onions (*Allium cepa*), wheat (*Triticum aestivum*), lettuce (*Lactuca* spp.), sugar beets, cultivated carrots (*Daucus carota* variety *sativus*), broccoli (*Brassica oleracea* variety *italica*), and corn (Rosenberg and Haley, 2004; Bartok and Conway, 2010). In another study in the Imperial Valley, Bartok and Conway (2010) reported that occupied burrows detected during walking line-transect surveys along randomly selected 1-km segments of roads were more likely to be adjacent to fields where cropland was present than in areas with no cropland, but with no obvious association with any particular cropland type. Owls were more likely to be present along earthen irrigation ditches (as opposed to concrete ditches) and along recently maintained ditches than unmaintained ditches. Number of occupied burrows was positively associated with the mean number of banks along roads and not with trench depth or paved roads (Bartok and Conway, 2010). In urban areas of Arizona, Beebe and others (2014) reported that Burrowing Owls inhabited agricultural fields and areas along pedestrian right-of-way trails along canals. Areas occupied by Burrowing Owls had a lower proportion of developed land (that is, land covered by buildings and roads) compared to unoccupied sites. Within natural areas on the New Mexico State University campus in Las Cruces, Botelho and Arrowood (1998) reported nest burrows in desert vegetation dominated by creosote bush (*Larrea tridentata*) and mesquite (*Prosopis* spp.), as well as within cliff walls. Within disturbed areas, Burrowing Owls nested within irrigated cultivated grass and parking lots. Berardelli and others (2010) examined reproductive success of Burrowing Owls in urban Las Cruces and in grasslands north of Las Cruces. Urban environments included residential, office, commercial, industrial, community space, and open space (that is, agricultural fields, parks, arroyos, and vacant lots), and owls nested in all of these areas. The grassland environment consisted of alkali sacaton (*Sporobolus airoides*), tobosagrass (*Hilaria mutica*), burrograss (*Scleropogon brevifolius*), threeawn (*Aristida* spp.), black grama (*Bouteloua eriopoda*), honey mesquite (*Prosopis glandulosa*), creosote bush, cholla (*Cylindropuntia imbricata*), and yucca (*Yucca* spp.); grasslands were grazed, and owl nests were associated with black-tailed prairie dog colonies (Berardelli and others, 2010). The authors found that mean fledging success per nest was similar between landscape types. High reproductive success in the urban environment was associated with fewer surrounding nests, larger nesting territories, and open space, whereas high reproductive success in grasslands was associated with fewer surrounding nests, large nesting territories, nests being closer to edges of colonies, and lower fledgling success of the nearest nest (Berardelli and others, 2010). In another study in and near Las Cruces, Griffin and others (2017) defined landscapes as urban, green space, or agricultural; juvenile Burrowing Owl survival was highest in areas with a greater percentage of agriculture within a 1-km radius of nest burrows. Green space landscapes had the highest apparent mortality rate, suggesting that urban parks and patches of native vegetation adjacent to, or surrounded by, urban development do not protect young owls.

Great Plains

Nesting and Roosting Habitat

As discussed in the preceding paragraphs, Burrowing Owls in the western States frequently breed within agricultural and urban habitats. In the Great Plains, however, Burrowing Owls prefer unbroken native prairie and typically avoid cultivated land (Bent, 1961; Schmutz, 1997). Although Burrowing Owls occasionally nest in cropland (Scott, 1940; Bue, 1955; Grant, 1965; Butts, 1973; Schmutz and Moody, 1989; John and Romanow, 1993; Poulin and others, 2005), most of these nests probably fail when the land is cultivated (T.I. Wellicome, University of Alberta, Edmonton, Alberta, written commun. [n.d.]). Clayton and Schmutz (1999) examined habitat selection of breeding Burrowing Owls in southeastern Alberta and on the Regina Plains of southeastern Saskatchewan. Land use was categorized into native pasture, tame pasture, cultivation, and a miscellaneous category. All nest sites (100 percent of 21 nest sites over 2 years) in Alberta were in native pastures. Most roost sites also were in native pastures, with only 2 percent of 522 roost sites occurring in reseeded pastures (Clayton and Schmutz, 1999). Within pastures, Burrowing Owls preferred shorter (less than or equal to [≤] 10 cm) grass coverage for both nesting and roosting. In the Regina Plains, nest sites and roost sites were nearly equally divided between native pastures and tame pastures. Tame pastures were selected for roosting more than native pastures when availability of the different land uses was considered (Clayton and Schmutz, 1999). In cropland, owls did not selectively nest in short-statured grass but did nest in strips of medium-to-tall grass between fields and near ponds, granaries, and roads, possibly because suitable habitat was lacking. Although owls used short-statured grass for nesting and roosting in all habitats examined, they foraged over areas of taller grassland vegetation (Clayton and Schmutz, 1999). In southeastern Alberta, fewer nest sites (41 percent of 34) than systematically matched unoccupied sites (59 percent of 27) occurred within 0.5 km of cropland (Schmutz, 1997). In southern Saskatchewan, Warnock and Skeel (2002) concluded that nest success of Burrowing Owls in private agricultural land was similar to breeding success in grasslands within the federally managed Grasslands National Park. Of 67 pairs in the agricultural landscape, 62 pairs were solitary, whereas 13 pairs of 25 in grasslands were colonial and all nest sites were in prairie dog colonies.

In Colorado, Kansas, Nebraska, and Oklahoma, Burrowing Owls were significantly more abundant in shortgrass prairies than in dryland agriculture fields (McLachlan, 2007). The best vegetation model for explaining the occurrence of Burrowing Owls in Conservation Reserve Program fields in Colorado, Kansas, Nebraska, and Oklahoma incorporated grass height; occurrence was highest in fields in which <25 percent of the grass was taller than 15 cm (McLachlan, 2007). In northeastern Wyoming, Burrowing Owls avoided shrub cover when selecting nest sites; odds of using a burrow decreased 3 percent per every unit increase in percent shrub cover within 30 m (Lantz and others, 2007). In Colorado, Burrowing Owls were uncommon in cultivated land (Olendorff, 1973). In Oklahoma, Burrowing Owls placed nests near edges of agricultural fields, potentially to have greater access to invertebrate food resources (Butts, 1973).

Burrow Types

As elsewhere throughout their breeding range, Burrowing Owls in the Great Plains are not known to dig their own burrows, and the species usually relies on burrowing mammals to excavate nest sites (Salt and Wilk, 1958; Bent, 1961; Berdan and Linder, 1973; Stewart, 1975; Wedgwood, 1976; Desmond, 1991; Stockrahm, 1995; Desmond and Savidge, 1996, 1999; Sidle and others, 2001). Burrowing Owls often nest within colonies of black-tailed prairie dog or Richardson's ground squirrel (Bent, 1961; Grant, 1965; Berdan and Linder, 1973; Butts, 1973; Stewart, 1975; Konrad and Gilmer, 1984; Haug, 1985; MacCracken and others, 1985b; Ratcliff, 1986; Thompson and Anderson, 1988; James and others, 1990; Desmond, 1991; Plumpton and Lutz, 1993b; Desmond and others, 1995; Stockrahm, 1995; Desmond and Savidge, 1996; Toombs, 1997; Conway and Simon, 2003; Shaffer and Thiele, 2013). Burrows may be scarce in areas lacking colonial burrowing rodents (Desmond and Savidge, 1996); in these areas, Burrowing Owls often use American badger excavations as nest sites (Scott, 1940; James and Seabloom, 1968; Butts, 1973; Stewart, 1975; Wedgwood, 1976; Konrad and Gilmer, 1984; Haug and Oliphant, 1990; Desmond and Savidge, 1996). Burrowing Owls nest less commonly in the burrows of other ground squirrels, white-tailed prairie dogs (*Cynomys leucurus*), Gunnison's prairie dogs (*Cynomys gunnisoni*), woodchucks (*Marmota monax*), striped skunks (*Mephitis mephitis*), foxes (red [*Vulpes vulpes*] or gray [*Urocyon cinereoargenteus*]), gray wolves (*Canis lupus*), coyotes (*Canis latrans*), and nine-banded armadillos (*Dasypus novemcinctus*) (Bent, 1961; Grant, 1963; Zarn, 1974; Clark and others, 1982; Martin, 1983).

Throughout the Great Plains, Burrowing Owls appear to prefer black-tailed prairie dog colonies more than colonies of other fossorial mammal species, including white-tailed prairie dog colonies, presumably because habitat is more open and vegetation is shorter within the former (Martin, 1983; Thiele and others, 2013). Throughout prairie Canada and western North Dakota, Burrowing Owls are associated with colonies of black-tailed prairie dogs and Richardson's ground squirrels and occasionally with American badgers (Murphy and others, 2001, Environment Canada, 2010). In eastern Wyoming, nests may be in colonies of either black-tailed or white-tailed prairie dogs (Martin, 1983; Thompson, 1984; Thompson and Anderson, 1988; Korfanta and others, 2001). In the Platte River Valley of Nebraska, Burrowing Owl nests were found only in upland prairie and commonly were associated with black-tailed prairie dog colonies (Faanes and Lingle, 1995). Of 92 Burrowing Owl nests in western Nebraska, 85 percent occurred in black-tailed prairie dog colonies and 15 percent in American badger excavations (Desmond, 1991). In eastern Colorado, 80 percent of 423 Burrowing Owls were found on black-tailed prairie dog colonies (VerCauteren and others, 2001), and Plumpton and Lutz (1993b) reported Burrowing Owls nesting in black-tailed prairie dog colonies in northeastern Colorado. In southwestern Kansas and southeastern Colorado, Burrowing Owls were observed almost exclusively within black-tailed prairie dog colonies, and only one owl was known to use a burrow outside of a prairie dog colony (Winter and Cully, 2007). Of 543 Burrowing Owl nests in the Oklahoma Panhandle, 66 percent occurred in black-tailed prairie dog colonies, although colonies constituted <20 percent of the landscape surveyed (Butts, 1973; Butts and Lewis, 1982). Five nests were in wheat (*Triticum* spp.) fields and edges of fallow fields where vegetation was kept short by black-tailed prairie dogs, and one nest was in a pasture of sand sagebrush (*Artemisia filifolia*) and grass. In the southern High Plains of Texas, Burrowing Owls nest almost exclusively in black-tailed prairie dog colonies (Ray and others, 2016).

Burrowing Owls generally use active prairie dog colonies more than relatively inactive prairie dog colonies (Bent, 1961; Butts and Lewis, 1982; Toombs, 1997; Desmond and others, 2000; Sidle and others, 2001; Tipton and others, 2008). Owls that use larger, well-populated prairie dog colonies are more likely to return to nesting sites in successive breeding seasons, experience lower nest depredation, and have higher nesting success than owls in smaller colonies or in colonies with lower densities of prairie dogs (Butts, 1973; Desmond and Savidge, 1996, 1999; Toombs, 1997). Removal of prairie dogs (for example, by poisoning or shooting) from colonies is followed by rapid deterioration of burrows and encroachment of dense vegetation; owls eventually stop using sites from which prairie dogs have been eliminated (Grant, 1965; Butts, 1973; Butts and Lewis, 1982; Restani and others, 2001; Sidle and others, 2001). Additionally, burrows may require structural maintenance by prairie dogs to remain suitable for owls (MacCracken and others, 1985b; Desmond, 1991; Desmond and Savidge, 1999). In northeastern Wyoming, Lantz and others (2007) examined the preference by Burrowing Owls of active prairie dog colonies at four scales: burrow, nest-site (within 30 m of focal burrow), prairie dog colony (within 100 m of focal burrow), and landscape (within 2 km of focal burrow). Model results indicated that nest burrows had longer tunnels, more available burrows within 30 m, less shrub cover within 30 m, more prairie dog activity within 100 m, and were closer to water than unoccupied burrows. The odds of burrow occupancy by nesting Burrowing Owls increased 143 percent per meter for every unit increase in tunnel length, 5 percent per borrow with number of usable burrows within a 30-m radius of a nest burrow, and 2 percent per percent prairie dog activity within 100 m (Lantz and others, 2007). These same variables affected daily nest survival (Lantz and Conway, 2009). In north-central Colorado, black-tailed prairie dog colonies used by owls for nesting had higher burrow densities than black-tailed prairie dog colonies not used for nesting (Plumpton, 1992; Plumpton and Lutz, 1993b). In southeastern Colorado, black-tailed prairie dog colonies occupied by owls had higher mean total burrow density than unoccupied colonies (101 compared to 76 burrows per hectare [ha], respectively), higher mean active burrow density (46 compared to 27 burrows per ha, respectively), and higher mean percentage of active burrows (43 compared to 24 percent, respectively) (Toombs, 1997). The density of Burrowing Owls in black-tailed prairie dog colonies in northeastern Colorado was positively related to the percentage of active burrows (Hughes, 1993). At least 50 percent of the burrows were active in 26 of 27 occupied colonies. For prairie dog colonies with more than 90 percent active burrows, mean density of Burrowing Owls was 2.9 owls per ha, and for those with 70–80 percent active burrows, mean density was 0.6 owl per ha, suggesting that owls selected colonies with high proportions of active burrows. In Colorado, Tipton and others (2008, 2009) reported that Burrowing Owl occupancy was higher in active prairie dog colonies than in inactive colonies, although owl occupancy in inactive colonies was much higher than in grasslands or in agricultural fields. In this species account, the term "inactive" refers to prairie dog colonies or burrows that are not in use by prairie dogs, and the term "active" refers to prairie dog colonies or burrows that are in use by prairie dogs. In western Nebraska, Burrowing Owl density in black-tailed prairie dog colonies was negatively correlated with the density of inactive burrows (Desmond, 1991) and positively correlated with density of active burrows (Desmond and others, 2000). In Oklahoma, black-tailed prairie dog colonies became unsuitable for Burrowing Owls because of the encroachment of dense vegetation within 1–3 years after abandonment by prairie dogs (Butts, 1973; Butts and Lewis, 1982). In New Mexico shortgrass prairies, Goguen (2012) reported that Burrowing Owl abundance was higher on colonies of black-tailed prairie dogs than on similar prairies without colonies, indicating a strong association of owls with prairie dogs. American badgers also were more strongly associated with prairies hosting prairie dog colonies than prairies without colonies.

Vegetation Characteristics Near Burrows

The structural characteristics and species composition of vegetation around burrows may affect suitability as owl nesting locations throughout the Great Plains. In south-central Saskatchewan, owls nesting in tame pastures had higher nesting success than those nesting in native pastures, possibly because of lower depredation rates or greater prey availability in tame pastures than in native pastures (Haug, 1985). In North Dakota mixed-grass prairies, plant species near black-tailed prairie dog burrows included blue grama (*Bouteloua gracilis*), bluegrass (*Poa* spp.), inland saltgrass (*Distichlis spicata*), junegrass (*Koeleria pyramidata*), needle and thread (*Hesperostipa comata*), sedge (*Carex* spp.), smooth brome (*Bromus inermis*), western wheatgrass (*Pascopyrum smithii*), knotweed (*Polygonum* sp.), pigweed (*Amaranthus* spp.), sagebrush (*Artemisia* spp.), yellow sweetclover (*Melilotus officinalis*), and prairie wildrose (*Rosa arkansana*) (Stockrahm, 1995). Burrowing Owls in central Wyoming selected burrows in prairie dog colonies surrounded by early successional plant communities (Thompson, 1984). In central South Dakota, the seral stage of grazed mixed-grass prairie affected Burrowing Owl density; Burrowing Owl density decreased from early to late seral stages (Fritcher and others, 2004). In southwestern South Dakota, Burrowing Owls used inactive or abandoned black-tailed prairie dog burrows surrounded by a higher percentage of bare ground, lower shrub coverage, and shorter vegetation than found in the rest of the colony (MacCracken and others, 1985b). Across western South Dakota, Thiele (2012) found similar habitat characteristics as MacCracken and others (1985b) for nest sites in prairie dog colonies. In north-central Colorado, burrows used as nest sites were closer to roads, farther from perches (that is, poles and woody plant stems), and surrounded by more bare ground and by shorter grasses and forbs than nonnest burrows (Plumpton, 1992; Plumpton and Lutz, 1993b). Burrowing Owls selected black-tailed prairie dog burrows with shorter average grass height (6.6–6.9 compared to 7.0–9.7 cm, respectively) and shorter average forb height (7.3 compared to 11.2 cm, respectively) within a 25-m radius of the burrow than control burrows that were selected at random from active prairie dog towns. In the Oklahoma Panhandle, all of 542 nests were in shortgrass or mixed-grass pastures with vegetation ≤10 cm tall (Butts, 1973; Butts and Lewis, 1982).

Perch Sites

A typical characteristic of burrows used by Burrowing Owls is the nearby availability of observation perches. In north-central Oregon, Burrowing Owls used observation perches in habitats where the average vegetation height was >5 cm (Green and Anthony, 1989). Mean perch height was 85.9 cm. Owls did not nest in habitats dominated by rabbitbrush or bunchgrasses, probably because of a combination of tall (>20 cm) vegetation and a lack of perches. In north-central Oregon and north-central Colorado where vegetation was short (<4.7 and <8 cm, respectively), observation perches were not used (Green and Anthony, 1989) or were farther from nests than expected by chance (Plumpton and Lutz, 1991; Plumpton, 1992). In southwestern Idaho, Burrowing Owl productivity was most closely related to distance to perch, possibly owing to higher perches providing increased visibility for prey as well as against predators (Belthoff and King, 2002). In southern California, Coulombe (1971) commented that when an owl pair had young within the burrow, one adult, usually the male, perched in the surrounding area as a sentinel. Copulation sometimes occurred at this sentry perch. In southern Arizona, Beebe and others (2014) reported that owls in their study area rarely used perches >1 m tall. In western Minnesota, territories always included observation perches such as fence posts, dirt mounds, boulders, or utility poles (Grant, 1965).

Another characteristic of burrows used by Burrowing Owls is the species' tendency to distribute shredded manure from horse (*Equus caballus*) or domesticated cattle (*Bos taurus*) in and around burrows and to line nests with manure (Scott, 1940; Salt and Wilk, 1958; Martin, 1973; Green and Anthony, 1989; Desmond and others, 1997). The function of this behavior was once considered a predator-avoidance strategy (that is, to mask nest odors) (Martin, 1973; Green and Anthony, 1989; Desmond and others, 1997). More recent studies have found that Burrowing Owls may use manure to provide bait for their insect prey or to serve as a signal to conspecifics that the burrow is occupied (Smith, 2004; Smith and Conway, 2007). In north-central Oregon, 72 percent of 32 successful nests were lined with manure, whereas only 13 percent of 15 depredated nests were lined with manure (Green and Anthony, 1997). In contrast, no differences in depredation rates were found for natural or artificial nests that had manure experimentally added or removed in southeastern Washington (Smith and Conway, 2007).

Use of Satellite Burrows

Another characteristic behavior of adult and juvenile Burrowing Owls is to use several nonnest (satellite) burrows, possibly to avoid nest parasites (Grant, 1965; Butts, 1973; Butts and Lewis, 1982; Konrad and Gilmer, 1984; Haug, 1985; Desmond, 1991; Plumpton and Lutz, 1993b; Desmond and Savidge, 1999; Ronan and Rosenberg, 2014). Use of satellite burrows also may be a predator avoidance strategy; spreading the brood among several burrows may reduce the risk of losing the entire brood to a predator (Desmond, 1991; Desmond and others, 1997; Toombs, 1997; Desmond and Savidge, 1999). Juvenile Burrowing Owls may use satellite burrows before migration to gain knowledge of the natal landscape to aid in decisions about returning in subsequent breeding seasons or in response to necessary movements to escape inter-sibling competition for food (King and Belthoff, 2001; Todd and others, 2007). Research concerning satellite burrows varies from describing characteristics of satellite burrows and their use by adult and young to recording density of satellite burrows around nest burrows. These topics will be discussed by geography in the following text.

In Oregon, some nests had as many as six satellite burrows within 50 m of the nest, some of which were used in later years as nest burrows themselves (Holmes and others, 2003). In a migratory population of Burrowing Owls in southwestern Idaho, burrow and vegetation characteristics were compared between occupied burrows and unoccupied but presumably suitable burrows within 200 m of the nest burrow (Belthoff and King, 2002). Measured burrow characteristics were entrance angle, height, and width; mound height; and number of burrows within 10 m. Measured vegetation characteristics were vegetation height 2 m from burrow and distance to and height of perch; distance to irrigated agriculture and to roads also were measured. For burrow characteristics, only tunnel angle differed between occupied and unoccupied burrows; each 1 degree increase in tunnel slope equated to a 17 percent reduction in odds of owl use (Belthoff and King, 2002). No burrow characteristics were related to nest productivity (that is, the maximum number of fledging-age young at the burrow entrance). No difference in vegetation coverage classes existed between nest and unoccupied burrows (Belthoff and King, 2002). In the same area, King and Belthoff (2001) monitored juvenile Burrowing Owls and determined that each juvenile used an average of five satellite burrows for as many as 14 days. Owls remained within the natal area for an average of 58 days after hatching before moving permanently beyond 300 m. Catlin and Rosenberg (2014) studied a nonmigratory population of Burrowing Owls in southern California. Of 34 radiomarked juvenile owls, high individual variation in postfledging movements were noted, with this variation attributed to differences between sex, fledging date, and sibling relationships. Ronan and Rosenberg (2014) demonstrated that Burrowing Owls may abandon nest burrows when satellite burrows are not available.

In southern Saskatchewan, Todd and others (2007) evaluated use of satellite burrows by radio-marked owlets in large, contiguous grasslands (that is, greater than or equal to [≥] 95 ha) and in small, isolated patches (that is, ≤58 ha and ≥1.5 km to next nearest grassland patch). Some owlets were fed food supplements. Owlets receiving supplemental food and residing in large grassland patches moved greater distances from nest burrows than similarly fed owlets in small patches. Nonsupplemented owlets from large and small patches did not differ in the maximum distance moved from the nest. Two of 32 individuals from small patches moved >800 m, whereas 10 of 23 owlets from large patches moved >800 m. Owlets in large patches moved farther from their nest before migration than owlets in small patches, suggesting that owlets in small patches were unwilling or unable to cross the cropland matrix of a fragmented landscape (Todd and others, 2007). In central Saskatchewan, an average of six American badger burrows occurred within 30 m of the nest burrow (Haug, 1985; Haug and Oliphant, 1987, 1990). Of five nest burrows in western North Dakota, average distance from the four nearest nonnest burrows was 7.8 m (Stockrahm, 1995). Observations made at 15 burrow sites by James and Seabloom (1968) revealed that most family units in southwestern North Dakota used from one to three satellite burrows, although a few family units used as many as 10 satellite burrows. In eastern Wyoming, most (actual number not given) nesting areas contained 2–11 available burrows (Thompson, 1984). In western Nebraska, Burrowing Owl chicks selected satellite burrows that were recently active more than expected by chance, perhaps because active burrows were better maintained by prairie dogs than inactive burrows (Desmond and Savidge, 1999). Successful nests had more active burrows within 75 m of the nest burrow than unsuccessful nests. In Oklahoma, black-tailed prairie dog colonies appeared to be the only habitat with a sufficient density of burrows to provide satellite burrows for owls (Butts and Lewis, 1982). In Iowa, three Burrowing Owl families used from one to five satellite burrows of the American badger (Scott, 1940).

Soil Texture and Types

Soil texture may be an important factor in selection of nest burrows by Burrowing Owls and in longevity of ABSs. In north-central Oregon, soil texture affected the longevity and reoccupancy rates of American badger excavations used by Burrowing Owls (Green and Anthony, 1989). In this chapter, the term “reoccupy” refers to the repeated use across years of specific burrows or excavations by Burrowing Owls, and the term “reuse” refers to the repeated use across years of generalized nesting areas by Burrowing Owls; burrow fidelity is the reoccupation across years of specific burrows or excavations by the same owl or breeding pair. Within 1 year, 46 percent of 85 nest burrows in loamy sand soils were silted in, and 52 percent of the remaining 46 excavations were reoccupied. In contrast, none of 13 nests in silty loam soils were silted in, and all were reoccupied. In another study in north-central Oregon, Holmes and others (2003) reported that 71 percent of 28 nests in sandy loam were successful, compared to 43 percent of 35 nests in loamy sand and 58 percent of 36 nests in silt loam. Although these differences in nest success were not statistically different, the proportion of burrows surviving from one season to the next was affected by soil type; burrows in sandy loam and silty loam were twice and three times as likely to survive, respectively, as burrows in loamy sand. Burrow reuse among years was highest in sandy loam soils, followed by loamy sand and silty loam, indicating that high reuse in soils with low burrow longevity could limit owl nesting opportunities. Burrows in sandier soils were most likely to collapse from trampling by livestock (Holmes and others, 2003). In northern Washington, ABSs did not fill in as quickly in soils of a mixture of clay and silt loam as ABSs in sandy loam and loam sand soil types (Menzel, 2018). In south-central Washington, Larson (2009) reported that Burrowing Owls nested more frequently in loamy sand and sandy loam soils than in silt loam. In the Imperial Valley of southern California, Coulombe (1971) reported that 86 of 104 nest burrows were in firm, eroded sandstone with a softer layer of silt beneath. Optimal breeding habitat in portions of Colorado, Montana, Nebraska, North Dakota, South Dakota, and Wyoming occurred in heavily grazed aridic ustoll and typic boroll soils (Kantrud and Kologiski, 1982). Beebe and others (2014) identified a relationship between soil type and owl burrow occupancy near Phoenix, Arizona; Gilman loam was the most prevalent soil type in the study area, and 81.8 percent of 11 avian surveys in which owls occurred were in this soil type.

In southern Saskatchewan, Warnock and Skeel (2002) examined nest success of Burrowing Owls in private agricultural lands and in grasslands within the federally managed Grasslands National Park. Nest success did not differ among soil groups of lacustrine, alluvial, and morainal soils. Ideal Burrowing Owl nesting habitat in Saskatchewan appeared to occur in regions with lacustrine soils, though these areas also were heavily fragmented by cropland (Wellicome and Haug, 1995; Warnock and James, 1997; T.I. Wellicome, written commun. [n.d.]). Consequently, Burrowing Owls in Saskatchewan frequently are found in soils that are not suitable for agriculture, although this may not indicate a preference for those soils by the mammals that create burrows that the owls use (Wedgwood, 1976; T.I. Wellicome, written commun. [n.d.]). In southwestern South Dakota, soils at nest sites were silty clay loams (MacCracken and others, 1985b). Burrowing Owls in east-central Wyoming nested within black-tailed prairie dog colonies in sandy loam soils (Thompson, 1984). In southeastern Colorado, black-tailed prairie dog colonies, and thus owl nests, were not found on sandy soils; sand may be an unsuitable substrate for maintaining stable burrows (Toombs, 1997).

Climate

Spatial and temporal variation in precipitation and temperature may affect the occurrence, abundance, and distribution of Burrowing Owls. Wilsey and others (2019) compiled avian occurrence data from 40 datasets to project climate vulnerability scores under scenarios in which global mean temperature increases 1.5, 2, or 3 degrees Celsius (ºC). Burrowing Owls ranked neutral in vulnerability during the breeding season under all three scenarios. Under projected greenhouse gas emission scenarios described by the Intergovernmental Panel on Climate Change (2000), Langham and others (2015) categorized the Burrowing Owl as a climate-endangered species, indicating that the species would lose more than 50 percent of its current distribution by 2050 across all scenarios, with no net gain from potential range expansion. Using data from 16,728 point-count surveys in the northern Great Plains, Correll and others (2019) quantified the relationship between grassland habitat specialism and species population trends; the authors determined that species with high specialism rankings, such as the Burrowing Owl, are more likely to experience declining population trends. Fisher and others (2015) conducted an 8-year study in southern Saskatchewan and Alberta that examined the effect of extreme precipitation events on Burrowing Owl nest survival, owlet survival, and annual productivity. Extreme precipitation occurred in June, when the potential for renesting was unlikely. Of 165 nest failures, 19 percent were caused by flooding and 12 percent by periods of intense rain followed by abandonment. Daily nest survival declined as daily precipitation exceeded 20 millimeters (mm). Owlets raised in broods that received supplemental food had the highest survival under any amount of precipitation, whereas owlet survival in unsupplemented broods decreased as precipitation increased. Annual productivity between 1960 and 2010 declined by 12 percent. Neither vegetation type nor soil texture near nests altered the effect of extreme precipitation (Fisher and others, 2015). In an earlier study, Fisher and others (2004) examined the effect of wind speed, air temperature, and nesting stage on owl nest-defense behavior; owl aggressiveness towards humans declined as wind velocity and temperatures increased and increased after eggs hatched. Using data from 10 sites spanning South Dakota to northern Mexico, Porro and others (2020) evaluated timing of nest-initiation dates for Burrowing Owls relative to precipitation, temperature, drought, and oceanic Niño variables; drought conditions on winter and migratory grounds increased the probability of delayed nest initiation, whereas wet conditions increased the probability of early nest initiation. On the Kirtland Air Force Base in New Mexico, the onset of drought and concomitant decreased precipitation and increased air temperature coincided with a 98.1 percent decline in Burrowing Owl pairs (from 52 pairs to 1 pair) during a recent 16-year period (Cruz-McDonnell and Wolf, 2016). Timing of breeding-ground arrival, pair formation, nest initiation, and hatch dates was delayed, and body mass of adults and juveniles declined; the population was on the verge of extirpation. The average annual temperature and average maximum precipitation of the previous 24 months explained 84.8 percent of the variation in number of breeding pairs. Lundblad and others (2021) evaluated this same population of owls after the easing of drought conditions, when the population had rebounded. Adding an additional 7 years of data to those of Cruz-McDonnell and Wolf (2016), Lundblad and others (2021) concluded that interannual variation in number of breeding pairs, once drought had ceased, was associated with the total number of fledglings produced the previous year, and that the main reason for population recovery was the increase in locally produced fledglings.

Prey Habitat

Burrowing Owls prey primarily on arthropods and small mammals (Butts, 1973; Gleason, 1978; MacCracken and others, 1985a) but are believed to be opportunistic feeders (Bent, 1961; Tyler, 1983; Thompson and Anderson, 1988; John and Romanow, 1993). Cannibalism (including intraspecific predation and scavenging) has been reported in some Burrowing Owl populations (Robinson, 1954; Bent, 1961; Coulombe, 1971; Green, 1983; Wellicome, 1997a; Moulton and others, 2005; Poulin and Todd, 2006).

Burrowing Owls forage in a variety of habitats, including cropland, pastures, prairie dog colonies, fallow fields, and sparsely vegetated areas (Butts and Lewis, 1982; Thompson and Anderson, 1988; Desmond, 1991; Wellicome, 1994; Gervais and others, 2003; Poulin and others, 2020). In southern Alberta and Saskatchewan, Marsh and others (2014b) outfitted male Burrowing Owls with Global Positioning System dataloggers to evaluate the cover types (that is, cropland, native grassland, tame grassland, roadway, stubble, tame hayland, water bodies, and wetlands) in which owls foraged. Different models evaluated different aspects. Models relating to resource selection focused on locations where owls were present, whereas models relating to foraging success included such variables as time spent foraging, distance traveled, prey-capture rates, and net-caloric return (Marsh and others, 2014b). Burrowing Owls successfully foraged across all cover types but foraging success models indicated that not a single cover type was selected over others, except that wetlands were avoided relative to native grasslands. From a net-caloric return perspective, native grassland had the highest net gain. The relative lack of prey capture near roads and habitat edges suggested that these areas were suboptimal foraging locations or that owls were not foraging when in these areas. Stubble had high prey-capture return rates (Marsh and others, 2014b). In a related study, Marsh and others (2014a) reported that Burrowing Owls appeared to fly over habitat patches in which vegetative structure made prey detection or capture less likely. Fly-over locations had higher vegetation height-density and lower percentage bare ground than capture or hover locations, suggesting that dense cover was not optimal habitat for hunting owls. The structure of vegetation at capture and at hover locations was similar, suggesting that owls hover when vegetation structure is likely to increase prey detection and capture. Burrowing Owls flew, hovered, and captured prey in most of the cover types, likely searching for local areas that optimize prey detection and capture. Marsh and others (2014a) were unable to conclude that any cover type negatively affected Burrowing Owl reproductive success by lowering successful foraging attempts, although mature cropland was not available for examination during the study.

Prey abundance may affect reproductive success of Burrowing Owls (Gleason, 1978; Wellicome, 1994; Clayton, 1997; Wellicome and others, 1997; Poulin and others, 2001). In southeastern Idaho, occurrences of Great Basin pocket mice (*Perognathus parvus*) and burying beetles (*Nicrophorus* spp.), potential prey of Burrowing Owls, were positively correlated with occurrence of cheatgrass, whereas the abundance of montane voles (*Microtus montanus*) was positively correlated with area of farmland (Rich, 1986; Moulton and others, 2005). In Idaho, Burrowing Owls foraged in irrigated crop fields where montane voles were plentiful (Rich, 1986). In southeastern Idaho, starvation among fledgling and dispersing juvenile owls appeared to be an important cause of mortality (Gleason, 1978). Prey abundance may strongly affect postfledging survival (Todd and others, 2003). In California, juvenile owls were observed foraging along farm roads and field edges (Gervais and others, 2003).

In southeastern Alberta, the consumption of voles (*Microtus* spp.) and deer mice (*Peromyscus* spp.) by owls was highly disproportionate to prey abundance (Schmutz and others, 1991). Burrowing Owls preyed on voles and deer mice yet consumed 1.45 voles for every mouse consumed despite a 113:6 ratio of mice to voles trapped. Prey abundance appeared to be limiting during the nestling stage in a Saskatchewan study (Wellicome, 1994, 1997a; Wellicome and others, 1997). Owl pairs that received supplementary food (that is, dead mice and quail [species names not provided]) during the nestling stage produced 41 percent more fledglings than pairs that did not receive supplementary food (Wellicome and others, 1997), and cannibalism was lower at food-supplemented nests than at unsupplemented nests (Wellicome, 1997a). Additionally, fledglings from food-supplemented nests were heavier than fledglings from unsupplemented nests (Wellicome, 1994). Enhanced reproductive output during 1 year in southeastern Saskatchewan was attributed to an extremely high abundance of voles during the breeding season (Clayton, 1997; Wellicome, 1997a; Todd, 2001), as was a significant increase in the population of breeding pairs the following season (Poulin and others, 2001). Contrary to the above studies, Ray and others (2016) found no relationship between relative abundance of small mammals and Burrowing Owl productivity or number of nesting pairs in a Texas study.

In southeastern Saskatchewan, prey abundance and prey species richness were evaluated in native grassland, road rights-of-way, cropland, summer fallow, pasture, and hayland (Wellicome, 1994). Periodically tilled habitats (cropland and fallow fields) had lower prey species richness than did native grassland, road rights-of-way, pasture, or hayland. Habitats with tall (30–60 cm) vegetation cover (road rights-of-way, native grassland, and mature cropland) had higher prey abundance than hayland, pasture, or fallow fields (Wellicome, 1994; Wellicome and Haug, 1995). However, vegetation >100 cm tall may be too tall for Burrowing Owls to locate or catch prey; for example, although prey abundance in cropland was high in southern Saskatchewan, Burrowing Owls avoided cropland as foraging habitat (Haug and Oliphant, 1987; 1990; Wellicome, 1994). In a study focused on Burrowing Owl habitat use, diet, and survival in southeastern Alberta and Saskatchewan, Clayton (1997) examined the relationship between the abundances of owl prey and vegetation structure; grasshoppers (species not identified) and deer mice (*Peromyscus maniculatus*) were negatively correlated with vegetation height and density, whereas vole abundance was positively correlated with vegetation height and density. Generally throughout Canada, wheat fields contain a low diversity of small mammals and are dominated by deer mice, which have low abundances early in the Burrowing Owl breeding season but attain very high abundances later in the breeding season (Wellicome and Haug, 1995). Heavily grazed pastures have a low abundance of prey; thus, heavy grazing in foraging areas may be detrimental to Burrowing Owls. In central Saskatchewan, Burrowing Owls appeared to prefer grass/forb areas (for example, road rights-of-way and uncultivated areas) more than nonirrigated cropland or native pastures, possibly because grasshopper (*Melanoplus* spp.) abundances were high in the preferred areas (Haug, 1985; Haug and Oliphant, 1990).

In western Nebraska, Burrowing Owls nesting in black-tailed prairie dog colonies took foraging trips of longer duration than owls nesting in American badger excavations within pastures, suggesting that prey availability was more limiting to owls nesting in prairie dog colonies than to those owls nesting in American badger excavations (Desmond, 1991). Increased competition for prey may explain the difference in duration of foraging trips; Burrowing Owls nested at higher densities in the prairie dog colonies. In the Oklahoma Panhandle, black-tailed prairie dog colonies that were densely populated by owls were within landscapes with more cropland and less grassland than less densely populated colonies, possibly because of higher rodent and arthropod populations in cropland (Butts, 1973). More than one-half of the prey (arthropods, small mammals, snakes) taken by Burrowing Owls in mid-summer were obtained outside of black-tailed prairie dog colonies (Butts and Lewis, 1982).

Area Requirements and Landscape Associations

Home-Range Size

Burrowing Owls generally stay close to the nest burrow during the day and forage farther from the nest between dusk and dawn (Haug, 1985; Haug and Oliphant, 1990). In central California, Gervais and others (2003) examined home-range sizes of breeding male owls over 2 years. In the first year, home-range sizes averaged 139 ha for 9 owls based on 95-percent fixed-kernel methods and 177 ha for 11 owls based on minimum convex polygons methods; in the second year, home-range sizes averaged 98 ha for 19 owls based on the first method and 189 ha for 22 owls based on the second method. Maximum distances traveled from the nest during the 2 years were 1,278 and 1,337 m, and mean distances traveled from the nest were 378 and 409 m. Home-range size was not related to any measured biological factors, which included percentage of grass and cropland cover, amount of edge, number of neighboring nests, number of rodents in regurgitated pellets, or the number of young fledged (Gervais and others, 2003). In southern California, Rosenberg and Haley (2004) estimated the mean area used by owls as 45.3 ha using the fixed-kernel method and as 184.5 ha using the adaptive-kernel method, cautioning that the former method was likely an underestimate and the latter method an overestimate. In Saskatchewan, no statistical relationships were found between pasture size and proportion of failed nests, number of chicks produced per successful nest, adult or juvenile survivorship, or movement of owls between pastures of various sizes (James, 1993). In western Minnesota, Grant (1965) estimated that nesting territories of two owl pairs covered 4.9 and 6.5 ha. For 5–9 owl pairs occupying a single feedlot in North Dakota, Grant (1965) estimated the size of nesting territories to be between 4.0 and 7.3 ha.

Foraging Area

Foraging-area requirements often are considerably larger than nesting-area requirements. In Oregon, Burrowing Owls captured rodents as much as 600 m from the nest but generally remained within 100 m of the nest when hunting insects (Green and Anthony, 1989). In central California, 80 percent of all foraging locations for male Burrowing Owls were within 600 m of nests, and foraging locations were closer to the nest than to random locations (Gervais and others, 2003). In southern California, more than 80 percent of six male foraging locations were within 600 m of nests, averaging 113.7 ha (Rosenberg and Haley, 2004). In southern Saskatchewan, six radio-tagged male owls foraged within areas ranging from 14 to 481 ha (mean of 241 ha) in a matrix of grazed pastures and cereal crops (Haug, 1985; Haug and Oliphant, 1990).

Foraging area for four owls in a heavily cultivated region of southern Saskatchewan averaged 35 ha (Sissons, 2003; Sissons and others, 2001). The disparity in reported sizes of foraging areas between the Saskatchewan studies of Haug (1985) and Sissons and others (2001) was acknowledged, but Sissons and others (2001) offered no explanation. Data for the study conducted by Sissons and others (2001) were gathered during the same year that southeastern Saskatchewan experienced a superabundance of voles (noted previously in the "Prey Habitat" section). Size of owl foraging areas in central Saskatchewan appeared to increase with decreasing prey densities (Haug, 1985). In eastern Wyoming, the size of diurnal foraging area of owls averaged 3.5 ha (number of foraging areas not given) (Thompson, 1984). In Texas, foraging distances during daylight hours were short (range of 9.5 to 42.4 m) (Chipman and others, 2008).

Nearest-Neighbor Distances

Nearest-neighbor distances for nesting Burrowing Owls vary by study, as the distribution of potential nest burrows is affected by whether burrows are part of prairie dog colonies or more widely scattered as characterized by American badger burrows. In north-central Oregon, average nearest-neighbor distances may have affected whether owl nests in American badger burrows were successful or unsuccessful (that is, by being abandoned) (Green and Anthony, 1989). For nine pairs of owl nests with nearest-neighbor distances ranging from 60 to 110 m, at least one of the two paired nests in the comparison was abandoned. Only 14 percent of 21 pairs of owl nests with nearest-neighbor distances >110 m had at least one abandoned nest. Such abandonments were attributed to competition for food resources. In southern California, average nearest-neighbor distances of 293 nests that included ABSs ranged from 125 to 166 m across 3 years (Rosenberg and Haley, 2004). Nearest-neighbor distances were not related to nest productivity. In south-central Saskatchewan, mean nearest-neighbor distance for six Burrowing Owl nests in abandoned badger burrows was 214 m (Haug and Oliphant, 1990). In southeastern Montana, mean nearest-neighbor distance for 11 Burrowing Owl nests in scattered prairie dog colonies was 2.2 km (Restani and others, 2001). In prairie-dog colonies in western North Dakota, mean nearest-neighbor distances were 1.4 km for 47 nests in the first year of the study and 1.7 km for 47 nests in the second year (Davies and Restani, 2006). In prairie dog colonies in southwestern South Dakota, mean nearest-neighbor distances were 296 m for 129 nests in the first year of the study and 267 m for 143 nests in the second year (Griebel and Savidge, 2003, 2007). Mean nearest-neighbor distance for owls nesting in 20 American badger excavations in western Nebraska was 240 m, compared to mean nearest-neighbor distances of 105 m for 118 nonclustered nests in small prairie dog colonies and 125 m for 105 nest clusters in large prairie dog colonies (Desmond, 1991; Desmond and others, 1995; Desmond and Savidge, 1996). Potential nest sites may have been limited outside of prairie dog colonies.

Burrowing Owls can be semicolonial (Bent, 1961; Poulin and others, 2020) and may cluster their nests within colonies of prairie dogs (Butts, 1973; Desmond, 1991; Desmond and others, 1995, 2000; Desmond and Savidge, 1996; Griebel and Savidge, 2007). Clustered nest distributions may reduce depredation risk by allowing owls to alert one another to potential predators (Desmond and others, 1995). In a 3-year study in western Nebraska, Desmond and Savidge (1996) examined the effect of the size of black-tailed prairie dog towns on owl nesting density and nest clustering. Owls only had room to cluster in large (>35 ha) prairie dog colonies and not in small (<35 ha) colonies. Mean nearest-neighbor distance in clusters was 125 m, whereas nearest-neighbor distance in small colonies in which nests were randomly placed was 105 m (Desmond, 1991; Desmond and others, 1995; Desmond and Savidge, 1996). Nest density was negatively related to size of prairie dog towns. Mean Burrowing Owl densities ranged from 1.7 to 5.8 owls per ha in small colonies, 0.17 to 0.2 owls per ha in large colonies, and 1.2 to 1.3 owls per ha in clusters in large colonies (Desmond and Savidge, 1996). Burrowing Owl densities also were negatively related to prairie dog colony size in northeastern Colorado (Hughes, 1993) and southwestern South Dakota (Griebel and Savidge, 2007).

Prairie Dog Colony Size

Studies of black-tailed prairie dog colonies indicate that the size of a prairie dog colony likely affects its suitability for Burrowing Owls. In north-central Montana, colonization by owls of black-tailed prairie dog colonies generally increased with colony size (Alverson and Dinsmore, 2014). In southwestern South Dakota, occupied colonies were significantly larger than unoccupied colonies in both years of a 2-year study (Griebel and Savidge, 2007). Mean sizes of occupied colonies were 47.0 and 52.8 ha compared to 4.8 and 5.9 ha in unoccupied colonies. In southeastern Colorado, 56 occupied colonies were larger (mean of 21.7 ha) than 18 unoccupied colonies (mean of 9.2 ha) (Toombs, 1997). When only active colonies were considered, the 55 occupied colonies were larger (mean of 21.7 ha) than the eight unoccupied colonies (mean of 9.8 ha), but the difference was not significant. In the Southern High Plains of Texas, the number of Burrowing Owl nesting pairs was positively correlated with colony size and the number of prairie dog burrows in a colony; however, the number of pairs was neither related to prairie dog density nor to an index of vacant burrows (Ray and others, 2016). Several other studies, however, found no effect of colony size on Burrowing Owl occupancy, including in north-central Colorado (Plumpton and Lutz, 1993b), northeastern Colorado (Orth and Kennedy, 2001), southeastern Montana (Restani and others, 2001), and western South Dakota (Thiele, 2012). Colony size may affect reproductive success of Burrowing Owls. The size of prairie dog colonies was positively correlated with fledging success rates in western Nebraska

(Desmond, 1991) and in 1 of 2 years in southwestern South Dakota (Griebel and Savidge, 2007).

Landscape Effects

In portions of the Great Plains, cultivation and fragmentation of grassland habitat have favored increased populations of predators that prey on Burrowing Owls. Burrowing Owls near Hanna, Alberta, where 85 percent of original grassland remained uncultivated, experienced the lowest depredation rates (<5 percent of nests, sample size not given) of any study area in Canada (Wellicome and Haug, 1995). In western Nebraska, however, Burrowing Owls that nested in landscapes dominated by cropland experienced higher fledging success (mean of 3.2 fledglings per pair) than owls nesting in rangeland landscapes (mean of 1.5 fledglings per pair), a difference that appeared to be related to depredation rates (Desmond, 1991). Precipitation during the year of this finding was slightly above normal, but during a drought year, no difference in the fledging success was observed between the two landscapes. Habitat fragmentation may make it easier for predators to locate Burrowing Owl nests (James and others, 1997; Warnock and James, 1997). In Saskatchewan, crowding of owls into smaller habitat patches may have increased nest abandonment through events such as depredation (intra- and interspecific), foraging interference, and aggression (Warnock and James, 1997). Additionally, extirpation of owls from habitat patches was less probable with increasing habitat continuity (Warnock, 1996, 1997). Pastures occupied by owls had a lower edge-to-area ratio than randomly chosen, unoccupied pastures (Wellicome and Haug, 1995; Warnock, 1996, 1997). In southeastern Alberta, Burrowing Owls did not appear to be limited by habitat availability based on a comparison of nesting and nonnesting sites (Schmutz and Moody, 1989; Schmutz, 1993, 1997). In an agriculturally fragmented area of northeastern Colorado, owls nested in black-tailed prairie dog colonies in a landscape that had more shortgrass patches than cropland patches; however, because shortgrass patches were small, they constituted a smaller percentage of the landscape than cropland patches by area (Biddle, 1996). On average, shortgrass patches were closer to the perimeter of black-tailed prairie dog colonies than were other patch types.

Landscapes around prairie dog colonies can be an important determinant of colony occupancy by Burrowing Owls. In southern Alberta and southern Saskatchewan, Scobie and others (2020) reported that the number of juvenile Burrowing Owls that fledged increased as the proportion of nocturnal home range covered by summer fallow and active cropland within 1.4 km of the nest increased, indicating that Burrowing Owls preferred to nest near cropland. Summer fallow may be more advantageous as a landscape component than active cropland; as active cropland surrounding the nest increased, fewer prey items were delivered to the nest, presumably because of less-accessible prey in taller-statured cropland fields than in summer-fallow fields. A prey-delivery model predicted that 2.9 vertebrate prey items would be delivered per hour to nests surrounded by 60 percent summer fallow compared to 1.4 prey items to nests surrounded by 60 percent active cropland. Fewer juvenile owls fledged from nests in landscapes with a higher proportion of cropland than summer fallow, potentially because cropland could provide greater opportunities for predators to prey upon juvenile owls. Nest survival was not related to percentage summer fallow or active cropland (Scobie and others, 2020). In southern Saskatchewan, Warnock and Skeel (2002) reported that nest burrows in privately owned agricultural landscapes were surrounded by more farmland and less grassland within 200-m and 200-km radii of nests, and less wetland within 2-km radii, than nest burrows in federally managed grasslands. In the agricultural landscapes, nest burrows had more length of fence lines, roads, single trees, utility poles, owl-perch sites, occupied farms, badger holes, and clusters of Richardson's ground squirrel burrows than in prairie dog colonies in the grassland landscapes (Warnock and Skeel, 2002). Owl burrows were closer to roads and farms and had fewer abandoned farmsteads in agricultural landscapes. For nests in the agricultural landscapes, successful nests had more clusters of Richardson's ground squirrels and more badger holes within 100 m than did unsuccessful nests. Successful nests also had fewer single trees within sight and a higher percentage of wetlands within 2 km of the nest burrow than did unsuccessful nests; no differences for distance to nearest owl pair, distance to nearest road, and number of potential owl perches were reported between successful and unsuccessful nests (Warnock and Skeel, 2002). For nests in grassland landscapes, successful nests were closer to farmyards and closer to roads than unsuccessful nests, potentially explained by reduced distances to foraging areas. Nests were mostly near riparian valley bottoms; a negative relationship between successful nests and wetland area within 2 km of nests was detected (Warnock and Skeel, 2002). In western North Dakota, Restani and others (2008) found no effect of fragmentation on Burrowing Owl abundance or reproductive performance. The authors found that the amount of cropland cover in the surrounding landscape was positively associated with the number of Burrowing Owl pairs and reproductive success, but the percentage of cropland was small relative to other cover types (grassland made up about 70 percent of the study area; percentage of cropland was not provided). In central and western South Dakota, the likelihood of Burrowing Owls occupying prairie dog colonies decreased with an increase of tree canopy cover within 800 and 1,200 m of colony centers (Thiele, 2012; Thiele and others, 2013, 2019). The coverage of grassland, cropland, or prairie dog colonies did not affect owl occupancy, thus leading the authors to conclude that in areas where colonies are not limiting, owls occupy colonies based on the absences of trees. The probability of a site being chosen for nesting dropped from >80 percent with 0 percent tree cover within 800 m to <50 percent with an increase to 3.5 percent tree cover within 800 m (Thiele and others, 2013). In north-central Colorado, owl occupancy of 15 prairie dog colonies was positively related to the number of fragmented patches of shortgrass habitat within 2,500 m of those colonies (Orth and Kennedy, 2001). Areas within 2,500 m of the 15 occupied prairie dog colonies were characterized by median values of 48.1 percent shortgrass prairie and 36.2 percent irrigated agriculture, whereas areas within 2,500 m of the seven unoccupied colonies had median values of 85.5 percent shortgrass prairie and 10.3 percent irrigated agriculture. Areas within 1,000 m of the 15 occupied prairie dog colonies had median values of 48.9 percent shortgrass prairie and 23.4 percent irrigated cropland, whereas areas within 1,000 m of seven unoccupied colonies had median values of 92.6 percent shortgrass prairie and 7.4 percent irrigated cropland (Orth and Kennedy, 2001). The authors suggested that Burrowing Owls selected nest sites in prairie dog colonies situated within surrounding landscapes that were more fragmented than the landscapes surrounding unoccupied colonies owing to potential higher prey availability in the former or to active control programs for prairie dogs in the latter (Orth and Kennedy, 2001). In Colorado, Tipton and others (2008) examined the relationship between Burrowing Owl occupancy and proportion of prairie dog colony in the surrounding landscape at three spatial scales (a 25-ha plot plus its 500-m; 1,500-m; or 2,250-m buffer). Burrowing Owl occupancy was negatively correlated with increasing proportion of prairie dog colony in the landscape at all three spatial scales, regardless of plot type (active or inactive, grassland or agriculture). The authors suggested that this negative association reflected the Burrowing Owl's requirement for habitat heterogeneity to support foraging needs (Tipton and others, 2008). In Conservation Reserve Program fields in Colorado, Kansas, Nebraska, and Oklahoma, the best-fitting landscape model to explain the occurrence of Burrowing Owls observed during point-count surveys occurred at the 2,400-m scale, although the model for the 1,200-m scale also was competitive (McLachlan, 2007). Burrowing Owl occurrence was positively related to agricultural land and negatively related to developed land within 2,400 m of point counts and was negatively related to grassland, water, and developed land within 600 and 1,200 m of point counts.

Brood Parasitism by Cowbirds and Other Species

The Burrowing Owl is an unsuitable host of the Brown-headed Cowbird (*Molothrus ater*), and no records of cowbird brood parasitism are known to exist for this species (Shaffer and others, 2019; Poulin and others, 2020). Behavioral and genetic evidence suggests that conspecific brood parasitism may occur in some populations of Burrowing Owls (Henny and Blus, 1981; Johnson, 1997; Conway and others, 2012; Groves, 2014).

Breeding-Season Phenology and Site Fidelity

Migratory Status

Most Burrowing Owls migrate, but some may overwinter in their breeding areas (Coulombe, 1971; Botelho and Arrowood, 1998; Belthoff and King, 2002; Conway and others, 2006; Poulin and others, 2020). Some Burrowing Owl populations demonstrate plasticity in migratory behavior, especially populations in the western States from Washington to New Mexico (Poulin and others, 2020). In south-central Washington, Conway and others (2006) reported that migratory adults returned to their breeding areas as early as late February, with most arriving by late March. In southern California, Rosenberg and Haley (2004) reported that owls typically initiate nesting in April and May, but also reported a nest that was found in December with 10–14 day-old young. Thus, the length of time that Burrowing Owls occupy their breeding grounds throughout the western States can vary widely. In the Great Plains, Burrowing Owls occupy their breeding grounds from about early April until September (Bent, 1961; Grant, 1965; Maher, 1974; Wedgwood, 1976; Gleason, 1978; Haug, 1985; Ratcliff, 1986; Haug and Oliphant, 1990; De Smet, 1992). As with owls in western States, some owls in the southern Great Plains overwinter on their breeding grounds (Butts, 1973; Arrowood and others, 2001).

Renesting

Renesting attempts following failed initial nesting attempts have been reported in California (Thomsen, 1971; Rosenberg and Haley, 2004; Rosier and others, 2006), Idaho (Riding and Belthoff, 2018), western Oklahoma (Butts, 1973), western Nebraska (Desmond, 1991), and Saskatchewan (Wedgwood, 1976; Haug, 1985). In southeastern California, Catlin and Rosenberg (2008) conducted an experimental depredation study with artificial burrows and reported that renesting occurred; one pair produced three clutches in one burrow, whereas another pair produced four clutches in four separate nest burrows. In Saskatchewan and Alberta, the mean clutch initiation date for renesting attempts was May 19 (range of April 30–June 9) (Fisher and others, 2015). In California, one case of double-brooding has been reported (Gervais and Rosenberg, 1999).

Mate Fidelity

Burrowing Owls may exhibit mate fidelity. In the NCA in Idaho, Riding and Belthoff (2018) reported that, of 15 owl pairs for which nesting locations were known in consecutive years, one pair reunited in the subsequent year. In central

California, Thomsen (1971) reported that five of nine pairs that had been together the year before arrived at the study site together the following year. In the Imperial Valley of southern California, Rosenberg and Haley (2004) reported that mate fidelity was high, with 86.4 percent of 22 pairs and 80 percent of 20 pairs having the same mates as the previous year during two 2-year study periods. In another study in southern California, Catlin and others (2005) reported that 42 percent of 272 owls remained with their mate between breeding seasons; 27 percent were presumed dead, 27 percent were widowed (one individual of a pair died), and 4 percent were divorced (that is, both individuals of a pair were still known to be alive but not paired with one another). In New Mexico, zero of nine breeding males and females remated the following year (Martin, 1973).

Natal- and Breeding-Site Fidelity

Burrowing Owls occasionally exhibit natal- and breeding-site fidelity (Wedgwood, 1976; Gleason, 1978; Otnes, 1980; Rich, 1984; Plumpton, 1992; Pezzolesi, 1994; Desmond and others, 1995; De Smet, 1997; Clayton and Schmutz, 1999; Lutz and Plumpton, 1999). Fidelity to the previous year's nest burrow also occurs (Plumpton and Lutz, 1993b), as does within-year fidelity to nest burrows during relocation efforts (Feeney, 1997). In southeastern Washington, Conway and others (2006) recorded rates of fidelity in two landscape types: urban and agricultural. Of 758 juvenile owls captured over 4 years, 4 percent returned to the agricultural area and 8 percent returned to the urban area. Of 332 adult owls, 30 percent returned to the agricultural area and 39 percent to the urban area. Only 4 percent of banded adults in the agricultural area and 10 percent in the urban area were resighted 3 years later. Of 335 adult owls that returned to breed on the same study area the following year, 36 percent used the same nest burrow and 62 percent returned to the same nesting area (Conway and others, 2006). Burrow fidelity and nesting-area fidelity were higher among males than females. In southern California, Catlin and others (2005) demonstrated that 66 percent of 167 owls remained within 100 m of their previous nest burrow, and that 69 percent of 86 owls that dispersed remained within 400 m of the original burrow. In a southern California study with ABSs over two 2-year periods, at least one member of the previous year's pair returned to the same box for 48 percent of 23 nest boxes during one 2-year period and 65 percent of 17 nest boxed in the second 2-year period (Rosenberg and Haley, 2004). Overall, 85 percent of 174 adults remained within 400 m of the previous year's nests; 16 percent of 124 juveniles returned as adults. Of five young banded at a nest box that were relocated the following year, one nested in its natal nest box with a nonparent mate. In northern California, Menzel (2018) found that, of 803 owls raised in ABSs, 15 percent occupied burrows at the nesting area the following year. Four percent of the 120 returning owls used their natal burrow during their first breeding season. Twenty percent occupied a burrow within 499 m of their natal burrow. Thomsen (1971) described several incidences of natal- and breeding-site fidelity for an owl population on the California Oakland Municipal Airport. In New Mexico, the number of banded owls that returned to the banding site in a previous year (more than a total of 27 not-always consecutive years) varied from 1 to 22 (Lundblad and others, 2021). Some banded birds were not detected at the banding sight for 1 or more years before being detected in subsequent years. One female owl that nested and was banded on the site returned and nested for 8 subsequent years and did not return to the site the year after her nest failed. In the NCA, Riding and Belthoff (2018) banded 488 adult and 2,354 owlets over a 14-year period and reported that marked owls returned to the study site 172 times.

In southeastern Alberta over a 4-year period, 8 of 21 banded owls used the same nest burrow in subsequent years, and 9 owls moved <250 m away from a previous year's nest burrow (Schmutz and others, 1989). In Manitoba, 18 percent of 417 banded young and 19 percent of 54 banded adults returned to within 45 km of their natal site (De Smet, 1992). In South Dakota, 86 percent of 43 prairie dog towns used the previous year by owls were occupied the following year (Griebel and Savidge, 2007). In western Nebraska, owls reused traditional nesting areas despite drastic between-year declines in habitat quality (Desmond and others, 2000). In north-central Colorado, 12 of 31 (39 percent) banded owls returned to the study area during the second year of the study, and 8 of those 12 (67 percent) used a burrow within the same prairie dog colony that they occupied the previous year (Plumpton and Lutz, 1993b). Of 20 black-tailed prairie dog colonies used by all owls in the previous year, 90 percent of colonies were reused by Burrowing Owls the following year, and of the 20 nest burrows used the previous year, 20 percent were reused the following year (Plumpton and Lutz, 1993b).

Burrow Fidelity

Burrows used in any particular year may be used again the next year (either in cases of burrow fidelity as described in the previous paragraph, or by new occupants) or after a period of nonuse years (Rich, 1984). Within the NCA of south-central Idaho, burrows were reoccupied for 1–3 years and then vacated for a period before being reoccupied (Rich, 1984). Burrow reoccupation was higher at rock outcrop sites (48.9 percent of 113 burrows reoccupied) than at American badger excavation sites (31.4 percent of 159 excavations reoccupied), possibly because of the more durable nature of rock outcrops. Of 113 outcrop sites, no burrows were destroyed during the 7-year study; of 159 American badger excavations, 16 percent were destroyed. Outcrop sites were used more often in consecutive years, with 23 used for 2 years and 12 used for 3 years. In comparison, 15 and 3 mound sites were used for 2 and 3 years, respectively, with one mound site being used for 4 consecutive years (Rich, 1984). Thirty-three percent of 80 artificial burrow clusters (that is, groups of three burrows placed around a historic nest location) were used at least 4 years in a 5-year study, and 18 percent were used in all 5 years (Belthoff and Smith, 2003). In the NCA in southwestern Idaho, Lehman and others (1998) reported that <45 percent of Burrowing Owl nesting areas used in 1 year were occupied the next year, and occupancy after 3 years was 15 percent. In southeastern Idaho, 60 percent of 15 American badger excavations were reoccupied the following year (Gleason, 1978). In central California, Smallwood and Morrison (2018) reported that 38 percent of 42 nest burrows were not used again throughout the remaining 5 years of the study, whereas 24 percent were used for 4–6 years, and 12 percent were used for all 6 years.

Near Saskatoon, Wedgwood (1976) reported one burrow in use for 6 years, one in use for 4 years, and two in use for 3 consecutive years. In Saskatchewan, sites that were reused by owls were less isolated and had more reoccupied sites nearby ("nearby" was not defined) than sites that were not reused (Warnock and James, 1996). In Manitoba, 38 percent of 118 territories were reoccupied over a 5-year period (De Smet, 1992).

Burrow fidelity and nest area reuse may increase if birds are reproductively successful during the previous year (Pezzolesi, 1994; De Smet, 1997; Feeney, 1997; Catlin and others, 2005; Riding and Belthoff, 2018). In southern California, Catlin and others (2005) determined that nesting success was the primary factor associated with owl dispersal; 73 percent of 15 female owls with failed nests dispersed, whereas 30 percent of 86 female owls with successful nests dispersed. For males, 65 percent of 26 male owls with failed nests dispersed, whereas 25 percent of 126 male owls with successful nests dispersed. Nesting failure was associated with greater dispersal distances for males and females. Owls whose nests failed in the previous year moved either ≤16 or ≥117 m, whereas owls that successfully nested did not show such a bimodal pattern. In the NCA in Idaho, owls were more likely to disperse if they were female or had fledged fewer young in the previous years (Riding and Belthoff, 2018). For adult males that returned to former nest sites in Colorado, productivity during the previous year was not significantly higher than productivity of males that changed nest sites (Lutz and Plumpton, 1999). Conversely, productivity was higher in the preceding year for female owls that returned to former nest sites than for females that changed nest sites in following years. Return rates for adult males and females did not differ. In southwestern South Dakota, Burrowing Owls nesting in burrows previously used by owls fledged more young than those nesting in previously unused burrows (Griebel and Savidge, 2007). In New Mexico, Martin (1973) found that of nine breeding males and nine females banded the previous year, six males and two females returned; all the males selected the same nest burrow as the one used the previous year, unless that burrow had been destroyed.

Species' Response to Management

Primary management concerns for the Burrowing Owl depend on location. Rosenberg and Haley (2004) stated that the single largest management concern for the Burrowing Owl population in California's Imperial Valley is how the canal irrigation system is managed, an idea seconded by Griffin and others (2017) for New Mexico, whereas the major factor limiting Burrowing Owl populations in the Great Plains is destruction of nesting habitat by urban development (Zarn, 1974; Konrad and Gilmer, 1984) and cultivation of grasslands (Grant, 1965; Konrad and Gilmer, 1984; Ratcliff, 1986; Faanes and Lingle, 1995). Additionally, the extirpation of gray wolves and the increase in tree encroachment on prairie ecosystems have allowed populations of other mammalian and avian predators to increase, probably to the detriment of Burrowing Owl populations (Wellicome and Haug, 1995; Clayton and Schmutz, 1999).

Rodent Control Efforts

Throughout the Burrowing Owl's range, elimination of burrowing rodents through control programs is a major concern, and rodent control is considered a factor in recent and historical declines of Burrowing Owl populations (Grant, 1965; Butts, 1973; Zarn, 1974; Butts and Lewis, 1982; Evans, 1982; Ratcliff, 1986; Pezzolesi, 1994; Faanes and Lingle, 1995; Toombs, 1997; Desmond and others, 2000; Murphy and others, 2001). Owl burrows occasionally are fumigated and sealed during rodent-control programs (Butts, 1973). In some locations, populations of black-tailed prairie dogs are in danger of local extirpation, and their colonies have become so isolated that repopulation through natural dispersal and colonization is unlikely (Benedict and others, 1996). Fragmentation and isolation of habitat patches are potentially important factors in the decline of black-tailed prairie dog populations, but these factors are largely unstudied. Declines of Burrowing Owl populations north and east of the Missouri River in North Dakota may be related to declines in Richardson's ground squirrel populations, whereas declines south and west of the Missouri River in North Dakota may be related to reductions in populations of black-tailed prairie dogs (Murphy and others, 2001). In western Nebraska, a 63 percent decline in Burrowing Owl numbers over a 7-year period in 17 black-tailed prairie dog colonies was associated with declines in black-tailed prairie dog densities because of prairie dog control activities (Desmond and others, 2000). Burrowing Owl reproductive success was positively correlated and nest depredation by American badgers was negatively correlated with the density of active black-tailed prairie dog burrows. Although nesting success for owls nesting in American badger excavations was comparable with findings from other studies (58 percent, with three fledglings per nest), lower-than-average nesting success in black-tailed prairie dog burrows (48 percent, with 1.9 fledglings per nest) appeared to be related to prairie dog control efforts (M.J.

Desmond, New Mexico State University, Las Cruces, New Mexico, written commun. [n.d.]; J.A. Savidge, Colorado State University, Fort Collins, Colorado, written commun. [n.d.]).

Artificial Burrow Systems

The combination of the loss of Burrowing Owl breeding habitat and loss of fossorial mammal colonies has led to strategies to protect the Burrowing Owl from further population decline. These strategies include the development and deployment of ABSs (Johnson and others, 2010), translocation of Burrowing Owls (Trulio, 1995) and fossorial mammals (Swaisgood and others, 2019), and supplementation of food (Delevoryas, 1997). The installation of ABSs provides nesting opportunities where burrowing mammals have been extirpated or where natural burrows are scarce (Haug, 1985; Thomson, 1988). ABSs have been used for Burrowing Owls since at least the 1970s (Collins and Landry, 1977; Henny and Blus, 1981) and are in widespread use in some areas, such as Washington, Idaho, and California (Smith and Belthoff, 2001b; Rosenberg and Haley, 2004; Smith and others, 2005; Riding and Belthoff, 2015; Menzel, 2018). ABSs may increase reproductive success (Wellicome and others, 1997; Menzel, 2018), although some studies have reported no differences between ABSs and natural burrows (Botelho and Arrowood, 1998; Smith and Belthoff, 2001b, Smith and others, 2005). In northern California, Menzel (2018) found that nesting success at one site was 83 percent for ABSs compared to 76 percent at natural burrows and 96 percent for ABSs and 75 percent at a second site. During 2 years in Saskatchewan, 5 percent of 63 nests in ABSs were depredated, whereas 37 percent of 35 nests in natural burrows were depredated (Wellicome and others, 1997).

ABSs placed within established Burrowing Owl populations may be more effective than ABSs placed in unoccupied areas, owing to the species' site fidelity (Smith and others, 2005). Occupancy of ABSs from 1 year to the next can vary. In northern California, Menzel (2018) analyzed occupancy rates of ABSs over a 22-year period at an airport and a 16-year period at a defense military-supply depot. During the first 8 years postinstallation at the airport site, 26 percent of 57 ABSs were occupied for one nesting season and only 5 percent were occupied for four seasons; one burrow was occupied for all 8 years. At the depot, occupancy varied from 0 to 10 percent. Of the 51 ABSs, 24 percent were occupied one nesting season, and 2 percent occupied for five nesting seasons. There are a number of considerations in implementing ABSs, including depth of burrow, tunnel diameter, and chamber size (Smith and Belthoff, 2001b; Nadeau and others, 2015). In southeastern California, Nadeau and others (2015) reported that the shallowest artificial burrows (15 cm) had a moderate probability (0.46) of being occupied, burrows with a depth between 28 and 40 cm had the highest probability (>0.80) of being occupied, and burrows with a depth of >53 cm had the lowest probability (<0.43) of being occupied. The authors surmised that Burrowing Owls may have preferred ABSs at moderate depths because these burrows provided a thermal refuge from aboveground temperatures and may have been cool enough to allow females to leave eggs unattended before the onset of incubation, but not so cool that incubating females spent most of their time on eggs. Nadeau and others (2015) found no effect of burrow depth on reproductive success. In the NCA in Idaho, Smith and Belthoff (2001b) found that Burrowing Owls preferred burrow chambers with >900 square centimeters of floor space and 10-cm diameter tunnels. Fresh horse or cattle manure could be provided near nesting areas if none is available (Green and Anthony, 1997).

Translocation

The relocation of Burrowing Owls and installation of ABS may be necessary where populations of owls plummet or where human activities render habitat no longer suitable for nesting (Trulio, 1995; Smith and Belthoff, 2001a). In areas where Burrowing Owl population levels are relatively low and where unoccupied or unused habitat is available, owls may be trapped and transplanted from other nearby populations. A Burrowing Owl reintroduction program in British Columbia indicated that 1-year-old, captive-bred Burrowing Owls could raise broods after being released, migrate south in winter, and return to release sites the following spring (Leupin and Low, 2001). However, 105 banded juvenile Burrowing Owls that had been captured in South Dakota and released in western Minnesota over 4 years resulted in no sightings of the released birds in subsequent years, including 8 years following the release (Martell and others, 2001). In some cases, the translocation of fossorial mammals may be justified; Swaisgood and others (2019) described the translocation of California ground squirrels to reestablish this species but also to provide burrows for the Burrowing Owl.

During the nestling stage in years of apparent prey shortages, supplemental food provisioning may increase reproductive success (Wellicome, 1994, 1997a; James and others, 1997). Overfeeding, however, may be detrimental because excessive food caching by owls may attract predators (Delevoryas, 1997).

Fire

Little information exists on the response of Burrowing Owls to burning of breeding habitats. In north-central Oregon, Burrowing Owls were observed nesting in American badger excavations in previously unused areas that recently had been burned, suggesting that fire may create suitable habitat by reducing vegetation around potential nest sites (Green and Anthony, 1989). In northwestern North Dakota, postsettlement fire suppression may be responsible for the development of a taller, denser, and woodier plant community than previously existed (Murphy, 1993). These vegetational shifts may have been responsible for the extirpation of Burrowing Owls in that region.

Haying

Mowing may be used to control the height of grasses and woody vegetation in areas where black-tailed prairie dogs previously occurred; abandoned black-tailed prairie dog colonies that were not mowed were not used by owls in north-central Colorado (Plumpton, 1992). Mowing also may enhance the attractiveness of nest sites for Burrowing Owls returning from their wintering grounds (Plumpton and Lutz, 1993b). Mowing throughout the breeding season apparently does not adversely affect nesting Burrowing Owls (T.I. Wellicome, written commun. [n.d.]). However, the burrowing activities of prairie dogs may be required to ensure the long-term suitability of burrows for owls; it may be necessary to release prairie dogs into inactive colonies (MacCracken and others, 1985b; T.I. Wellicome, written commun. [n.d.]).

Grazing

Information on the effect of grazing in western States is sparse. In Oregon, trampling of burrows by livestock (domestic sheep [*Ovis aries*] and cattle) resulted in the collapse of 24 percent of 29 burrows over 2 years and the failure of 4 active nests over 3 years (Holmes and others, 2003). In addition to trampling, Burrowing Owls have been reported to drown in livestock-watering tanks (Lantz and others, 2007). In the contemporary Great Plains landscape, frequent heavy grazing by livestock and prairie dogs maintains the short vegetation structure that Burrowing Owls prefer (James and Seabloom, 1968; Butts, 1973; Stewart, 1975; Wedgwood, 1976; Konrad and Gilmer, 1984; MacCracken and others, 1985b; Bock and others, 1993). Cessation of grazing may negatively affect Burrowing Owl populations (T.I. Wellicome, written commun. [n.d.]). In south-central Saskatchewan, heavily grazed grasslands with poor soils were used frequently by Burrowing Owls, and moderate-to-heavy grazing on grasslands with good soils reduced lush vegetative growth and provided Burrowing Owl habitat (Wedgwood, 1976). In southern Saskatchewan, Warnock and Skeel (2002) reported higher breeding success of Burrowing Owls in grazed areas in agricultural landscapes; breeding success was 25 percent at 4 mowed sites, 50 percent at 8 sites with no grazing or mowing, and 73 percent at 80 grazed sites. In southern Saskatchewan and Alberta, owls nested in pastures with shorter vegetation than in randomly chosen pastures, and owls preferred native or tame pastures more than cultivated land (Clayton, 1997). In North Dakota, Burrowing Owls nested in moderately or heavily grazed mixed-grass pastures but not in hayed or lightly grazed mixed-grass (Kantrud, 1981). In North Dakota, a reduction in the number of sheep grazing over the past 20 years north and east of the Missouri River may have contributed to declines in Burrowing Owl populations; researchers rarely observed native prairie that was cropped short by sheep grazing (Murphy and others, 2001). In South Dakota, Burrowing Owl densities were higher on plots grazed by American bison (*Bison bison*) than on plots grazed by cattle or on ungrazed plots, perhaps because of differences in grazing patterns between bison and cattle (Murray, 2005). In the Platte River Valley of Nebraska, Burrowing Owls preferred nest sites that were in heavily grazed or mowed native grasslands (Faanes and Lingle, 1995). In the Oklahoma Panhandle, grazing of taller grasses may create conditions that attract ground squirrels and prairie dogs, thus increasing burrow availability (Butts, 1973). In portions of Colorado, Kansas, Oklahoma, Texas, and New Mexico, Pavlacky and others (2021) evaluated the benefit to Burrowing Owls of grazing practices (for example, managing livestock stocking rates, pasture rotations, and grazing intensity and duration) designed to meet the nesting and brood-rearing requirements of the Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*). The authors concluded that the grazing practices that benefitted Lesser Prairie-Chickens were not beneficial for Burrowing Owls; percent change in owl densities were negative on the Lesser Prairie-Chicken Initiative grazed acres relative to reference grasslands grazed under typical grazing conditions for the region.

Pesticides

Use of insecticides and rodenticides can be especially detrimental to Burrowing Owls; pesticides not only reduce the owl's food supply and the number of burrowing mammals, but these chemicals also may be toxic to the owl (Ratcliff, 1986; James and Fox, 1987; James and others, 1990; Baril, 1993; Berkey and others, 1993; Pest Management Regulatory Agency, 1995; Hjertaas, 1997b; Wellicome, 1997b; Mineau and others, 1999). Burrowing Owls have been reported to ingest poisoned rodents and to forage on the ground for insects in areas littered with poison grains (Butts, 1973; James and others, 1990). In central and southern California, pesticide residues collected from Burrowing Owl eggs, feet, and feathers contained low levels of selenium, organophosphorus, and organochlorine (Gervais and others, 2000). Eggs most frequently contained dichlorodiphenyldichloroethylene (DDE) and selenium, and eggshell thickness was 22.6 percent thinner than eggshells collected 59–61 years earlier. Feather samples contained organophosphorus residues, and footwash samples contained chlorpyrifos. DDE levels from eggs from the Imperial Valley from the Gervais and others (2000) study were compared to egg levels 6 years later; DDE levels were similar between periods, ranging from 0.10 to 3.01 micrograms (µg) per gram (Gervais and Catlin, 2004). DDE levels in eggs of an owl population in the San Joaquin Valley varied from 0.06 to 32.82 µg per gram over a 6-year period; these levels did not appear to reduce the reproductive potential of adult Burrowing Owls (Gervais and Anthony, 2003). In the NCA of south-central Idaho, Stuber and others (2018) determined that levels of DDE, organophosphate, and carbamate were too low to cause toxicity or reproductive impairment of Burrowing Owls. DDE levels in eggs varied from 0 to 3.5 µg per gram. In a rural-urban transition zone in western Arizona, carcasses of 22 adult

Burrowing Owls (representing 25 percent of the local adult population) were found <10 m of their burrow entrances (Justice-Allen and Loyd, 2017). Lethal levels (0.077–0.497 milligrams per kilogram) of brodifacoum, an anticoagulant rodenticide, were detected in three of the Burrowing Owls; the other 19 carcasses were too decomposed for analysis, but secondary poisoning also was suspected in these owls.

In southern Saskatchewan, owls in pastures treated with strychnine-coated grain to control Richardson's ground squirrels weighed less than owls in untreated pastures, suggesting a sublethal effect or a reduction in small-rodent prey (James and others, 1990). A breeding population of Burrowing Owls in the Oklahoma Panhandle declined by 71 percent within 1 year after grain coated with sodium fluoroacetate was applied to control prairie dogs in the colony in which the owls were nesting (Butts, 1973). By the end of the breeding season, no owls remained at the site.

Carbaryl and carbofuran are two insecticides used to control agricultural pests, with the latter being one of the most toxic carbamate compounds (Pest Management Regulatory Agency, 1995). In Saskatchewan, reproductive output of Burrowing Owls was not diminished significantly by one or more exposures to carbaryl within 50 or 400 m of the nest burrow; however, spraying of carbofuran within 50 m of the nest burrow caused a 54 percent reduction in the number of young per nest (James and Fox, 1987). When both carbaryl and carbofuran were sprayed within 400 m of the nest, productivity of pairs decreased about 35 percent more than when carbaryl alone was applied. Direct overspray of carbofuran to the nest burrow resulted in an 83 percent reduction in brood size and an 82 percent reduction in nesting success (James and Fox, 1987; Fox and others, 1989). Carbofuran application within 50 m of the nest burrow, without direct overspray, resulted in a 17 percent reduction in brood size and a 27 percent reduction in nesting success compared with burrows exposed to carbaryl or chloropyrifos. Carbofuran has been banned from use in its granular formulations in the United States and Canada (Pest Management Regulatory Agency, 1995; L. Cole, Environmental Protection Agency, Office of Pesticide Programs, Washington, D.C., written commun. [n.d.]; P. Mineau, Canadian Wildlife Service, Hull, Québec, written commun. [n.d.]), as well as in most of its liquid formulations in Canada (Pest Management Regulatory Agency, 1995). The liquid formulation is still certified for use in corn in Canada, and pesticide drift could affect Burrowing Owls nesting near such fields (P. Mineau, written commun. [n.d.]). Additionally, liquid carbofuran is still registered for several uses in the United States; uses of this chemical in corn and alfalfa fields may be particularly dangerous to the Burrowing Owl (L. Cole, written commun. [n.d.]; P. Mineau, written commun. [n.d.]).

Collisions and Other Human-Caused Mortality

Anthropogenic features such as roads, vehicles, fences, aircraft, and energy infrastructure may be detrimental to Burrowing Owls. In California, road grading and ditch maintenance to maintain agricultural canals and drains destroyed natural nest burrows; fatally buried adults, chicks, and eggs; and caused surviving adult owls to disperse >1,000 m away in the following breeding season (Catlin and Rosenberg, 2006). Vehicles operated during agricultural cultivation, road repair and development, oil and gas activities, or lawn maintenance also can bury owls in burrows (Konrad and Gilmer, 1984; Environment Canada, 2010). Burrowing Owls sometimes collide with vehicles, and vehicular collision is one of the main causes of death in Canada, after predation (Clayton and Schmutz, 1999; Todd, 2001; Todd and others, 2003; Environment Canada, 2010). In Saskatchewan, Todd and others (2003) reported that 5 of 64 radio-marked Burrowing Owls died from anthropogenic causes—4 from vehicular collisions and 1 from a barbed-wire fence collision. Two owls died from unknown causes. In Saskatchewan, Todd (2001) described cause-specific mortality for radio-marked juvenile Burrowing Owls over 2 years. In 1 year, 0 of 12 marked juveniles died. In the second year, 15 of 33 juveniles died—8 of depredation, 1 of vehicular collision, 1 of barbed-wire collision, 2 of starvation, 1 of siblicide or cannibalism, and 2 of unknown cause. In Idaho, Gleason and Johnson (1985) reported that 6 of 22 confirmed mortalities were from collisions with motor vehicles. In Colorado, Plumpton and Lutz (1993a) reported that vehicular disturbance at the level of 0–16 vehicles per 15 minutes was positively correlated with locomotion and alert behaviors in Burrowing Owls; however, the authors questioned whether the magnitude of these relationships was biologically meaningful, as vehicular disturbance had no effect on nesting productivity despite nest burrows being close to roads. Burrowing Owls are known to get impaled and die on barbed-wire fences (Lohoefener and Ely, 1978; Gillihan, 2000; Todd and others, 2003). In South Dakota, Lohoefener and Ely (1978) reported finding one Burrowing Owl entangled in a barbed-wire fence and 10 immature owls dead on roads. DeVault and others (2011) ranked the relative hazards of wildlife to aircraft within 152 m of ground level, based on data from 1990 to 2009 extracted from a Federal database. The database included 20 Burrowing Owl strikes, and the relative hazard score for Burrowing Owl was 3 out of a possible 100 (higher scores indicating higher risk). Lundblad and others (2021) indicated that airports and military installations have active eradication efforts for Burrowing Owls because of perceived collision risks with aircraft, but no data or further information were provided.

Energy Development

Burrowing Owls may be negatively affected by energy development. In the mixed-grass prairies of southern Alberta and Saskatchewan, Scobie and others (2016) examined Burrowing Owl nighttime movement patterns in relation to human infrastructure (that is, compressor stations, oil wells, paved roads, towns, and buildings) and artificial light and noise associated with gas and oil wells. Movements of the owls were affected more by proximity of human infrastructure than by intensity of sensory disturbances (that is, sound and light) associated with such infrastructure. Selection of daytime roosts by nesting adult male Burrowing Owls declined near roads as average vehicle speed increased (Scobie and others, 2014). Male Burrowing Owls avoided roads with vehicle speeds >80 km per hour, ostensibly because auditory disturbances from passing vehicles interfered with their ability to communicate the presence of predators to their mates and young. Coal-bed methane development may negatively affect Burrowing Owls. Carlisle and others (2018) examined raptor nest-site use in relation to the proximity of coalbed-methane sites in Wyoming; Burrowing Owls used nest sites in undeveloped areas (that is, >805 m from the nearest active coalbed methane well) more than nest sites in developed areas (that is, <805 m from the nearest well). Although these results suggested potential avoidance of nesting near coal-bed methane development, the occurrence and hence, availability, of prairie dog colonies as nesting sites for owls were not examined, and this factor also could contribute to where owls nested.

Burrowing Owls are known to be at risk of collisions with wind turbines (Smallwood and others, 2007, 2008, 2009a, 2009b, 2010; Smallwood and Thelander, 2008; Smallwood and Karas, 2009). Beston and others (2016) developed a prioritization system to identify avian species most likely to experience population declines in the United States from wind facilities based on the species' current conservation status and the species' expected risk from wind turbines. The Burrowing Owl scored a 3.53 out of nine; 8.08 percent of the Burrowing Owl breeding population in the United States was estimated to be exposed to wind facilities. Diffendorfer and others (2021) concluded, based on modeling exercises involving turbine-caused mortality rate and potential biological removal, that Burrowing Owls had a relatively low potential for population impacts from wind fatalities. Loss and others (2013) reviewed published and unpublished reports on collision mortality at monopole wind turbines (that is, with a solid tower rather than a lattice tower) in the contiguous United States; 11 Burrowing Owl mortalities were reported at two wind facilities. Wulff and others (2016) examined diurnal flight heights of Burrowing Owls and determined that the species' mean flight height was 10 m, which is not within the rotor-swept zone of wind-turbine blades. Smallwood and others (2008) ranked fatalities of birds attributed to wind facilities in west-central California by classifying turbines on a tiered system from 1 to 5, with Tier I turbines causing the most fatalities. Classifications were based on variables representing wind turbine and tower attributes, landscape settings, and the arrangement of turbines on the landscape. Tier I and II wind turbines were responsible for all of 10 Burrowing Owl fatalities and 94 percent of 16 fatalities of other raptor species (Smallwood and others, 2008).

Management Recommendations from the Literature

Protection of Burrowing Animals

Management recommendations for the Burrowing Owl center primarily on the protection of the subterranean burrows that the species requires for nesting. The form of protection of these burrows may vary regionally, given that the characteristics of suitable burrows vary regionally. For example, burrows in western States are likely to occur in landscapes dominated by industrial uses (for example, airports, military installations; Arrowood and others, 2001; Menzel, 2018) or agricultural land uses (Rosenberg and Haley, 2004) or where existing burrows are provided by noncolonial mammals such as American badgers (Holmes and others, 2003). Hence, protection of burrows cannot be achieved by simply protecting colonies of prairie dogs (Benedict and others, 1996). In western landscapes, the persistence of burrows depends as much on the conservation of nesting habitat within military installations (Trulio and Chromczak, 2007; Lundblad and others, 2021) and maintenance along irrigation canals (Rosenberg and Haley, 2004) as it does on the conservation of burrowing mammals (Trulio and Chromczak, 2007). ABSs are more frequently used in western States than in the Great Plains, and the use of ABSs is a widely adopted management practice when natural burrows are destroyed or unavailable (Arrowood and others, 2001; Klute and others, 2003; Ronan and Rosenberg, 2014). Numerous publications provide recommendations for the design, implementation, and maintenance of ABSs and offer insights into mitigating the loss of natural burrows for nesting Burrowing Owls (Olenick, 1990; Smith and Belthoff, 2001b; Belthoff and King, 2002; Johnson and others, 2010; Riding and Belthoff, 2015; Ronan and Rosenberg, 2014; Menzel, 2018).

In contrast, in the Great Plains, primary protection efforts focus on the conservation of landscapes that support colonial mammals, such as the black-tailed prairie dog (Holroyd and others, 2001; Poulin and others, 2020). In the Great Plains, maintaining large, contiguous expanses of native grassland benefits Burrowing Owls (Benedict and others, 1996; Warnock, 1997; Warnock and James, 1997; Clayton and Schmutz, 1999; Thiele and others, 2013; R.K. Murphy, Eagle Environmental, Inc., Albuquerque, New Mexico, written commun. [n.d.]), as preservation of large tracts of prairie is crucial to conserving the small-mammal community on which Burrowing Owls depend (Benedict and others, 1996). Lantz and others (2007) stressed that most elements of Burrowing Owl nesting habitat in the Great Plains can be managed at the scale of the prairie dog colony. Maintaining an active prairie dog colony with ample burrow availability and low vegetative cover are key components (Lantz and others, 2007; Lantz and Conway, 2009). Thiele and others (2019) recommended prioritizing the protection of prairie dog colonies without trees in the surrounding landscape and discouraging the planting of new shelterbelts near occupied colonies. Furthermore, tree removal near prairie dog colonies with existing trees may enhance the attractiveness of those colonies to Burrowing Owls.

Conservation on Public and Private Lands

Klute and others (2003) summarized conservation actions to benefit the Western Burrowing Owl that include the continuation, expansion, and creation of protected landscapes and of policies and programs aimed at reversing the range-wide decline of the Burrowing Owl population. Landscape-protection efforts occur on public and private lands. In areas where fragmentation is high because of urbanization and agriculture, public lands protect imperiled habitats upon which Burrowing Owls rely. Examples include the Naval Weapons Systems Training Facility for sagebrush steppe (Holmes and others, 2003); the Carrizo Plain National Monument, Kirtland Air Force Base, and the White Sands Missile Range for desert grasslands and scrub land (Arrowood and others, 2001; Rosier and others, 2006; Lundblad and others, 2021); and National Grasslands throughout the Great Plains for native prairies (Sidle and others, 2001; Lantz and others, 2007). Many public lands, especially military installations, harbor Burrowing Owl populations even if the protection of native ecosystems is not a top priority. Examples include Moffett Federal Airfield (Trulio and Chromczak, 2007), Lemoore Naval Air Station (Gervais and Anthony, 2003), and Naval Radio Transmitter Facility (Smallwood and Morrison, 2018), all in California; and the National Nuclear Security Administration Pantex Plant in Texas (Chipman and others, 2008; Ray and others, 2016).

Privately owned lands also play a crucial role in Burrowing Owl conservation (Kremen and Merenlender, 2018). More than 70 percent of the United States is privately owned (Ciuzio and others, 2013). In eastern Washington, Conway and others (2006) stated that most owls encountered during 1,165 roadside point-count surveys were on private land. Particularly in the Great Plains, colonies of black-tailed prairie dogs persist on private land. VerCauteren and others (2001) reported that 80 percent of 372 owl locations were on private lands in eastern Colorado. “Working lands” is a contemporary term for privately owned lands, such as rangelands and farmland, that have the capability to sustain landowners’ agriculture-based livelihoods while also sustaining biodiversity (Kremen and Merenlender, 2018). Conservation partnerships between Federal, State, and Tribal agencies; nongovernmental organizations; and private landowners result in programs like grassbanks. A grassbank is a conservation tool that exchanges the value of a given amount of forage that is not produced for conservation benefits (Gripne, 2005). The reestablishment of prairie dogs on the Gray Ranch in New Mexico is an example of a grassbank that has benefitted Burrowing Owls (Arrowood and others, 2001). Klute and others (2003) listed other partnerships that were developed specifically to aid in the recovery of Burrowing Owl populations in the United States. In Canada, Operation Burrowing Owl, a private stewardship program, has been successful at obtaining landowner cooperation in conservation efforts and has provided valuable population data for owls in Canada (Hjertaas, 1997a). Programs that offer financial incentives to landowners to conserve perennial cover, such as the Conservation Reserve Program in the United States, may maintain and create nesting habitat for Burrowing Owls in the Great Plains (Thomson, 1988; Warnock, 1996; McLachlan, 2007). However, programs aimed to benefit one species may not necessarily benefit others; Pavlacky and others (2021) demonstrated that the Lesser Prairie-Chicken Initiative of the Conservation Reserve Program has not benefitted the Burrowing Owl and urged continued monitoring of the effectiveness of private-land conservation programs.

Government agencies and municipalities play an important role in Burrowing Owl conservation by funding conservation easements in prime Burrowing Owl habitat (Butts, 1973; Haug and Oliphant, 1987; Thomson, 1988; Toombs, 1997). In the United States, Government agencies that shift from subsidizing prairie dog reduction to finding workable alternatives that maintain viable prairie dog communities while sustaining ranching livelihoods will provide a win-win solution for owl conservation and livestock producers (Benedict and others, 1996; Desmond and Savidge, 1999). Benedict and others (1996) stressed that not only is the eradication of prairie dogs costly and unnecessary, in most cases it is ecologically detrimental. If lethal control of burrowing mammals is warranted, Butts (1973) recommended avoiding the nesting period of Burrowing Owls and relocating owls on an experimental basis before control proceeds. Butts (1973) further recommended that traps, poisoned meat, or poisoned grain should not be used to control burrowing mammals when owls are present; fumigation of burrows unoccupied by owls should be considered as an alternative method (Butts, 1973; Thomson, 1988). However, it may be difficult to determine which burrows are unoccupied once owl fledglings begin to use satellite burrows (M.J. Desmond, written commun. [n.d.]). Benedict and others (1996) and Toombs (1997) called for increased regulation of poisoning and shooting of prairie dogs, particularly on public lands.

Pesticides

Programs that encourage the reduction or restriction of insecticides will further benefit Burrowing Owls (Thomson, 1988). In situations where insect control is necessary, practices such as applying insecticides with the lowest toxicity to nontarget organisms and avoiding spraying within 400–600 m of owl nest burrows during the breeding season are recommended by several researchers (Haug, 1985; Haug and Oliphant, 1987, 1990; James and Fox, 1987; Fox and others, 1989; Gervais and others, 2003). Gervais and others (2003) further recommended that pesticide exposure of nonnest burrows be minimized in late summer, when young owls are most likely to be using them, cautioning that nonbreeding owls can be cryptic and determining their presence should not be based only on casual observations.

Land Management

Several management actions can be implemented to make grassland habitat more attractive to and safe for Burrowing Owls. Because Burrowing Owls nest and roost in short-statured grasslands and prey on mammals and insects that live in tall grass, conserving a mosaic of habitats may be important (Clayton and Schmutz, 1999; Marsh and others, 2014a). Where vegetation is relatively tall (>5 cm; Green and Anthony, 1997), observation perches for owls can be provided (Grant, 1965; Plumpton and Lutz, 1991; Green and Anthony, 1997). Livestock grazing can maintain grassland vegetation at heights preferred by Burrowing Owls (Wedgwood, 1976). Marsh and others (2014a) recommended ensuring a mosaic of vegetation heights to increase foraging success by Burrowing Owls, potentially by implementing grazing regimes that encourage a heterogeneity of grass heights. In cropland landscapes, the practice of alternating strips of cropland with strips of the previous year's crop stubble was further recommended to provide adequate foraging areas for owls. Implementation of rotational grazing systems in pastures that have been managed by annual, season-long grazing may help to increase prey populations (Wellicome and others, 1997). Other potential foraging habitat, such as road rights-of-way, hayland, and uncultivated areas of dense, tall vegetation within 1 km of nesting areas, can be maintained, restored, or enhanced (Haug, 1985; Haug and Oliphant, 1990; Pezzolesi, 1994; Wellicome, 1994, 1997a; Warnock, 1997; Gervais and others, 2003). In heavily cultivated regions, the planting of permanent herbaceous strips may increase habitat for rodent prey (Wellicome and others, 1997).

Maintenance and Protection of Traditional Nest Sites

Because Burrowing Owls often reuse nesting sites occupied in previous years, the identification and maintenance of traditional nesting sites has been highlighted as important by several researchers (Butts, 1973; Zarn, 1974; Haug, 1985; Ratcliff, 1986; Warnock, 1997). Rich (1984) recommended that known nesting sites should be monitored annually so that delayed reuse of sites can be detected, and that unoccupied but suitable areas also should be monitored in the event that an area is newly colonized or recolonized. Lundblad and others (2021) cautioned that formerly occupied habitat should not automatically be considered unsuitable, because properly managed habitat with burrowing mammals may be recolonized later. Especially for burrows in sandy soils, monitoring may be necessary to adjust livestock stocking rates, duration, and season of grazing to ameliorate burrow collapse by trampling (Holmes and others, 2003).

In the Great Plains, active colonies of black-tailed prairie dogs provide ideal nesting habitat for Burrowing Owls. Prairie dog colonies of at least 35 ha appeared to provide adequate space for nesting Burrowing Owls in Nebraska (Desmond and others, 1995), but increasing the size of black-tailed prairie dog colonies by reintroducing prairie dogs where they have been eliminated or by releasing additional prairie dogs into active colonies will promote colony expansion (Pezzolesi, 1994; Toombs, 1997; T.I. Wellicome, written commun. [n.d.]). Conversely, the loss of prairie dogs from a given colony ultimately renders it unsuitable for Burrowing Owls (Grant, 1965; Butts, 1973; Desmond and Savidge, 1996, 1999), although abandoned prairie dog colonies can be maintained at an early successional stage with short (<8 cm) vegetation (Plumpton and Lutz, 1993b). Mowing can help maintain vegetation at an early successional stage, and in the northern Great Plains, optimal timing of mowing is mid-March to improve nest-site attractiveness during nest initiation (Plumpton, 1992; Plumpton and Lutz, 1993b). Mowing in mid- to late summer does not appear to be detrimental to nesting owls (T.I. Wellicome, written commun. [n.d.]). However, mowing abandoned colonies may be effective only in the short term because burrows may require maintenance by prairie dogs to remain suitable for owls (MacCracken and others, 1985b; Desmond and Savidge, 1999).

Increasing populations of Richard's ground squirrels in their historical range may reduce depredation pressures on Burrowing Owls. In Saskatchewan, Richardson's ground squirrels are an alternate prey source for predators of Burrowing Owls (Butts, 1973; Wedgwood, 1976; Haug, 1985; Ratcliff, 1986; Stockrahm, 1995; Wellicome and others, 1997).

Collisions and Other Human-Caused Mortality

Scobie and others (2014) recommended that speed limits on roads near areas known to be actively or traditionally used by Burrowing Owls be <80 km per hour; this speed limit allows owls to avoid vehicular collisions and to hear and react to predators. To minimize the collision of Burrowing Owls with wind turbines, researchers have recommended siting turbines away from areas typically used by migrating or breeding owls, especially colonies of colonial burrowing mammals, and by maximizing tower height so that fewer turbines are needed to produce an equivalent energy output (Kuvlesky and others, 2007; Smallwood and others, 2007, 2008, 2009a, 2009b; Smallwood and Thelander, 2008). Wulff and others (2016) and Kolar and Bechard (2016) recommended avoiding wind-turbine placement in locations with high concentrations of trees or shrubs that provide nesting and perching habitat for avian predators, such as hawks and other owls, and avoiding placement in locations with high prey densities, such as prairie dog towns, in which avian predators concentrate their foraging activities.

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Table P1. Measured values of vegetation structure and composition in Burrowing Owl (*Athene cunicularia hypugaea*) 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; <, less than; --, no data ; >, greater than]

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)
Butts, 1973 (nests)	Oklahoma	Multiple	Multiple	<10	--	--	--	--	--	--	--
Clayton and Schmutz, 1999	Alberta, Saskatchewan	Mixed-grass prairie	Grazed	<10	--	--	--	--	--	--	--
Green and Anthony, 1989 (nests)	Oregon	Cheatgrass (*Bromus tectorum*) habitat	--	--	9.8[a]	28.3	--	--	54.8	--	--
Green and Anthony, 1989 (nests)	Oregon	Snakeweed (*Gutierrezia sarothrae*) habitat	Grazed	--	4.7[a]	36	--	--	49	--	--
Green and Anthony, 1989 (nests)	Oregon	Bitterbrush (*Purshia tridentata*) habitat	--	--	31.1[a]	--	--	11.4	49	--	--
Lantz and others, 2007 (nests)	Wyoming	Mixed-grass prairie	Grazed	--	--	--	--	6	20	--	--
MacCracken and others, 1985b (nests)	South Dakota	Shortgrass prairie	Grazed	13	--	35[b]	45	1	42	16	--
Marsh and others, 2014a (prey-capture points)	Alberta, Saskatchewan	Multiple	Multiple	--	5.4[c]	--	--	--	47.4	--	--
Marsh and others, 2014a (flying-foraging points)	Alberta, Saskatchewan	Multiple	Multiple	--	11.4[c]	--	--	--	43.4	--	--
Marsh and others, 2014b (hovering-foraging points)	Alberta, Saskatchewan	Multiple	Multiple	--	5.3[c]	--	--	--	47.7	--	--
Plumpton, 1992 (nests)	Colorado	Shortgrass prairie, tame grassland	Multiple	6.7[d]	--	12	30	--	58	--	--
Sissons, 2003 (foraging sites)	Alberta	Cropland, mixed-grass prairie, tame grassland	Crop, grazed	--	6.4[c]	--	--	--	10.8	27	--
Stockrahm, 1995 (nests)	North Dakota	Mixed-grass prairie	--	<31	--	--	--	--	--	--	--
Thiele, 2012[e] (nests)	South Dakota	Multiple	Multiple	--	6.8[c]	55[b]	34	<1	16	--	--
Thompson, 1984 (nests)	Wyoming	Shortgrass prairie	Grazed	--	--	24–30[b]	29–37	1–4	25–33	6–10	--

[a]Effective vegetation height.

[b]Grass and sedge (*Carex* species) cover combined.

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

[d]Forb height.

[e]The sum of the percentages is >100%, based on methods described by the authors.

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