The Effects of Management Practices on Grassland Birds—Brewer's Sparrow (*Spizella breweri breweri*)

Chapter AA of

The Effects of Management Practices on Grassland Birds

Professional Paper 1842–AA

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

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By Brett L. Walker,[1,2] Lawrence D. Igl,[3] and Jill A. Shaffer[3]

Chapter AA of

The Effects of Management Practices on Grassland Birds

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

U.S. Department of the Interior
DAVID BERNHARDT, Secretary

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Conversion Factors

International System of Units to U.S. customary units

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

Abbreviations

2,4–D	2,4–Dichlorophenoxyacetic acid
2,4,5–T	2,4,5–Trichlorophenoxyacetic acid
BBS	Breeding Bird Survey
CRP	Conservation Reserve Program
n	sample size number
n.d.	no date
PRBO	Point Reyes Bird Observatory
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—Brewer's Sparrow (*Spizella breweri breweri*)

By Brett L. Walker,[1,2] Lawrence D. Igl,[3] and Jill A. Shaffer[3]

Capsule Statement

Keys to Brewer's Sparrow (*Spizella breweri breweri*) management include maintaining extensive, unfragmented patches of suitable breeding habitat; reducing conifer cover and height; preventing the invasion of conifers and nonnative plants, especially cheatgrass (downy brome [*Bromus tectorum*]); minimizing disturbance to soil; and restricting the use of pesticides and herbicides during the breeding season (April–July). Brewer's Sparrows have been reported to use breeding habitats with 12–170 centimeter (cm) vegetation height, 2–34 cm visual obstruction reading, 1–74 percent grass cover, less than (<) 19 percent forb cover, 1–65 percent shrub cover, 1–75 percent bare ground, 2–61 percent litter cover, and <1 cm litter depth. During post-fledging dispersal in July, Brewer's Sparrow adults and young may shift habitat use to nearby aspen (*Populus* species [spp.]), riparian shrub, or deciduous mountain shrub habitats, so these habitats also may be important for management. The descriptions of key vegetation characteristics of breeding habitat from the literature are provided in table AA1 (after the "References" section). Vernacular and scientific names of plants and animals follow the Integrated Taxonomic Information System (https://www.itis.gov).

Brewer's Sparrow. Illustration by Beth Peluso Grassi, used with permission.

Breeding Range

Two subspecies of Brewer's Sparrows breed in North America: the Sagebrush Brewer's Sparrow (*Spizella breweri breweri*) and the Timberline Brewer's Sparrow (*Spizella breweri taverneri*). This account deals only with the Sagebrush subspecies, which breeds in the western Great Plains, Rocky Mountains, Intermountain West, Columbia and Snake river basins, and the Great Basin, and does not deal with the Timberline subspecies, which breeds from northwestern Montana north through the Canadian Rockies to east-central Alaska (Doyle, 1997; Griffin and others, 2003). Differences in habitat use, vocalizations, morphology, plumage characteristics, and genetics between the two subspecies may warrant a future taxonomic split of the Brewer's Sparrow into two distinct species (Sibley and Monroe, 1990; Klicka and others, 1999, 2001; but see Mayr and Johnson [2001] for an opposing view).

Sagebrush Brewer's Sparrows breed from southern British Columbia east to southeastern Alberta and southwestern Saskatchewan; south through the Columbia River Basin east of the Cascade crest; and throughout the Great Basin east of the Sierra Nevada crest as far south as southern California, southern Nevada, and northern Arizona (National Geographic Society, 2011). The species regularly breeds east to northwestern New Mexico, eastern Colorado, northwestern Nebraska,

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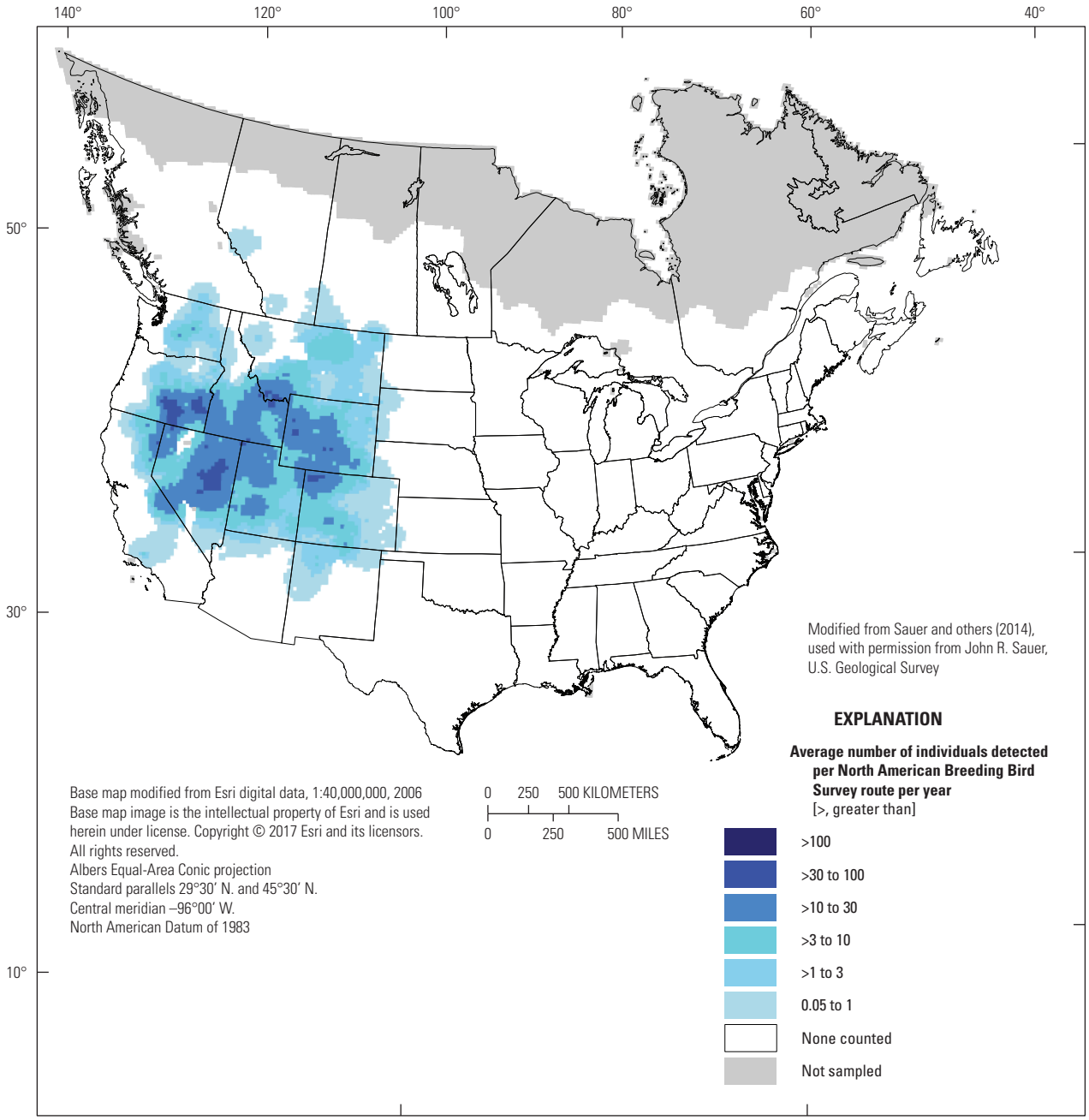

Figure AA1. The breeding distribution of the Brewer's Sparrow (*Spizella breweri*) in the United States and southern Canada, based on North American Breeding Bird Survey (BBS) data, 2008–12. The BBS abundance map provides only an approximation of breeding range edges.

western South Dakota, and southwestern North Dakota, with sporadic breeding in western Nebraska, extreme southwestern Kansas, western Oklahoma, and northern Texas (Sutton, 1967; Stewart, 1975; Salt and Salt, 1976; Johnsgard, 1979; Kantrud, 1982; Cannings and others, 1987; Faanes and Lingle, 1995; National Geographic Society, 2011; Rotenberry and others, 2020). It is unclear whether individuals breeding in high-elevation subalpine habitats in the western United States are taxonomically closer to *S. b. breweri* or to *S. b. taverneri* (Rising, 2002). The relative densities of Brewer's Sparrows in the United States and southern Canada, based on North American Breeding Bird Survey (BBS) data (Sauer and others, 2014), are shown in figure AA1 (not all geographic places mentioned in this report are shown on figure).

Suitable Habitat

Brewer's Sparrows are closely associated with shrublands dominated by big sagebrush (*Artemisia tridentata*). For that reason, they generally are considered a "sagebrush-obligate" or "shrubland-obligate" species (Paige and Ritter, 1999; Dreitz and others, 2017; Rotenberry and others, 2020). Sagebrush habitats vary by soil type, topographical and elevational characteristics, and amount of precipitation received, and range from grasslands with scattered sagebrush (*Artemisia* spp.) to dense shrublands with a sparse understory (Paige and Ritter, 1999). Because these habitats often are not clearly delineated in the literature, the following general definitions were applied in this report. "Shrubsteppe" is characterized by the codominance of sagebrush and native bunchgrasses, moderate shrub cover (10–20 percent), moderate precipitation, and a significant understory component of grasses and forbs (West, 1996; Paige and Ritter, 1999; Montana Partners in Flight, 2000). Shrubsteppe is found in the western Great Plains, Rocky Mountains, and the Columbia and Snake river basins. "Arid sagebrush shrublands" are characterized by denser shrub cover (20–80 percent), less precipitation, and a sparser understory of grasses and forbs than true shrubsteppe and are typical of the Great Basin (West, 1988; Montana Partners in Flight, 2000). In this account, both shrubsteppe and arid sagebrush shrublands are simply referred to as "shrubsteppe." "Semidesert shrubsteppe" is characterized by areas where sagebrush mixes with shrubs that are more typical of arid or semiarid deserts. Semidesert shrubsteppe is found in localized patches and transition zones in the southern Great Plains (Johnsgard, 1979), Great Basin (Wiens and Rotenberry, 1981), and Southwest (Larson and Bock, 1986).

Brewer's Sparrows breed in shrubsteppe, transition zones between shrubsteppe and shortgrass prairie, and semidesert shrubsteppe (Fautin, 1946; Stewart, 1975; Johnsgard, 1979; Rotenberry and Wiens, 1980a; Kantrud and Kologiski, 1983; Wiens and others, 1987a; Faanes and Lingle, 1995; Dreitz and others, 2017; Miller and others, 2017; Rotenberry and others, 2020). Suitable habitat includes sagebrush-dominated shrublands with greater than [>] 10 percent average shrub cover and an average shrub height of 0.5–1.5 meters (m) (Larson and Bock, 1986; Dobler and others, 1996; Sarell and McGuinness, 1996; Rotenberry and others, 2020). In general, Brewer's Sparrow abundance decreases as average shrub cover decreases below 10–13 percent, and Brewer's Sparrows may disappear entirely when average shrub cover is below 3–8 percent (Larson and Bock, 1986; Dobler and others, 1996; Duchardt and others, 2020). In the Thunder Basin National Grassland in eastern Wyoming, abundance of male Brewer's Sparrows increased with an increase in sagebrush canopy cover and herbaceous canopy cover within 30 m, and males were only present at sites with sagebrush cover within 250 m; this resulted in a prediction of 6.5 males per square kilometer (km^2) at 10 percent sagebrush canopy cover and 10 percent herbaceous canopy cover within 30 m and 31 males per km^2 at 60 percent sagebrush canopy cover and 90 percent herbaceous canopy cover (Duchardt and others, 2020). In the western Great Plains, Brewer's Sparrow occupancy was positively associated with the percentage of sagebrush habitat in 1-km^2 sampling plots; the absence of sagebrush habitat led to low probabilities of occurrence (Dreitz and others, 2017). In a multi-State study throughout the northern Great Plains, Brewer's Sparrows were rare in grassland-dominated areas of the northern, eastern, and southern portions of the study region (Kantrud and Kologiski, 1983). Brewer's Sparrows occasionally are detected in shortgrass prairies (or prairies with short-statured vegetation) in Colorado, Kansas, Nebraska, Oklahoma (McLachlan, 2007), North Dakota (Rich, 2005), and South Dakota (Pettingill and Dana, 1943). The species occasionally uses Conservation Reserve Program (CRP) fields, including some with little or no sagebrush or shrub cover (Igl and Murphy, 1996; Schroeder and Vander Haegen, 2006; Igl, 2007).

Brewer's Sparrow habitats typically are dominated by one or more subspecies of big sagebrush, including basin big sagebrush (*Artemisia tridentata* subspecies [ssp.] *tridentata*), mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*), and Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) (Huey and Travis, 1961; Fautin, 1975; McGee, 1976; Wiens and Rotenberry, 1981; Rotenberry, 1986; Wiens and others, 1986; Cannings and others, 1987; Sedgwick, 1987; Knopf and others, 1990; Kerley and Anderson, 1995; Welch, 2002, 2005; Noson and others, 2006; Chalfoun and Martin, 2007; Harrison and Green, 2010; Vander Haegen and others, 2015; Rotenberry and others, 2020). Other dominant or codominant shrubs in Brewer's Sparrow habitat may include threetip sagebrush (*Artemisia tripartita*), dwarf sagebrush (*Artemisia scopulorum*), black sagebrush (*Artemisia nova*), little sagebrush (also commonly referred to as low sagebrush; *Artemisia arbuscula*), white sage (*Salvia apiana*), Bigelow sage (*Artemisia bigelovii*), tarragon (*Artemisia dracunculus*), green (also commonly referred to as yellow) rabbitbrush (*Chrysothamnus viscidiflorus*), rubber rabbitbrush (*Ericameria nauseosa*), greasewood (*Sarcobatus* spp.), and antelope bitterbrush (*Purshia tridentata*) (Baldwin, 1956; Fautin, 1975; Larson and Bock, 1986; Biermann and others, 1987; Faanes and Lingle, 1995; Welch, 2005; Chalfoun and Martin, 2007; Krannitz, 2007; Rotenberry and others, 2020). Brewer's Sparrows also occur in transition areas where big sagebrush is adjacent to, or intermixed with, scabland sagebrush (*Artemisia rigida*), bud sagebrush (*Picrothamnus desertorum*), shadscale saltbush (*Atriplex confertifolia*), winterfat (*Krascheninnikovia lanata*), green ephedra (or Mormon tea [*Ephedra viridis*]), spiny hopsage (*Grayia spinosa*), broom snakeweed (*Gutierrezia sarothrae*), curl-leaf mountain-mahogany (*Cercocarpus ledifolius*), fourwing saltbush (*Atriplex canescens*), and rubber rabbitbrush (Walcheck, 1970; Hill, 1980; Larson and Bock, 1986; Knopf and others, 1990; Medin, 1990a; Faanes and Lingle, 1995; Rotenberry and others, 2020). However, in Washington, the species occurred only rarely in mixed shrublands consisting of big sagebrush, spiny hopsage, green rabbitbrush, and rubber rabbitbrush and an understory of

cheatgrass and Sandberg's bluegrass (*Poa secunda*) (Schuler and others, 1993). Brewer's Sparrows less commonly breed in other shrub-dominated habitats that lack sagebrush, including brushy slopes, regenerating clearcuts, and burned areas with greenleaf manzanita (*Arctostaphylos patula*), snowbrush ceanothus (*Ceanothus velutinus*), shrubby cinquefoil (*Dasiphora fruticosa*), golden currant (*Ribes aureum*), antelope bitterbrush, curl-leaf mountain mahogany, serviceberry (*Amelanchier* spp.), and snowberry (*Symphoricarpos* spp.) (Grinnell and others, 1930; Burleigh, 1972; Beaver, 1976; Knopf and others, 1990; Kingery, 1998; Wisdom and others, 2000; Krannitz, 2007). Rarely, Brewer's Sparrows breed in patches of russet buffaloberry (*Shepherdia canadensis*) (Saunders, 1914), in creosotebush (*Larrea tridentata*) (Hill, 1980), or in vineyards (Tyler, 1910).

Specific characteristics of Brewer's Sparrow habitat vary by region. In the western Great Plains, Brewer's Sparrows are common in transition zones between shrubsteppe and shortgrass prairies in southern Alberta, central and southeastern Montana, western North Dakota and South Dakota, and eastern Wyoming; abundant in shrubsteppe of central and northern Wyoming and south-central Montana; and uncommon in local areas of semidesert shrubsteppe (Feist, 1968a, 1968b; Walcheck, 1970; Wiens, 1970; Best, 1972; Fautin, 1975; Kantrud and Kologiski, 1983; Biermann and others, 1987; Faanes and Lingle, 1995; Logan, 2001; Chalfoun and Martin, 2007). In transition habitats between shrubsteppe and shortgrass prairies, Brewer's Sparrows use areas with a denser understory of grasses and forbs (64–73 percent), lower sagebrush cover (5–10 percent), and shorter sagebrush (0.25–1.0 m) than in shrubsteppe (Feist, 1968a, 1968b; Best, 1972; Logan, 2001). In Saskatchewan mixed-grass prairies, Bleho (2009) evaluated the relationship between Brewer's Sparrow abundance and vegetation structure within pastures grazed season-long (June to October) at moderate grazing intensity (about 43 percent utilization); Brewer's Sparrow abundance was positively associated with measures of patchiness of vegetation height-density and patchiness of bare ground cover but negatively associated with patchiness of shrub cover. In southwestern North Dakota, Brewer's Sparrows were rare in grasslands with sparse (5.5 percent) cover of Wyoming big sagebrush (Rich, 2005). In central Montana, the species occurred at low densities (0.13 pair per hectare [ha]) in mixed shrublands with an average shrub cover of 17 percent (9 percent big sagebrush, 8 percent black greasewood [*Sarcobatus vermiculatus*]), but densities were much higher (1.2 pairs per ha) in nearby stands of silver sagebrush (*Artemisia cana*) (total shrub cover 53 percent) with an understory of cheatgrass and western wheatgrass (*Pascopyrum smithii*) (Walcheck, 1970). In shrubsteppe habitat in eastern Montana, Brewer's Sparrows were more common in low-productivity sites than in high-productivity sites, which likely reflected that sagebrush shrubs grow in poorer, less productive soils; productivity was based on an index of biomass potential that relates abiotic factors (including soil, climate, and topography) to the expected amount of nontree biomass that can grow annually (Golding and Dreitz, 2017).

In the Columbia River Basin in southern British Columbia, 32 percent (sample size not given) of Brewer's Sparrows were detected in sparse (<10 percent shrub cover) sagebrush habitats, 48 percent were in moderately dense (10–30 percent shrub cover) sagebrush habitats, and 20 percent were in dense (>30 percent shrub cover) sagebrush habitats (Sarell and McGuinness, 1996). Within the southern Okanagan and Similkameen valleys of British Columbia, Brewer's Sparrow presence was higher at sagebrush sites having higher elevations and sites with higher percent cover of parsnipflower buckwheat (*Eriogonum heracleoides*), junegrass (*Koeleria macrantha*), intact cryptobiotic crusts, and litter (Paczek, 2002; Paczek and Krannitz, 2005). The species was generally absent from sites with a northern exposure or with flora that is characteristic of drier, disturbed areas, such as brittle pricklypear (*Opuntia fragilis*) and sand dropseed (*Sporobolus cryptandrus*). Within occupied sites, Brewer's Sparrow abundance was positively associated with percent cover of threetip sagebrush, parsnipflower buckwheat, silky lupine (*Lupinus sericeus*), sagebrush, and litter (Paczek, 2002; Paczek and Krannitz, 2005). In another study in the South Okanagan Region of British Columbia, however, Brewer's Sparrow occupancy was best predicted by the cover of big sagebrush, with the greatest likelihood of occupancy occurring at 20–25 percent cover of big sagebrush; forb cover and grass cover were not good predictors of occupancy (Harrison, 2008; Harrison and Green, 2010).

In the Great Basin region, Brewer's Sparrows occur in sagebrush habitats with shrub cover similar to that found in shrubsteppe farther north but with a sparser understory (Wiens and Rotenberry, 1981; Rotenberry, 1986; Vander Haegen and others, 2000, 2001). In the Great Basin in eastern Washington, Brewer's Sparrows were significantly more abundant in shrubsteppe habitats with deep, loamy soils and above-average precipitation, plant productivity, and shrub cover (Vander Haegen and others, 2000, 2001). The species was least abundant in low-elevation sites characterized by low precipitation and sandy soils, despite high shrub densities at those sites; elevations ranged from <250 m in southern study areas to 750 m in northern study areas. In central Oregon, Brewer's Sparrows were most abundant in shrubsteppe habitats averaging 18.6 percent shrub cover with little or no juniper (*Juniperus* spp.) cover, less abundant in mid-successional sites with 12.6 percent shrub cover and 6.1 percent juniper cover, much less abundant in recently burned (<5 years) grassland sites with <5 percent shrub cover, and largely absent from old-growth pinyon (*Pinus*)-juniper (*Juniperus*) sites with 5.4 percent shrub cover and 23 percent juniper cover (Reinkensmeyer and others, 2007). In the northwestern Great Basin that included portions of southeastern Oregon and northern Nevada, a significant negative association existed between Brewer's Sparrow abundance and habitat features associated with transition zones between shrubsteppe and more-arid habitats (for example, the diversity of shrub species present, and the percentage cover of spiny hopsage, bud sagebrush, and bare rock) (Wiens and Rotenberry, 1981). Brewer's Sparrows

were rare in areas with low-growing, spiny shrubs typical of arid or semiarid deserts (Wiens and Rotenberry, 1981; Rotenberry, 1986; Schuler and others, 1993). The abundance of Brewer's Sparrows was highest in areas with tall, moderately dense sagebrush (Wiens and others, 1987a). Brewer's Sparrows tended to be less abundant in areas with higher grass cover and higher turnover of bird species among years; these areas generally are habitat transition zones that occasionally support bird species, such as Western Meadowlark (*Sturnella neglecta*), for which shrubsteppe is a secondary habitat (Rotenberry and Wiens, 1980b). Brewer's Sparrows were consistently abundant at a site with 32 percent total shrub cover (19 percent sagebrush, 13 percent other shrubs) and 24 percent grass cover, whereas the species was abundant in only 1 of 2 years at a site with 25 percent total shrub cover (23 percent sagebrush, 2 percent other shrubs) and 39 percent grass cover (Rotenberry and Wiens, 1989, 1991).

In the Snake River Basin and the northern Great Basin in southwestern Idaho, percentage of shrub cover and shrub patch size were the most important vegetation features predicting presence or absence of Brewer's Sparrows at a site; the probability of Brewer's Sparrow occupancy increased as shrub cover and shrub patch size increased (Knick and Rotenberry, 1995). The species also was more common in areas with relatively little disturbed ground. Brewer's Sparrow distribution was accurately predicted by mapping the distribution of large, stable, and intact patches of sagebrush (Knick and Rotenberry, 1999, 2000). In southern and central Idaho in the southern Great Basin, Brewer's Sparrow presence was higher in areas with more shrub cover at the plot scale (8 point counts in a 1-kilometer [km] radius circle) and with more sagebrush and more total shrubs at the point scale (100-m vegetation transect centered at the point of each bird survey) (Miller and others, 2017). In central Nevada in the southern Great Basin, Brewer's Sparrows were 1.8 times more abundant, on average, in undisturbed shrubsteppe with 18–21 percent shrub cover and a sparse understory than in 20- to 30-year-old western wheatgrass plantings recolonized by sagebrush with 1–12 percent shrub cover (McAdoo and others, 1989). In east-central Nevada, Brewer's Sparrows were abundant in stands of Wyoming and mountain big sagebrush, less abundant in transition zones between sagebrush and other vegetation types, rare in shadscale saltbush deserts, and absent from pinyon-juniper woodlands (Medin, 1990a, 1990b, 1992; Medin and others, 2000). In southeastern Idaho and north-central Utah of the southern Great Basin, Brewer's Sparrows were most common in undisturbed shrubsteppe (12–49 percent shrub cover), less common in western wheatgrass plantings recolonized by sagebrush (3–40 percent shrub cover), rare in sagebrush/saltbush transition zones, and absent from recent western wheatgrass plantings (Olson, 1974). In Utah, Brewer's Sparrows nested in black greasewood on alkali bottomlands but were absent from adjacent dry hillsides with stunted pinyon-juniper woodlands (Hardy, 1945). In another Utah study, Brewer's Sparrows were only associated with immature Utah juniper (*Juniperus osteosperma*) woodlands characterized by low canopy cover and low density of mature junipers and high coverage of shrubs and juniper seedlings or saplings (Pavlacky and Anderson, 2004). In four mountain ranges in Nevada, the Brewer's Sparrow was associated only with pinyon-juniper woodlands that were relatively open and had a well-developed sagebrush-dominated understory; the species was not found in high-density pinyon-juniper woodlands (Fleishman and Dobkin, 2009). In mountains of southeastern California, Brewer's Sparrows nested in tracts of sagebrush within singleleaf pinyon (*Pinus monophylla*) and limber pine (*Pinus flexilis*) woodlands (Fisher, 1893; Wauer, 1964).

In northwestern Colorado in the Piceance Basin of the Colorado Plateau, the Brewer's Sparrow preferred open areas with large shrubs and gradual slopes and were most abundant in areas distant from woodland edges (Sedgwick, 1987). In a second study in Colorado in the Piceance Basin, Brewer's Sparrows were detected at low densities (3.1–5.6 territories per 10 ha) in plots with 5.2–5.6 percent shrub cover within a matrix of pinyon-juniper woodland (O'Meara and others, 1981). In a third study in northwestern Colorado, Brewer's Sparrow densities responded more strongly to horizontal (plant basal and canopy gap, plant cover, shrub density) and vertical characteristics (height and shrub density) of plant communities than to species composition (Williams and others, 2011). The species preferred open-canopy plant communities with scattered, tall (40–100 cm) shrubs, such as those provided by the greasewood, Wyoming big sagebrush, and spiny hopsage communities that were common in saline lowland, loamy, and sandy soils (Williams and others, 2011). However, Brewer's Sparrow densities were low in plant communities with desirable tall shrubs but with undesirable horizontal characteristics (such as dense, closed-canopy shrub communities). Brewer's Sparrow densities were highest in saline lowland and loamy soil ecological sites than in sandy-skeletal ecological sites (Williams and others, 2011). In another study in northwestern Colorado, Brewer's Sparrow densities were positively related to shrub cover, although densities declined with increased richness of shrub species (Gallo and Pejchar, 2016). In a fourth study in northwestern Colorado, Brewer's Sparrow abundance in sagebrush habitats increased with greater shrub cover and taller shrubs and grasses and peaked at approximately 38 percent herbaceous cover (Timmer, 2017). In New Mexico, Brewer's Sparrows were found only on 5 of 9 sites with the highest total shrub cover (Larson and Bock, 1986). The species preferred areas with above-average shrub cover, above-average shrub height, and below-average bare ground.

In the Columbia and Snake river basins, the Great Basin, and the Colorado Plateau, Brewer's Sparrows breed over a wide range of elevations (100–3,150 m) but are most abundant in broad, flat valleys with extensive sagebrush-dominated shrubsteppe habitats and minimal soil disturbance and are less abundant in smaller patches of sagebrush (Grinnell and Miller, 1944; Baldwin, 1956; Huey and Travis, 1961; Walcheck, 1970; Olson, 1974; Schroeder and Sturges, 1975; McGee, 1976; Rotenberry and Wiens, 1980a; O'Meara and others, 1981; Krementz and Sauer, 1982; Larson and Bock, 1986;

Rotenberry, 1986; Wiens and others, 1986, 1987a; Sedgwick, 1987; Rotenberry and Wiens, 1989, 1991; Knick and Rotenberry, 1995; Sarell and McGuinness, 1996; Welch, 2002). In northeastern Oregon, Brewer's Sparrows were rarely detected in high-elevation (average of 1,500 m) native grasslands (Johnson, 2010). In Idaho, Miller and others (2017) reported that the probability of Brewer's Sparrows occupying a study plot of poor, moderate, or good habitat (sample size number [*n*]=312; each plot was a 1-km^2 circle) was greater at higher elevations than at lower elevations; elevations varied from 913 to 2,323 m above sea level.

Brewer's Sparrows most often build nests in sagebrush, although the species occasionally nests in other shrubs with similar vegetation structure, including spiny hopsage, antelope bitterbrush, green rabbitbrush, rubber rabbitbrush, black greasewood, and western snowberry (*Symphoricarpos occidentalis*) (Fautin, 1946; Feist, 1968a, 1968b; Best, 1972; Rich, 1980; Petersen and Best, 1985; Sarell and McGuinness, 1996; Mahony, 2003; Rotenberry and others, 2020; D. Humple, Point Reyes Bird Observatory [PRBO], Bolinas, California, written commun. [n.d.]; W.M. Vander Haegen, Washington Department of Fish and Wildlife, Olympia, Washington, written commun. [n.d.]). Rarely, Brewer's Sparrows build nests in Douglas-fir (*Pseudotsuga menziesii*) saplings, hawthorn (*Crataegus* spp.), wild rose (*Rosa* spp.), spotted knapweed (*Centaurea stoebe*), or giant wildrye (*Leymus condensatus*) (Tyler, 1910; Fautin, 1946; Sarell and McGuinness, 1996; Mahony, 2003; Rotenberry and others, 2020). After a fire, pairs may nest in bunchgrasses or various species of large perennial forbs for several years until sagebrush regenerates (Mahony, 2003).

Nest heights range from 5 to 104 cm, and nest-shrub heights range from 14 to 191 cm (table AA2; after the "References" section). In southeastern Idaho, Brewer's Sparrows preferred to nest in shrubs that were taller (mean height 69 cm; range 42–104 cm] than was sampled in available habitat (mean height 43 cm; range 8–107) (Petersen and Best, 1985). Although 70 percent of all shrubs available were <50 cm tall, 93 percent of 58 nests were in shrubs >50 cm tall. Individuals selected nest shrubs of moderate foliage density and did not nest in shrubs <42 cm or >104 cm in height. Nesting birds did not show a preference for nest shrubs with denser-than-average foliage or with a continuous canopy (Petersen and Best, 1985). Nests were situated, on average, 18 cm from the edge and 24 cm from the top of nest shrubs. Average heights of nests increased 6 cm over the course of the breeding season, but average height from the nest to the top of the nest shrub did not change (Petersen and Best, 1985). In Idaho sagebrush, average nest-to-crown distance was 39 cm (Rich, 1980).

Shrub cover, shrub height, shrub vigor, and grass cover are important in nest-site selection. On average, Brewer's Sparrows prefer nest sites surrounded by relatively dense (26–43 percent) shrub cover (table AA2), but the percentage of shrub cover near nests varies (Petersen and Best, 1985; Larson and Bock, 1986). In areas with sparse, low-growing shrubs, Brewer's Sparrows usually select nest sites in denser patches of taller shrubs (Castrale, 1982; Petersen and Best, 1985; Bock and Bock, 1987; Rotenberry and others, 2020). When shrub cover is uniformly tall and dense, the species may prefer areas with below-average shrub cover and higher grass and forb cover (Rotenberry and others, 2020). The height and density of grass surrounding the nest shrub may play an important role in concealing nests from predators and in ameliorating the effects of extreme weather (Best, 1972). In Montana, the number of nesting attempts by Brewer's Sparrows was greater where shrub cover was higher (Chalfoun and Martin, 2007). In northeastern Wyoming, Brewer's Sparrows selected nest sites with taller, more-vigorous shrubs with greater branching density and greater visual obstruction (Barlow and others, 2020). In a 2-year study in northwestern Wyoming, Ruehmann and others (2011) determined that Brewer's Sparrows settled earlier and laid larger clutches in sagebrush habitats with a native grass understory but subsequently suffered higher rates of nest predation than in sagebrush habitats with a smooth brome (*Bromus inermis*) understory; the overall probability of nest survival for 57 Brewer's Sparrow nests with an understory of smooth brome was higher (0.56 and 0.85 for first and second years, respectively) than nest survival for 55 nests with an understory of native grass species (0.28 and 0.68 for first and second years, respectively). Ruehmann and others (2011) surmised that the denser foliage provided by smooth brome later in the nesting season increased nest concealment from nest predators and may have supported higher insect abundance.

Brewer's Sparrows prefer to nest in shrubs that are alive or mostly alive (Winter, 1984; Petersen and Best, 1985; Barlow and others, 2020; Rotenberry and others, 2020). In northeastern Wyoming, Brewer's sparrows selected nest shrubs with higher percentage of living foliage (Barlow and others, 2020). In southeastern Idaho, females built 58 nests in live foliage, even if the nest shrub was partly dead; 71 percent of 58 nests were in shrubs with 100 percent live foliage, 93 percent of nests were in shrubs with >75 percent live foliage, and all nests were in shrubs with >50 percent live foliage (Petersen and Best, 1985). Brewer's Sparrows showed no preference for nesting in shrubs with denser-than-average foliage unless the shrub was dead (Best, 1972; Rotenberry and others, 2020).

The Brewer's Sparrow prefers to forage in tall, live shrubs, particularly big sagebrush, rather than in dead shrubs or small, live shrubs of other species (for example, green rabbitbrush, rubber rabbitbrush). Brewer's Sparrows spend most of their time (75 percent) in tall, live sagebrush and less time (25 percent) on the ground (Winter, 1984; Wiens and others, 1987b; Rotenberry and Wiens, 1998). Tall, live sagebrush may provide more food resources, or alternatively, because males often sing from and forage in the same shrub, they may prefer elevated song perches instead of specific foraging sites (Castrale, 1983; Knopf and others, 1990; Rotenberry and Wiens, 1998). Males also sometimes sing from elevated perches in mountain mahogany and Utah juniper (*Juniperus osteosperma*) (Castrale, 1983; Knopf and others, 1990). In Utah, the mean height of 110 perches was 85 cm (Castrale, 1983). The height, width, and perpendicular width of shrubs used as song perches were significantly greater than shrubs surrounding the

song perch, but the availability of song perches is probably less important in habitat selection than the availability of suitable nesting or foraging sites.

Moisture and environmental conditions may affect reproductive investment and productivity of Brewer's Sparrows. In shrubsteppe habitat in central Oregon, Rotenberry and Wiens (1989, 1991) reported that Brewer's Sparrows had larger clutch sizes and greater reproductive success (based on number of fledglings produced) in wetter years than in drier years; the authors indicated that the observed patterns represented adaptive flexibility (that is, the ability to assess favorable environmental conditions between years and to adjust reproductive investment accordingly). The species may be insensitive to short-term variation in weather. Petersen and Best (1986b) reported that growth of Brewer's Sparrow nestlings was not correlated with annual variation in any weather parameter (that is, daily maximum temperature and total precipitation for the brood-rearing portion [June–July] of the breeding season and the 2-month period [April–May] preceding the appearance of most nestlings). The future distribution of Brewer's Sparrows and their breeding habitat may be affected by climate-induced changes to temperature and precipitation. Using a combination of BBS, eBird (https://www.ebird.org; Sullivan and others, 2009), and point-count data, Nixon and others (2016) modeled the effect of future climate change scenarios on Brewer's Sparrow breeding distribution in North America and along the boreal forest-prairie ecotone in Alberta; the models predicted that the suitable climate area for Brewer's Sparrows would decline dramatically within the next 80 years, with limited geographical shift. Under projected greenhouse gas emission scenarios described by the Intergovernmental Panel on Climate Change (2000), Langham and others (2015) categorized the Brewer's Sparrow as a climate-threatened species, indicating that the species would lose more than 50 percent of its current distribution by 2080 across all Intergovernmental Panel on Climate Change scenarios, with no net gain from potential range expansion. Fleishman and others (2014) estimated the current location, quality, and connectivity of habitat for Brewer's Sparrows in four mountain ranges in the central Great Basin and projected the future location, quality, and connectivity of habitat for the species given different scenarios of climate-induced land-cover change. The area occupied by Brewer's Sparrows was projected to decrease by 10–20 percent given a scenario of expansion of pinyon-juniper woodland by the year 2100.

Area Requirements and Landscape Associations

Territory size of the male Brewer's Sparrow varies among regions, sites, and years but is usually about 0.25–2.0 ha; territory size decreases with increased density of breeding pairs and is larger in unsaturated habitats (Wiens and others, 1985; Cannings and others, 1987). Territory density varies from 0.13 to 2.5 males (or pairs) per ha (Walcheck, 1970; Schroeder and Sturges, 1975; Castrale, 1982; Wiens and others, 1985; Rotenberry and Wiens, 1989; Dobler and others, 1996; Walker, 2000; Reinkensmeyer and others, 2007; Rotenberry and others, 2020).

The Brewer's Sparrow may be area sensitive. In British Columbia, the species inhabited extensive tracts of big sagebrush (Cannings and others, 1987; Sarell and McGuinness, 1996). The species can successfully breed in small patches (for example, 6 ha) of suitable shrubsteppe habitat within a larger unsuitable matrix of agricultural lands (Wisdom and others, 2000; Vander Haegen, 2007), and the species can occur in sagebrush-dominated patches within forests (O'Meara and others, 1981; Wilson and others, 2009). However, evidence suggests that smaller sagebrush patches (especially within fragmented landscapes) in some parts of the species' range are occupied less often and may act as population sinks (that is, death rates exceed birth rates and immigration exceeds emigration) (Knick and Rotenberry, 1995). In disturbed landscapes of southwestern Idaho, isolated patches of sagebrush were occupied less often than patches in less fragmented shrubsteppe, suggesting that smaller patches of habitat are of marginal suitability (Knick and Rotenberry, 1995). In a second study in southwestern Idaho, Brewer's Sparrow abundance in fragmented shrubsteppe was similar to abundance in contiguous shrubsteppe habitat, but nest success was lower in the fragmented shrubsteppe habitat (Schoeberl, 2003). In northwestern Colorado, Brewer's Sparrows were most common in large sagebrush openings within pinyon-juniper woodlands and less common in small sagebrush patches (Sedgwick, 1987). Within shrub-dominated mountain meadows in northern Utah, the occurrence of Brewer's Sparrows increased as meadow area increased (Wilson and others, 2009). Brewer's Sparrows were reliably recorded in mountain meadows >40 ha, whereas meadows <40 ha were occupied only if the nearest conspecific neighbor was within 140 m. Wilson and others (2009) concluded that landscape processes (for example, metapopulation dynamics) that allow birds to occupy small meadows may be different from those operating in larger meadows. In a 3-year study in eastern Washington, nesting success and season-long productivity of Brewer's Sparrows were lower in shrubsteppe fragments (mean=495 ha) than in more continuous shrubsteppe patches (a minimum of 1.5 km to a developed edge) (Vander Haegen, 2007). In that same study area, predation of both real and artificial nests was higher in fragmented shrubsteppe patches (median size=146 ha) than in unfragmented patches (median size=115,368 ha) (Vander Haegen and others, 2002). In pastures in western South Dakota and southwestern North Dakota, Brewer's Sparrow occurrence increased with increasing proportions of pastures with sagebrush (Lewis and Higgins, 2010). In a 400-m buffer centered on the midpoint of the bird survey transects, the percent of the buffer that was pasture with shrubs was 95.2 percent where Brewer's Sparrows were present and 82.8 percent where they were absent. In the 800-m buffer, the percent of pasture with shrubs was 86.3 percent where Brewer's Sparrows were

present and 75.6 percent where they were absent (Lewis and Higgins, 2010). In northwestern Colorado, Brewer's Sparrows selected taller sagebrush within 30 m and 1 km of survey points and greater herbaceous cover (up to 35 percent) within 5 km of survey points (Timmer, 2017).

Several researchers have examined the effect of habitat at different spatial scales on Brewer's Sparrow abundance. In British Columbia, the species avoided sagebrush sites surrounded within 500 m by agricultural fields and selected sagebrush sites that had more coniferous forest at both the 1- and 2-km scales (Paczek, 2002). In southeastern Oregon, Brewer's Sparrow abundance was positively associated with percentage of sagebrush cover and sagebrush height at the local scale (within 100 m of bird-survey points) (Noson and others, 2006). At the landscape scale (within 1 km of bird-survey points), abundance was positively associated with percentage of sagebrush cover and sagebrush edge density (total length of sagebrush edge divided by total area) and negatively associated with percentage of juniper cover (Noson and others, 2006). In Montana, Chalfoun and Martin (2007) examined the breeding habitat preferences of Brewer's Sparrows across the spatial scales of the nest patch, the territory, and the landscape. Both shrub density and density of potential nest shrubs were greater in nest patches than in plots systematically sampled within the study sites. At the territory scale, Brewer's Sparrows consistently selected territories with greater shrub cover and density of potential nest shrubs than habitat outside of territories. At the landscape scale, Brewer's Sparrows settled at higher densities in landscapes with high shrub cover and low shrub density. In southern British Columbia and northern Washington, Knight and others (2014) reported that the mean number of detections of male Brewer's Sparrows was 2–10 times higher in sagebrush habitat at least 400 m from the edges of orchards or vineyards (that is, interior sagebrush habitat) than in sagebrush habitat adjacent to orchards or vineyards, despite otherwise similar vegetation structure and composition. One Brewer's Sparrow nest was found in sagebrush habitat adjacent to orchards, none were found in sagebrush habitat adjacent to vineyards, and 14 were found in interior sagebrush habitat. However, in a subsequent publication, Knight and others (2016) reported that Brewer's Sparrow abundance (measured as the maximum raw number of individuals recorded during a single point count) did not differ between interior sagebrush habitat and sagebrush habitat adjacent to agriculture.

Brewer's Sparrow. Illustration by Patsy Renz, used with permission.

Brood Parasitism by Cowbirds and Other Species

The Brewer's Sparrow is an uncommon host of the Brown-headed Cowbird (*Molothrus ater*) (Friedmann, 1963; Shaffer and others, 2019; Rotenberry and others, 2020). Published and unpublished rates of cowbird brood parasitism of Brewer's Sparrow nests are summarized in Shaffer and others (2019) and varied from 0 percent (several studies) to 58 percent of 19 nests in northern Washington (N. Mahony, written commun. [n.d.] in Shaffer and others, 2019), with most studies reporting little or no parasitism (Rich, 1978; Reynolds, 1981; Biermann and others, 1987; Cannings and others, 1987; Rotenberry and Wiens, 1989; Vander Haegen and Walker, 1999, Logan, 2001; Mahony and others, 2006; Vander Haegen, 2007). Multiple parasitism by cowbirds is uncommon in Brewer's Sparrow nests (Paine, 1968; Vander Haegen and Walker, 1999). In eastern Washington, Brewer's Sparrow nests initiated early in the breeding season, before most cowbirds arrived, were parasitized less frequently than nests initiated later in the breeding season (Vander Haegen and Walker, 1999).

Anecdotal evidence suggests that the risk of cowbird parasitism in shrubsteppe increases with proximity to cowbird feeding areas and with proximity to high perches from which male cowbirds can display and female cowbirds can search for nests (Rich, 1978; Biermann and others, 1987; Freeman and others, 1990; Vander Haegen and Walker, 1999). In southern Alberta, cowbirds and parasitized nests were recorded at a site within 3 km of a cattle feedlot, but cowbirds were not recorded (and did not parasitize nests) at a site 10 km from the feedlot (Biermann and others, 1987). Logan (2001) reported no cowbird parasitism of 44 Brewer's Sparrow nests in contiguous shrubsteppe habitat in central Montana, but he found high parasitism rates of nests of other bird species (about 50 percent of nests) in nearby riparian areas. In eastern Washington, cowbirds were more abundant in fragmented shrubsteppe than in less fragmented landscapes (Vander Haegen and others, 2000). Cowbird parasitism rates also were higher in fragmented shrubsteppe landscapes (that is, where past conversion to agriculture left shrubsteppe existing only as islands or as interconnected fragments in an agricultural matrix) than in continuous shrubsteppe landscapes (that is, where shrubsteppe communities were primarily unaffected by agriculture) (Vander Haegen, 2007).

Hatching and fledging success of cowbirds in Brewer's Sparrow nests is poor, perhaps because some Brewer's Sparrows abandon parasitized nests (Vander Haegen and Walker, 1999). Nine of 13 parasitized nests in southern Alberta, four of 14 parasitized nests in eastern Washington, and six of 22 parasitized nests in southern British Columbia were abandoned (Biermann and others, 1987; Vander Haegen and Walker, 1999; Mahony, 2003). In contrast, only five of 267 unparasitized nests were abandoned in eastern Washington (Vander Haegen and Walker, 1999). Biermann and others (1987) reported that only two cowbirds fledged from 18 parasitized nests in southern Alberta. Vander Haegen and Walker (1999) reported that only two cowbird young fledged from 14 parasitized nests over 2 years in eastern Washington. Only one cowbird fledged from 22 parasitized nests over 4 years in southern British Columbia (Mahony, 2003). Cowbird parasitism also is associated with reduced fledging success. Among Brewer's Sparrow nests that fledged at least one host young in eastern Washington, parasitized nests fledged fewer host young per nest (1.75, n=8) than unparasitized nests (3.12, n=295) (Vander Haegen, 2007).

Breeding-Season Phenology and Site Fidelity

In the Great Plains, Brewer's Sparrows arrive on the breeding grounds from mid-April through early June and depart in August and September (Paine, 1968; Salt and Salt, 1976; South Dakota Ornithologists' Union, 1991; Kingery, 1998). In other parts of their breeding range, males arrive between mid-April and mid-June (Cannings and others, 1987; Sarell and McGuinness, 1996; Walker, 2000; Harrison, 2008; Harrison and Green, 2010; Rotenberry and others, 2020). The species generally arrives earlier at lower latitudes and at lower elevations, and males generally arrive earlier than females (Rotenberry and others, 2020). The mean arrival date of females may vary by as many as 15 days among years (Walker, 2000). In the Great Plains, the peak nesting period for Brewer's Sparrows is mid-May through July, with nests reported from May 24 through July 3 in western South Dakota (South Dakota Ornithologists' Union, 1991) and from May 26 through June 27 in southern Alberta (Biermann and others, 1987). In other regions, breeding occurs from early April through late July, with a peak between early May and early July (Tyler, 1910; Fautin, 1946; Rich, 1980; Howe and others, 1996; Vander Haegen and Walker, 1999; Walker, 2000; Ruehmann and others, 2011; Rotenberry and others, 2020). Dates of nest initiation may vary by as much as 2 weeks in consecutive years (Best, 1972; Walker, 2000). Brewer's Sparrows in the northern part of their range regularly initiate two nesting attempts per season and, in rare cases, successfully fledge young from three consecutive nests (Mahony and others, 2001). Fall migration may begin as early as late July, but most Brewer's Sparrows depart the breeding latitudes from mid-August through October (Paine, 1968; Rotenberry and others, 2020).

Second and subsequent nesting attempts are initiated by Brewer's Sparrows between early June and mid-July (Walker, 2000; Ruehmann and others, 2011; Rotenberry and others, 2020). Latest known dates of nest initiation are July 20 in southern British Columbia (Mahony, 2003) and July 22 in Oregon (Rotenberry and others, 2020). Young birds generally remain within 200 m of the nest until they become independent from their parents, about 30 days after fledging (Yu, 1999). Within the breeding season, pairs whose first nests were depredated typically renested farther away and in patches with different vegetative characteristics than their first nests compared to pairs that renested following a successful first nest, suggesting that Brewer's Sparrows exhibit facultative and adaptive behavioral responses to nest failure (Chalfoun and Martin, 2010).

Brewer's Sparrow males often exhibit site fidelity to breeding territories or breeding locations (Petersen and Best, 1987; Walker, 2000; Harrison and Green, 2010; Rotenberry and others, 2020). Estimates of site fidelity based on return rates of marked birds vary from 25 percent of 12 males in southeastern Idaho (Petersen and Best, 1987; Rotenberry and others, 2020) to 50 percent of 24 males in eastern Washington (Walker, 2000). Abe (2007) reported 20–38 percent site fidelity of color-banded adults (males and females combined) over 3 years across five study plots in western Montana. Among males that returned in subsequent years in southern British Columbia, a greater proportion returned to the same territory if they fledged at least one young the previous year (about 71 percent; sample size unclear) than if they did not fledge young the previous year (about 28 percent), suggesting that prior reproductive success plays a role in interannual territory fidelity (Harrison, 2008; Harrison and Green, 2010). In the southern Okanagan and Similkameen valleys of British Columbia, Mahony (2003) reported a high degree of adult breeding site fidelity; 26–66 percent of 132 adult females and 29–60 percent of 140 adult males returned in a subsequent year. In a 3-year study in Grand Teton National Park in Wyoming, 9 percent of 148 banded females and 18 percent of 133 banded males were resighted in their same breeding areas in a subsequent breeding season (Chalfoun, 2011). Information about natal-site fidelity of Brewer's Sparrows is limited (Rotenberry and others, 2020). Abe (2007) resighted 1.4 percent of 491 banded nestlings at natal sites 1–2 years later, and Mahony (2003) resighted 5.2 percent of 460 banded nestlings during a 3-year period. Rotenberry and others (2020) reported that, of 400 nestlings banded in 7 years, none returned to breed in their natal site. Wiens and Rotenberry (1985) indicated that the failure of their study to show a consistent or rapid response by Brewer's Sparrows to a major habitat change (sagebrush control by herbicide application) may have been related to time lags produced by site fidelity of breeding individuals.

At the northern periphery of the species' range, where the species breeds in small clusters within larger areas of suitable habitat, conspecific cueing and social attraction (that is, clustered breeding that is unrelated to resource distribution) may have played a role in Brewer's Sparrow habitat selection (Harrison and others, 2009). Croteau and others (2007) reported that, at the northern edge of the species' range, where sagebrush is naturally fragmented (for example, by conifers), Brewer's Sparrows populations consisted of a single genetic population in which gene flow among the isolated breeding locales was unimpeded. Croteau and others (2007) concluded that juvenile dispersal linked the isolated breeding locales of this species and that suitable breeding habitat may be colonized relatively quickly.

Species' Response to Management

Management activities have substantially altered, and continue to alter, breeding habitat for Brewer's Sparrows (Vale, 1975; Young, 1989; Rotenberry, 1998; Paige and Ritter, 1999). Sagebrush often is removed by chaining (that is, dragging a heavy anchor chain between two bulldozers or other equipment), burning, herbicide spraying, plowing, or during construction of energy infrastructure, and these areas often are then planted with nonnative species (for example, crested wheatgrass [*Agropyron cristatum*] or alfalfa [*Medicago sativa*]) to increase forage for livestock or as part of a reclamation effort (Vale, 1974; Rotenberry, 1998). Almost all shrubsteppe in western North America currently is, or historically has been, grazed by cattle or sheep (Vale, 1975; Young, 1989; Paige and Ritter, 1999). Prescribed burns and mechanical shrub-removal treatments also are used to reduce shrub cover, either to increase forage for livestock, to create habitat mosaics for other species such as Greater Sage-Grouse (*Centrocercus urophasianus*), or both (Petersen and Best, 1987, 1999; Connelly and others, 2000; Norvell and others, 2014).

The following is a review of the effects of sagebrush removal, burning, grazing, herbicide spraying, removal of pinyon-juniper and other conifers, grassland restoration, and energy development on populations and individuals of Brewer's Sparrows. Several authors have emphasized the need to study posttreatment responses for longer than 3 years to overcome problems associated with site fidelity of individuals and masking of treatment effects by natural fluctuations in abundance (Wiens and Rotenberry, 1985; Wiens and others, 1986; Rotenberry, 1998; Petersen and Best, 1999; Norvell and others, 2014). Thompson (2002) and Knick and others (2003) recommended that research evaluating demographic parameters should use marked individuals rather than indices of abundance based on singing males.

Brewer's Sparrows dramatically decrease in abundance or disappear after complete removal of sagebrush (Best, 1972; Schroeder and Sturges, 1975; Castrale, 1982; Bock and Bock, 1987; Welch, 2002). Planting of nonnative grasses following sagebrush removal hinders recolonization by sagebrush and delays recovery of suitable habitat for Brewer's Sparrows (Olson, 1974; Reynolds and Trost, 1980, 1981; McAdoo and others, 1989). In eastern Wyoming, long-term disturbance by black-tailed prairie dogs (*Cynomys ludovicianus*) led to prolonged clipping and girdling of sagebrush, low values of sagebrush canopy cover on prairie dog towns, and avoidance by Brewer's Sparrows and other sagebrush-obligate birds (Duchardt and others, 2019). Brewer's Sparrows were 4.5 times more abundant in undisturbed surrounding sagebrush shrublands than on prairie dog towns (Duchardt and others, 2019). In a central Oregon study across a successional gradient from grassland to shrubsteppe to juniper woodland, Brewer's Sparrow densities were lower (0.41 bird per ha per year) in recently burned (within previous 5 years) grassland sites with <5 percent shrub cover of mostly rabbitbrush (*Chrysothamnus* spp.) than densities (1.64 birds per ha per year) in unburned (>40 years since previous burn) shrubsteppe with 18.6 percent shrub cover of mostly mountain big sagebrush (Reinkensmeyer and others, 2007). In south-central Montana, Brewer's Sparrows were absent from a site 2–3 years after a fire eliminated all sagebrush cover, even though grass and forb cover were similar on burned and unburned plots (Bock and Bock, 1987).

After partial removal, sagebrush quickly becomes reestablished unless weeds invade treated areas (Castrale, 1982). Control of sagebrush by chaining leaves small, young shrubs that regenerate and provide nest sites for Brewer's Sparrows within 4 years after treatment, but the effect of partial sagebrush removal on reproductive success and survival is unclear (Castrale, 1982). In California, Brewer's Sparrows continued to nest in areas sprayed with the herbicide 2,4,5–Trichlorophenoxyacetic acid (2,4,5–T) that retained some live shrubs for at least 2 years after treatment (Beaver, 1976). In a high-elevation area of Utah, mechanical removal of 80 percent of sagebrush cover from 40 to 60 percent of treated study areas with a pasture aerator had no effect on Brewer's Sparrow extirpation probability or indices of abundance within 4 years following treatment (Norvell and others, 2014). The long-term effects of partial sagebrush removal are unknown.

Partial removal of sagebrush may reduce foraging opportunities for individuals (Wiens and others, 1986). In central Oregon, experimental reductions of sagebrush cover from 22 to 14 percent did not affect the placement or size of territories but caused males on treatment plots to forage less and sing more than males on control plots (Wiens and others, 1986). Males spent more time in unmanipulated blocks (those with no shrubs removed) than in blocks in which shrubs had been removed.

There is limited information or understanding on the effects of fire on populations of sagebrush-obligate birds, but burning of sagebrush generally decreases the abundance of Brewer's Sparrows (Knick and others, 2005). Burning may negatively affect populations by promoting the spread of nonnative weeds and the subsequent conversion of shrubsteppe habitats to nonnative annual grasslands, particularly within

more-arid, lower-elevation sites (Knick and Rotenberry, 1995, 1997, 1999, 2000, 2002). In a study in shrubsteppe in the Intermountain West, Brewer's Sparrows were present on 12 of 13 transects in unburned sagebrush but were absent from 13 adjacent transects in burned sagebrush that were reseeded to nonnative perennial grasses and forbs (Welch, 2002). In south-central Wyoming shrubsteppe, indices of abundance were four times higher on untreated control plots with 37 percent average sagebrush cover and mean shrub height of 31 cm than on burned areas with 6 percent average sagebrush cover and mean shrub height of 20 cm (Kerley and Anderson, 1995). In southern British Columbia, the species nested in areas that had been burned 3–6 years earlier, but they used a much greater diversity of plant species for nesting after burning, including large perennial forbs (Mahony, 2003). Six years after burning, the species returned to nest in sagebrush that had germinated after fire. In eastern Oregon, Holmes (2007) evaluated the effect of prescribed burns on Brewer's Sparrow abundance in the third year postburn. Brewer's Sparrow abundance was 7 percent lower on sites that were lightly burned than on unburned sites and 55 percent lower on sites in which 70 percent of the canopy had been burned. Removal of 5–35 percent of the shrub layer caused a 7-percent reduction in Brewer's Sparrow detections. In southeastern Oregon, Noson and others (2006) determined that burning negatively impacted Brewer's Sparrows abundance because of the destruction of the shrub layer. In southwestern Idaho, over a 13-year period, the abundance of Brewer's Sparrows declined in areas where habitat changes were greatest because of fire (Knick and Rotenberry, 2000). In Utah, Castrale (1982) compared indices of Brewer's Sparrow abundance on a regenerating 4-year-old burned site, a regenerating 4-year-old chained site, and a regenerating 17-year-old plowed site. Brewer's Sparrows were largely absent from burned areas (0.06–0.22 pair per ha), except in intact remnants of sagebrush, and they occurred at relatively low densities (0.38–0.47 pair per ha) on chained and plowed sites.

Partial burns are less detrimental to Brewer's Sparrow populations than complete burns and may have little or no long-term effects on populations (McGee, 1976; Holmes, 2007). In burned mountain big sagebrush of western Wyoming and eastern Oregon, Brewer's Sparrows continued to nest in remaining patches of unburned shrubs (McGee, 1976; Petersen and Best, 1987, 1999; Holmes, 2007). In southeastern Idaho, an incomplete prescribed burn (45 percent of the area was burned) resulted in significantly lower densities of Brewer's Sparrows in the 2 years following the burn, but densities exceeded those on control plots during the third and fourth years postburn (Petersen and Best, 1987). Mean nest height and nest-shrub height decreased 9.7 and 10 cm postburn, respectively (range of 11–26 nests across 5 years). Within 5 m of the nests, the height of shrubs decreased 14 cm, sagebrush cover decreased from 32 to 15 percent, and bare ground cover increased from 48 to 58 percent near nests postburn. In the 4 years following the burn, there was no consistent effect of prescribed burning on return rates, mating success, nestling growth rate, reproductive success, or nest survival. Continued monitoring of burned and unburned plots over 6 years indicated that prescribed burning by itself did not have any long-term effects on Brewer's Sparrow abundance (Petersen and Best, 1999).

Burning also may affect arthropod food resources or adult foraging behavior. Arthropods constituted most of the (70–80 percent) of the adult diet and 100 percent of the nestling diet during the breeding season (Feist, 1968a; Best, 1972; Petersen and Best, 1986a; Howe and others, 2000; Rotenberry and others, 2020). In southeastern Idaho, prescribed burning did not affect the composition of nestling diets, largely because adults avoided burned areas and continued to forage for arthropods in unburned areas (Winter, 1984; Petersen and Best, 1986a). Although nesting Brewer's Sparrows spend 40–50 percent of their time foraging, prescribed burning had no effect on their activity budgets, feeding-trip frequency, or prey load size (Winter, 1984). After burning, males flew 1.5 times farther from nests to forage, but this did not change the duration of their foraging bouts (Winter, 1984).

Brewer's Sparrow abundance and productivity are generally higher in ungrazed or lightly to moderately grazed shrubsteppe than in heavily grazed shrubsteppe (Kantrud and Kologiski, 1982, 1983; Sarell and McGuinness, 1996; Logan, 2001). In Saskatchewan, Brewer's Sparrow abundance did not differ between grazed and ungrazed mixed-grass prairies (Bleho, 2009). In the northern Great Plains in the United States, Brewer's Sparrow abundance in shrubsteppe was highest in lightly grazed areas and lowest in heavily grazed areas (Kantrud and Kologiski, 1983). In transition zones between shrubsteppe and shortgrass prairies, Brewer's Sparrow abundance was highest in lightly to moderately grazed areas (Kantrud and Kologiski, 1983). Densities of Brewer's Sparrow were highest on lightly grazed mixed-grass prairie sites with ustic aridisol soils (light-colored soils that are low in organic carbon) and dominated by big sagebrush (Kantrud and Kologiski, 1982). In most other soil groups, Brewer's Sparrow densities were higher where grazing was moderate, and in all soil groups, Brewer's Sparrow densities were lowest where grazing was heavy (Kantrud and Kologiski, 1982). In central Montana, Brewer's Sparrows occurred at higher densities and had higher nesting success on ungrazed plots than on adjacent grazed plots (Logan, 2001). In southeastern Idaho, Reynolds and Trost (1980, 1981) found similar numbers of Brewer's Sparrow nests on nearby grazed and ungrazed plots. In the Okanagan Valley of British Columbia, Sarell and McGuinness (1996) reported that Brewer's Sparrows preferred establishing breeding territories in areas of fair or good range condition with >25–75 percent of the grasses being decreasers (that is, grasses that decline in response to prolonged grazing; McClean and Marchand, 1968) than in areas of poor range condition with <25 percent of the grasses being decreasers. In the Columbia River Basin of eastern Washington, Brewer's Sparrow abundance was higher on shrubsteppe plots with >25 percent cover of native, climax vegetation than on plots with <25 percent climax vegetation (Dobler and others, 1996; Vander Haegen and others, 2000).

Little is known regarding the effects of grazing on individual Brewer's Sparrows. Livestock occasionally trample low-lying Brewer's Sparrow nests or dislodge them from nest shrubs (N. Mahony, pers. commun. [n.d.] in Paczek, 2002; Johnson, 2010).The effects of grazing systems on Brewer's Sparrow abundance or productivity have been poorly studied. In eastern Montana, Golding and Dreitz (2017) compared Brewer's Sparrow abundance in native rangeland that was grazed using season-long grazing (that is, continuous presence of livestock in the same area during the growing season [May through November] repeatedly over multiple years) and rest-rotation grazing (that is, alternating 2- to 3-month grazing periods, followed by 15–18 months of rest, such that a given area will not be grazed during the same season repeatedly over multiple years). The Brewer's Sparrow was equally abundant in both grazing systems, indicating that grazing system had no effect on their abundance (Golding and Dreitz, 2017).

Brewer's Sparrow abundance usually declines following spray application of herbicides that reduces the amount of live sagebrush (Best, 1972; Schroeder and Sturges 1975; Kerley and Anderson, 1995). Brewer's Sparrows generally prefer to nest and forage in live sagebrush and live foliage (Petersen and Best, 1985; Wiens and others, 1987b; Rotenberry and Wiens, 1998; Rotenberry and others, 2020). In central Montana, indices of abundance declined 54 percent after 1 year on plots where all sagebrush plants were killed by spraying with the herbicide 2,4–Dichlorophenoxyacetic acid (2,4–D) at a rate of 2.3 kilograms (kg) per ha (Best, 1972); 72 percent of 39 nests were in shrubs with >75 percent green foliage. The species remained absent from these plots after 5 years (Pyrah and Jorgensen, 1974 in Braun and others, 1976). In that study, total sagebrush cover decreased from 21 to 0 percent, forb cover decreased from 25 to 2 percent, and grass cover increased from 39 to 71 percent 1 year after spraying. In contrast to those total-kill plots, indices of Brewer's Sparrow abundance on partial-kill plots did not change after 1 year. In shrubsteppe of south-central Wyoming, indices of abundance were four times higher on untreated control plots with 37 percent sagebrush cover and mean shrub height of 31 cm than on sprayed areas (sprayed 20–22 years previously with 2,4–D; application rate not reported) with 15 percent sagebrush cover and mean shrub height of 22 cm (Kerley and Anderson, 1995). At high-elevation sites in Wyoming, indices of abundance were 67 percent lower on treated sites 1 year after spraying with 2,4–D at 3.4 kg per ha and 99 percent lower 2 years after spraying; Brewer's Sparrows remained abundant (0.75–1.1 nesting pairs per ha) on nearby unsprayed control sites (Schroeder and Sturges, 1975). No Brewer's Sparrow nests were found on sprayed plots, and adults were observed only in areas with intact patches of live sagebrush. Spraying active nests with 2,4–D at concentrations of 3.4 kg per ha during the incubation phase had no measurable effect on hatching success, nestling survival, or fledging success, and subsequent defoliation of the nest shrub did not significantly alter average nest temperature (Schroeder and Sturges, 1975). In south-central Oregon, Brewer's Sparrow densities fluctuated dramatically and unpredictably in response to an herbicide treatment of 2,4–D (application rate was not reported), followed by removal of dead sagebrush (some shrubs survived) and reseeding with crested wheatgrass (Wiens and Rotenberry, 1985). Densities were estimated as 1.5, 2.8, and 3.4 individuals per ha in the first, second, and third years before the treatment, respectively. Densities were estimated as 2.0, 0.7, and 3.4 individuals per ha in the first, second, and third years following the treatment, respectively. These fluctuations were not related to population changes occurring elsewhere in this region. Treatment effects may have been confounded by site fidelity of individuals, and annual variation in breeding phenology may have contributed to fluctuations in density estimates (Wiens and Rotenberry, 1985). On brush-covered mountain slopes in east-central California, the number of pairs on territories did not change in response to spraying of the herbicide 2,4,5–T (0.54 kg per ha on one plot and 0.72 kg per ha on another) the previous autumn, despite widespread reductions in live foliage and apparent changes in food resources (Beaver, 1976). Although most shrubs lost their leaves in response to herbicides, shrub physiognomy did not change, and pairs continued to nest in dead shrubs the following summer.

The effects of insecticide and herbicide spraying also may result in shifts in Brewer's Sparrow nest placement, diet, and parental behavior (Best, 1972; Schroeder and Sturges, 1975; Howe and others, 1996). In central Montana, Brewer's Sparrows switched to nesting in larger, denser shrubs after sagebrush was killed by spraying with 2,4–D (Best, 1972). Grass cover was greater at nests placed in dead sagebrush, either because Brewer's Sparrows preferred this characteristic or because grass cover was greater in sprayed areas. The proportion of arthropods in adult diets decreased from 71–81 percent before treatment with the herbicide 2,4–D at 3.4 kg per ha to 38–53 percent after treatment, suggesting that defoliation of sagebrush reduced arthropod availability (Best, 1972). On control plots, Brewer's Sparrow diets consisted of 76 percent arthropods, 12 percent plant foods, and 12 percent other food items, whereas diets on sprayed plots consisted of 46 percent arthropods, 39 percent plant foods, and 15 percent other food items. Although herbicide spraying induced a shift in adult diet, how that shift affected nestling diet, nestling survival, reproductive success, and adult survival was not studied (Best, 1972). In Wyoming, no nests were found in areas sprayed with 2,4–D (application rate not reported) and the only individuals found in sprayed areas were within remaining patches of live sagebrush (Schroeder and Sturges, 1975). Large areas of sagebrush also are treated annually with insecticides to control unwanted insects such as mosquitoes (Culicidae) and grasshoppers (Acrididae) (George and others, 1995; Howe and others, 1996). In shrubsteppe of southeastern Idaho, ultra-low volume aerial spraying of malathion, a broad-spectrum insecticide, at 0.59 kg per ha during the breeding season reduced insect densities on the study plot but resulted in no immediate fatalities of adult Brewer's Sparrows and produced no consistent differences in hatching

success, nestling survival, nest success, or the number of young fledged per nest (Howe and others, 1996). Nestling growth rates and mass at fledging were significantly reduced on sprayed plots in 1 of the 2 years of the study. Because of reduced food availability associated with spraying, the average duration of feeding trips on treated sites was 5 minutes longer than on untreated sites. The mass of food delivered to nestlings did not differ between treated and untreated sites (Howe and others, 2000).

Trees may negatively affect Brewer's Sparrow abundance and reproductive success (Welstead, 2002; Donnelly and others, 2017). Removal of early to mid-successional pinyon-juniper via prescribed burns or mechanical removal is currently a widespread management tool used to counteract spread of pinyon-juniper into sagebrush ecosystems and to restore habitat for sagebrush-obligate species (Baruch-Mordo and others, 2013; Knick and others, 2014). Successful restoration of shrubsteppe habitats seems limited after dense stands of pinyon-juniper have become established and shrub, grass, and forb understories have been reduced (Knick and others, 2014), and little information has been published on the response of Brewer's Sparrow to tree removal (Holmes and others, 2017). In the Okanagan Valley of British Columbia, Brewer's Sparrow abundance declined as the density of ponderosa pine (*Pinus ponderosa*) >2 m tall increased (Krannitz, 2007). In the South Okanagan region of British Columbia, survival of Brewer's Sparrow nests declined with an increase in tree density (that is, the count of all coniferous or deciduous trees >5 m tall within 100 m of the nest) (Welstead, 2002). A few short-term studies have been conducted on the effectiveness of prescribed burning, chaining, or mechanical removal of pinyon-juniper in restoring shrubsteppe habitat. In Idaho, Miller and others (2000) found that mid- to late-successional sites of pinyon-juniper contain tall, dense stands that have largely outcompeted the sagebrush understory, so it is much more effective to treat early-successional sites for sagebrush restoration. Following mechanical removal of dense pinyon-juniper woodlands in south-central Oregon, there were few Brewer's Sparrow detections, and there was no increase in detections from the pretreatment year to the third-year posttreatment (Sabol, 2005). In a study investigating western juniper (*Juniperus occidentalis*) removal in sagebrush steppe in Oregon, Holmes and others (2017) reported that Brewer's Sparrow densities increased linearly in the first 3 years following tree removal; average densities (45.4 territories per km^2) 3 years after treatment were more than twice as high as densities (21.5 territories per km^2) in untreated areas. In southern Utah, the relative abundance of Brewer's Sparrows significantly increased 1 year after mechanical thinning (that is, cutting all selected tree types and leaving them lie in place where they fell) of a pinyon-juniper woodland (Crow and van Riper, 2010). At four sites in the Intermountain West, Brewer's Sparrow abundance did not increase after an incomplete removal of pinyon-juniper by prescribed fire (that is, burning 30–97 percent of study areas) (Knick and others, 2014). Woodlands did not become suitable habitat for Brewer's Sparrows within 3–5 years posttreatment; posttreatment, burned sites retained 6–24 percent cover of residual pinyon-juniper woodland that averaged 3–6 m tall. However, within 1 year, Brewer's Sparrows colonized two burned locations adjacent to an expansive shrubsteppe landscape, at which residual pinyon-juniper woodland had been mechanically removed to <1 percent cover following the original prescribed fire treatment. In western Colorado, Brewer's Sparrows were detected only at low densities (0.31–0.56 territory per 10 ha) on plots with 5.2–5.6 percent shrub cover where pinyon-juniper woodland had been removed by chaining 8–15 years earlier (O'Meara and others, 1981). In northwestern Colorado, Brewer's Sparrow density was higher at sites that had been mechanically chained 40 years earlier to remove forest cover than at reference pinyon-juniper woodlands that were never mechanically disturbed (Gallo and Pejchar, 2016). Using data from the BBS in the western United States, Donnelly and others (2017) assessed predictors influencing the spatial distribution of Brewer's Sparrows; greater than 85 percent of areas that underwent targeted conifer removal (similar to tree removals implemented for Greater Sage-Grouse conservation) coincided with moderate-to-high Brewer's Sparrow abundance.

Brewer's Sparrows may derive some benefit from the reversion of cropland to perennial cover of grasses, forbs, and shrubs (Schroeder and Vander Haegen, 2006; Vander Haegen and others, 2015). In eastern Washington, Schroeder and Vander Haegen (2006) compared Brewer's Sparrow detections in CRP fields to those in extant shrubsteppe. Detections were most common in extant shrubsteppe surrounded by either shrubsteppe or cropland, were one-half as common in old CRP fields (that is, planted to nonnative bunchgrasses before 1996) surrounded by shrubsteppe, and were about one-tenth as common in old CRP fields surrounded by cropland or in new CRP fields (that is, planted after 1995 to a mixture of nonnative and native species, including big sagebrush) (Schroeder and Vander Haegen, 2006). Brewer's Sparrows were only detected in CRP fields with regenerating or planted sagebrush and were most common in CRP fields with "well-established" sagebrush (that is, shrubs of sufficient cover and height to support breeding birds). Brewer's Sparrow nest success was slightly higher in CRP fields, but clutch size and the number of fledglings per nest did not differ between old or new CRP and extant shrubsteppe (Schroeder and Vander Haegen, 2006). In Washington CRP fields planted to perennial grasses, forbs, and shrubs, percentage shrub cover was positively associated with Brewer's Sparrow abundance (Vander Haegen and others, 2015). Brewer's Sparrows were not detected in CRP fields in shortgrass prairie regions of Colorado, Kansas, Oklahoma, or Nebraska (McLachlan, 2007), but have been detected in CRP fields with minimal or no sagebrush cover in South Dakota, North Dakota, Minnesota, and Montana (Igl and Murphy, 1996; Igl, 2007, 2009).

In some parts of the species' breeding range, loss of sagebrush habitat through residential and urban development

poses a threat to nesting habitat for Brewer's Sparrows (Sarell and McGuiness, 1996; Paige and Ritter, 1999; Croteau and others, 2007). In Colorado, Brewer's Sparrow densities were higher in lands devoted to ranching than in exurban areas (that is, low-density residential development that occurs beyond incorporated city limit) or in protected areas (that is, areas protected from residential development) (Maestas and others, 2001). Private ranches had higher native plant and animal biodiversity and were on the most-productive, lowest-elevation sites; protected areas were on the least-productive, highest-elevation sites. In exurban areas, disturbances typically associated with human developments (for example, human residences, domestic pets, nonnative plants) are spread farther across the landscape than in more-concentrated developments, such as urban and suburban areas. Elevations varied from 1,740 to 2,200 m above sea level (Maestas and others, 2001). In Grand Teton National Park in Wyoming, Brewer's Sparrows tended to avoid nesting near a highway and a new pedestrian pathway through sagebrush habitats, with no evidence of acclimation over time (Chalfoun, 2011). However, Brewer's Sparrows fledged more young in nests in experimental plots that straddled the highway and pathway than in nests in control plots that were >500 m from the road and pathway. Chalfoun (2011) suggested that nesting birds may have indirectly benefitted from lower risk of nest predation by nesting close to the transportation corridor.

Energy development and concomitant loss and fragmentation of shrubsteppe habitats may affect Brewer's Sparrow abundance and productivity (Ingelfinger and Anderson, 2004; Gilbert and Chalfoun, 2011; Duchardt and others, 2020). In Wyoming, Brewer's Sparrows were less abundant within 100 m of gas-well access roads than 100–200 m from the roads, ostensibly because traffic disturbance was higher along access roads and shrub cover was reduced along the road edge (Ingelfinger and Anderson, 2004). In another Wyoming study, Brewer's Sparrow abundance decreased by 0.3 individual per natural gas well per km^2, which translated into an average loss of 2.5 individuals per km^2 at a well density of 8 wells per km^2 (Gilbert and Chalfoun, 2011). Also in Wyoming, Brewer's Sparrow nest survival declined with increased rodent activity; rodent activity increased with increasing habitat loss caused by development of natural gas wells (Hethcoat and Chalfoun, 2015b). In that same study, the probability of daily survival of Brewer's Sparrow nests decreased by 1.3 percent with every additional hectare of sagebrush habitat lost from natural gas development within 1 km^2 of each nest (Hethcoat and Chalfoun, 2015a). On private and public lands in Wyoming, Mutter and others (2015) found no evidence of Brewer's Sparrows avoiding natural gas-well pads or associated roads in shrubsteppe and semidesert shrubland habitats. In the Thunder Basin National Grassland in Wyoming, Brewer's Sparrow density declined with presence of oil and gas wells within 500 m of point-count locations, increasing road density within 1 km of point-count locations (nonlinear effect), and presence of natural disturbance (that is, long-term prairie dog disturbance) (Duchardt and others, 2020). Beston and others (2016) developed a prioritization system to identify avian species (428 species evaluated) 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 Brewer's Sparrow scored a 2.84 out of nine, where nine indicated high risk; 1.73 percent of the Baird's Sparrow breeding population in the United States was estimated to be exposed to wind facilities. 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; four Brewer's Sparrow mortalities were reported at three wind facilities. Keinath and Kauffman (2014) indicated that Brewer's Sparrows were among the top 35 of 156 ranked species of conservation concern for exposure to wind, oil, and gas developments in Wyoming.

Management Recommendations from the Literature

Major threats to Brewer's Sparrow populations are similar to those faced by other declining sagebrush-obligate species (for example, Greater Sage-Grouse) and include conversion of sagebrush habitats to agriculture or pasture, habitat fragmentation, invasion by nonnative plants, altered fire regimes, livestock overgrazing, conifer encroachment, soil disturbance, conversion to urban or residential housing, and energy development (Vale, 1974; Sarell and McGuinness, 1996; Rotenberry, 1998; Knick, 1999; Paige and Ritter, 1999; Connelly and others, 2000; Wisdom and others, 2000; Knick and Rotenberry, 2002; Knick and others, 2003; Noson and others, 2006; Gilbert and Chalfoun, 2011; Sage Grouse Initiative, 2015; Holmes and others, 2017). These processes often act synergistically (Knick and Rotenberry, 2000). Although some shrubsteppe habitat remains in relatively pristine condition, much of it has been moderately or heavily disturbed and may require intensive management to restore conditions suitable for Brewer's Sparrows (Bock and others, 1993; Knick and Rotenberry, 2002; Knick and others, 2003). Paige and Ritter (1999) reviewed specific strategies for managing local sagebrush habitat for Brewer's Sparrows and other sagebrush-obligate species and emphasized the importance of tailoring management strategies to local conditions.

Protecting intact sagebrush habitats is critical to meeting the needs of the Brewer's Sparrows and other sagebrush-obligate species (Cannings and others, 1987; Sarell and McGuinness, 1996; Noson and others, 2006; Wilson and others, 2009). Conserving and managing large, unfragmented blocks of suitable, intact sagebrush will necessitate a coordinated approach by multiple stakeholders, including private landowners and Federal and State natural resource agencies (Montana Partners in Flight, 2000; Knick and others, 2003). The size of such

areas will depend on the suitability of remaining sagebrush habitat for reaching population goals in the region. Schoeberl (2003) recommended preserving larger, unfragmented shrubsteppe habitat because Brewer's Sparrows have higher reproductive success in these areas.

Brewer's Sparrows and other shrub-obligate species will benefit from preserving large, intact sagebrush stands with average shrub cover of 10–40 percent, average shrub height of 40–110 cm, and a diverse understory of grasses and forbs native to the local area (Petersen and Best, 1985, 1987; Larson and Bock, 1986; Dobler and others, 1996; Montana Partners in Flight, 2000; Rotenberry and others, 2020). Within each stand, nesting Brewer's Sparrows prefer moderately dense sagebrush and medium-sized shrubs (see table AA2). In some habitats with shallow soils and low plant productivity, Brewer's Sparrows may use smaller shrubs for nesting (0.3–0.7 m tall) (for example, Feist, 1968b; Best, 1972; Schroeder and Sturges, 1975; Logan, 2001). In shrubsteppe and transition zones between shrubsteppe and shortgrass prairies in the northern Great Plains, Brewer's Sparrows may prefer areas with high grass and forb cover (for example, 30–80 percent), whereas sparser ground cover of grasses and forbs (for example, 10–30 percent) may be appropriate in the Great Basin (Paige and Ritter, 1999).

Paige and Ritter (1999) recommended identifying and protecting remaining sagebrush habitats, especially those with high biological diversity, an intact understory of native grasses and forbs, and an intact cryptobiotic soil crust. Cryptobiotic soil crusts prevent erosion and hinder the establishment of nonnative plant species. Soil disturbance fractures and eliminates cryptobiotic soil crusts and facilitates invasions by nonnative plants; minimizing soil disturbance from livestock trampling and farm and recreational vehicles will benefit Brewer's Sparrows and other sagebrush obligate birds (Paige and Ritter, 1999). Because disturbance from livestock grazing is ubiquitous in shrubsteppe habitats, cryptobiotic soil crusts and native understories may need to be restored or allowed to regenerate in many areas (Saab and others, 1995).

Habitat restoration and protection actions (for example, tree removal, reducing the threat of invasive plants) that target Greater Sage-Grouse habitats also will benefit Brewer's Sparrows and other sagebrush-associated wildlife (Dobler and others, 1996; Donnelly and others, 2017; Holmes and others, 2017; Timmer, 2017; Barlow and others, 2020). Brewer's Sparrow abundance in the western United States was greater in landscapes containing active sage-grouse leks, which was attributed to greater sagebrush cover surrounding leks (Donnelly and others, 2017). In Oregon, Holmes and others (2017) reported an increase in Brewer's Sparrow densities 3 years following juniper removal to restore habitat for Greater Sage-Grouse. In northeastern Wyoming, Barlow and others (2020) concluded that the overlap in local habitat preferences for the Greater Sage-Grouse and Brewer's Sparrow provides some support that the Greater Sage-Grouse is a useful umbrella species for the sagebrush ecosystem. In northwestern Colorado, Brewer's Sparrow density averaged 3.43 birds per ha in areas likely to be occupied by Greater Sage-Grouse compared to 2.74 birds per ha in areas irrespective of where sage-grouse were likely to occur (Timmer, 2017). In southwestern Colorado, however, mechanical treatments (roller chopping, disking, brush mowing, Dixie Harrow, and Lawson Aerator techniques) to improve Gunnison Sage-Grouse (*Centrocercus minimus*) habitat reduced Brewer's Sparrow densities in treated areas (Lukacs and others, 2015).

Holmes and others (2017) concluded that conifer removal designed with the explicit goal of maintaining sagebrush canopy cover and preventing cut trees from protruding above the shrub understory may result in increased abundance of shrub-obligate birds, such as the Brewer's Sparrow. Knick and others (2014) emphasized that conifer removal was unlikely to benefit sagebrush-obligate birds if management treatments (for example, burning) are not specifically designed to benefit these species. Tree encroachment into sagebrush habitats may contribute to an increase in predators of Brewer's Sparrow nests (Knick and others, 2014), nest parasitism by Brown-headed Cowbirds (Vander Haegen and Walker, 1999), or both.

The negative effects of complete removal of sagebrush may be minimized by incomplete or partial burns that reproduce the mosaic of sagebrush and grassland habitats created by historical fire regimes in sagebrush steppe (Miller and Rose, 1999; Noson and others, 2006). Complete removal of sagebrush eliminates suitable nesting habitat for Brewer's Sparrows and promotes the spread of invasive plants (Rotenberry, 1998; Paige and Ritter, 1999). Reseeding former shrubsteppe with nonnative grasses for livestock production further delays recolonization by sagebrush, thereby reducing habitat quality for Brewer's Sparrows (Reynolds and Trost, 1981; McAdoo and others, 1989). Overgrazed areas with extremely dense sagebrush (>50 percent) may need to be thinned to reestablish native perennial grasses and forbs in the understory (Paige and Ritter, 1999). However, the benefit of thinning must be weighed against the cost of soil disturbance and the risk of promoting weed invasion. If sagebrush must be eliminated, Castrale (1982) recommended treating areas before territory establishment in early spring or after the birds have departed the area in late summer or early fall. If sagebrush control is necessary for livestock production, incomplete burning, chaining, and spraying of sagebrush allow faster regeneration of suitable nesting habitat for Brewer's Sparrows than complete burning or plowing (Braun and others, 1976; Castrale, 1982; Winter, 1984; Peterson, 1995). Sagebrush may regenerate within 5–10 years after spraying or chaining, and sagebrush may recolonize adjacent burned or plowed areas, reestablishing the original cover (but not the original height) within about 35 years (Harniss and Murray, 1973), depending on the size and shape of the treatment. The negative impact of prescribed burns on Brewer's Sparrows can be lessened by allowing some sagebrush canopy to remain unburned (Holmes, 2007). All shrub-removal methods run the risk of contributing to the spread of invasive plants into disturbed areas (Rotenberry, 1998).

The ecological effects of nonnative species are unpredictable and often cause permanent, undesirable changes to the landscape and to populations of native plants and animals (Whisenant, 1990; Billings, 1994; Knick and Rotenberry, 1995, 1997, 1999; Paige and Ritter, 1999; Wisdom and others 2000). Nonnative grasses and forbs, especially those that are invasive or highly flammable (for example, cheatgrass), threaten sagebrush habitats and populations of sagebrush-obligate birds; several publications have underscored the importance of locating and controlling these invasive plants (Billings, 1994; Paige and Ritter, 1999; Wisdom and others, 2000). Loss of sagebrush habitat after invasion by nonnative plants alters fire regimes and may be irreversible (Knick and Rotenberry, 1995, 1997, 1999). Historically, sagebrush steppe burned every 60–100 years; cheatgrass reduces fire-return intervals to every 3–5 years, a timeframe in which sagebrush cannot regenerate (Whisenant, 1990). Management activities that restore native shrubs, grasses, and forbs will benefit Brewer's Sparrows (Saab and others, 1995; Knick and others, 2003). Chambers and others (2014, 2017) provided guidance to prioritize landscapes for restoration of sagebrush habitats across multiple scales based on concepts of resistance to invasion of annual grasses and resilience to altered fire regimes.

Saab and others (1995) recommended managing stocking rates to reduce livestock impacts on the grass and forb understory and to reduce soil compaction and disturbance (Saab and others, 1995). Eliminating livestock grazing altogether, or significantly reducing stocking rates, reduces the risk of nonnative plant invasions and may improve the quality of sagebrush habitats for Brewer's Sparrows (Saab and others, 1995). However, light grazing may maintain Brewer's Sparrow abundance (Kantrud and Kologiski, 1983) and reduce risk of catastrophic wildfire by reducing grass understories. Brewer's Sparrows are occasional cowbird hosts and their populations may be vulnerable to brood parasitism where land conversion to agriculture and fragmentation provide contact zones between cowbirds and nesting Brewer's Sparrows (Rich 1978). Paige and Ritter (1999) recommended managing livestock facilities (that is, livestock corrals, feedlots, and stock tanks) and minimizing livestock concentrations near sagebrush areas to reduce sources of food (for example, waste grain) for Brown-headed Cowbirds. New livestock facilities should be situated in areas surrounded by existing agricultural land rather than near sagebrush habitats (Paige and Ritter, 1999).

A primary management consideration is avoiding application of herbicides or insecticides in sagebrush habitats during the breeding season (Paige and Ritter, 1999). If insecticides are used, Paige and Ritter (1999) recommended developing an integrated pest management plan that considers natural pathogens, suitable crop and grazing practices, minimal use of insecticides, rapidly degrading chemicals with low toxicity to nontarget organisms, and minimum application rates. Delaying application of insecticides until September will avoid peak periods of nesting and fledgling development, reduce the loss of food supply, and avoid the chance of secondary poisoning (Paige and Ritter, 1999). Peterson (1995), Rotenberry (1998), and Paige and Ritter (1999) included additional information on managing sagebrush habitats for sagebrush bird communities.

Hethcoat and Chalfoun (2015a) recommended that the effects of energy development on Brewer's Sparrows and other sagebrush-dependent species may be minimized by reducing the conversion of habitat surrounding well pads during initial well construction. Habitat conversion can be minimized by employing directional drilling or restricting new wells to existing well pads (Hethcoat and Chalfoun, 2015a). Reestablishment of habitat and recolonization by sagebrush-obligate species, such as the Brewer's Sparrow, may take decades after a natural gas site is abandoned and reclaimed (Ingelfinger and Anderson, 2004).

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Table AA1. Measured values of vegetation structure and composition in Brewer's Sparrow (*Spizella breweri breweri*) breeding habitat by study. The parenthetical descriptors following authorship and year in the "Study" column indicate that the vegetation measurements were taken in locations or under conditions specified in the descriptor; no descriptor implies that measurements were taken within the general study area.

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

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)
Abe, 2007 (nests)	Montana	Sagebrush (*Artemisia*) steppe	Grazed	27[a], 72[b]	4.0[c]	28[d]	--	42	22	--	--
Abe, 2007 (nests)	Montana	Sagebrush steppe	Ungrazed	30[a], 71[b]	5.3[c]	50[d]	--	32	7	--	--
Baldwin, 1956	Montana	Sagebrush steppe	--	30–90[b]	--	--	--	--	--	--	--
Barlow and others, 2020 (nests)	Wyoming	Sagebrush steppe	--	60.6[e]	34.0[c]	--	7.8	26.1	--	--	--
Best, 1970[f] (nests)	Montana	Sagebrush steppe	Before spraying	--	--	39–46	8–25	21–36	30–36	38–55	--
Best, 1970[f] (nests)	Montana	Sagebrush steppe	Sprayed, total sagebrush kill	--	--	71	2	0	27	60	--
Best, 1970[f] (nests)	Montana	Sagebrush steppe	Sprayed, partial sagebrush kill	--	--	49	3	28	25	67	--
Bleho, 2009	Saskatchewan	Mixed-grass prairie	Ungrazed	--	7.4[c]	15.6	4.5	6.2	4.7	60.9	--
Bleho, 2009	Saskatchewan	Mixed-grass prairie	Grazed	--	4[c]	17.9	6.9	3.6	8.4	45.2	--
Castrale, 1982 (nests)	Utah	Sagebrush steppe	Multiple	68.5[b]	--	--	--	--	--	--	--
Feist, 1968a (nests)	Montana	Sagebrush steppe	--	30.5–63.5[b]	--	27	6	16.5	42	--	--
Holmes, 2007	Oregon	Sagebrush steppe	Unburned	--	--	--	--	--	--	25.3	--
Holmes, 2007	Oregon	Sagebrush steppe	Burned	--	--	--	--	--	--	6.4	--
Howe and others, 1996	Idaho	Sagebrush steppe	Sprayed	--	--	14–19	2–15	22–25	--	--	--
Ingelfinger and Anderson, 2004	Wyoming	Sagebrush steppe	--	27[b]	--	--	--	16.5	--	--	--
Kerley and Anderson, 1995[g]	Wyoming	Sagebrush steppe	Grazed	31[b]	--	24	17	36	33	10	--
Kerley and Anderson, 1995[g]	Wyoming	Sagebrush steppe	Grazed, sprayed	23[b]	--	27	18	15	46	20	--
Kerley and Anderson, 1995[g]	Wyoming	Sagebrush steppe	Grazed, burned	17[b]	--	34	17	6	45	11	--
Logan, 2001 (nests)	Montana	Mixed-grass prairie	Grazed	27.6[a]	14.6[c]	--	--	--	--	--	--
Logan, 2001 (nests)	Montana	Mixed-grass prairie	Ungrazed	30.1[a]	20.6[c]	--	--	--	--	--	--
Logan, 2001	Montana	Mixed-grass prairie	Grazed	12.4[a]	2.2[c]	13.4	2.8	10.7	56.8	--	0.4
Logan, 2001	Montana	Mixed-grass prairie	Ungrazed	15.1[a]	3.4[c]	17.7	3.3	7.3	44.8	--	0.6

Table AA1. Measured values of vegetation structure and composition in Brewer's Sparrow (*Spizella breweri breweri*) breeding habitat by study. The parenthetical descriptors following authorship and year in the "Study" column indicate that the vegetation measurements were taken in locations or under conditions specified in the descriptor; no descriptor implies that measurements were taken within the general study area.—Continued

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

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)
McAdoo and others, 1989	Nevada	Multiple	--	26–52[b]	--	--	--	1–21	--	--	--
Miller and others, 2017	Idaho	Sagebrush steppe	Poor quality habitat	20.5[a], 55.5[e]	--	13.6	4.8	6.1	34.2	11.4	--
Miller and others, 2017	Idaho	Sagebrush steppe	Moderate quality habitat	18.8[a], 54.9[e]	--	12.8	4.8	8.9	34.0	11.2	--
Miller and others, 2017	Idaho	Sagebrush steppe	Good quality habitat	19.0[a], 61.4[e]	--	13.1	5.3	10.6	32.2	11.8	--
Noson and others, 2006	Oregon	Sagebrush steppe	Burned, unburned	60.3[a]	--	5.4	--	6.7	--	--	--
Olson, 1974	Idaho, Utah	Multiple	--	--	--	--	--	3–49	--	--	--
O'Meara and others, 1981	Colorado	Pinyon (*Pinus*)-juniper (*Juniperus*) woodland	8–15 Year post-chaining treatment	--	--	3.2–6.9	0.4–1.9	5.2–17	--	--	--
Petersen and Best, 1985 (nests)	Idaho	Sagebrush steppe	--	54[b]	--	--	--	29	46	--	--
Petersen and Best, 1985	Idaho	Sagebrush steppe	Unburned	39.7–43.8[b]	--	5.4–10.6	0.9–3.0	27.8–29.5[h]	47.6–53.5	2.8–8.8	--
Petersen and Best, 1985	Idaho	Sagebrush steppe	Burned	37.1–46.6[b]	--	5.6–16.4	2.0–6.5	15.4–28.0[h]	44.7–70.0	2.4–13.6	--
Reynolds and Trost, 1980 (nests)	Idaho	Sagebrush steppe	Grazed, ungrazed	--	--	--	--	41–65	--	--	--
Ruehmann and others, 2011 (nests)	Wyoming	Sagebrush steppe	Native grass understory	39.4[b]	--	58.7	--	32.2	--	--	--
Ruehmann and others, 2011 (nests)	Wyoming	Sagebrush steppe	Smooth brome (*Bromus inermis*) understory	52.2[b]	--	64.5	--	43	--	--	--
Sarell and McGuinness, 1996 (nests)	British Columbia	Multiple	--	64–170[b]	--	--	--	--	--	--	--
Schroeder and Vander Haegen, 2006	Washington	Sagebrush steppe landscape	Shrubsteppe	109.4[b]	10.3[c]	68.6	4.1	19.6	2.5	--	--
Schroeder and Vander Haegen, 2006	Washington	Sagebrush steppe landscape	New CRP (planted after 1995)	30.5[b]	6.9[c]	73.0	15.4	2.1	1.0	--	--

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[cm, centimeter; %, percent; --, no data; CRP, Conservation Reserve Program; >, 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)
Schroeder and Vander Haegen, 2006	Washington	Sagebrush steppe landscape	Old CRP (planted before 1996)	77.3[b]	5.4[c]	74.2	3.0	8.6	1.7	--	--
Schroeder and Vander Haegen, 2006	Washington	Cropland landscape	Shrubsteppe	96.5[b]	12.0[c]	69.7	4.4	11.9	2.7	--	--
Schroeder and Vander Haegen, 2006	Washington	Cropland landscape	New CRP (planted after 1995)	28.4[b]	9.0[c]	69.3	9.6	1.9	1.2	--	--
Schroeder and Vander Haegen, 2006	Washington	Cropland landscape	Old CRP (planted before 1996)	52.2[b]	5.3[c]	76.3	3.1	1.5	1.5	--	--
Vander Haegen and others, 2000	Washington	Sagebrush steppe	Loamy soil	65[e]	--	55.0	16.7	13.9	--	--	--
Vander Haegen and others, 2000	Washington	Sagebrush steppe	Sandy soil	70[e]	--	57.6	18.3	8.1	--	--	--
Vander Haegen and others, 2000	Washington	Sagebrush steppe	Shallow soil	49[e]	--	38.4	12.0	10.4	--	--	--
Vander Haegen, 2007	Washington	Sagebrush steppe	Continuous landscape	82.1[e]	--	45.5	--	25.5	19.4	--	--
Vander Haegen, 2007	Washington	Sagebrush steppe	Fragmented landscape	78.0[e]	--	47.1	--	24.4	15.3	--	--
Walcheck, 1970[f]	Montana	Greasewood (*Sarcobatus*)-sagebrush shrubland	--	--	--	24	25	17	20	--	--
Walcheck, 1970[f]	Montana	Sagebrush steppe	--	--	--	49	6	53	3	--	--
Wiens, 1970[i]	Colorado	Shortgrass prairie	Heavily winter-grazed	--	0.7[j]	73.5	5	4	23.5	19.6	0.3
Wiens and others, 1987a	Nevada, Oregon	Sagebrush steppe	--	--	--		--	37	--	--	--
Wiens and Rotenberry, 1985[k]	Oregon	Sagebrush steppe	Pretreatment	--	--	1–4	--	19–24	70–75	--	--
Wiens and Rotenberry, 1985[k]	Oregon	Sagebrush steppe	Posttreatment	--	--	10–57	--	4–12	--	--	--
Williams and others, 2011	Colorado	Sagebrush steppe	Loamy soil	39.4[b]	--	--	--	17.3	42	42.5	--

Table AA1. Measured values of vegetation structure and composition in Brewer's Sparrow (*Spizella breweri breweri*) breeding habitat by study. The parenthetical descriptors following authorship and year in the "Study" column indicate that the vegetation measurements were taken in locations or under conditions specified in the descriptor; no descriptor implies that measurements were taken within the general study area.—Continued

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

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)
Williams and others, 2011	Colorado	Sagebrush steppe	Saline lowland soil	63.2[b]	--	--	--	45.9	27.1	52.1	--
Williams and others, 2011	Colorado	Sagebrush steppe	Sandy soil	31[b]	--	--	--	16	39.8	40.2	--
Williams and others, 2011	Colorado	Sagebrush steppe	Sandy-skeletal soil	28.9[b]	--	--	--	22.4	41.6	39.5	--
Winter, 1984[l]	Idaho	Sagebrush steppe	Edge	--	--	9.5	4.4	34	57.2	--	--
Winter, 1984[l]	Idaho	Sagebrush steppe	Burned	--	--	8	5.3	7	86.7	--	--
Winter, 1984[l]	Idaho	Sagebrush steppe	Unburned	--	--	9.2	5.2	25.1	65.2	--	--
Winter, 1984[l]	Idaho	Sagebrush steppe	Preburned	--	--	8.4	3.8	30.6	60.4	--	--

[a]Grass height.

[b]Sagebrush height.

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

[d]Value represents grass and forb cover combined.

[e]Shrub height.

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

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

[h]Values represent big sagebrush (*Artemisia tridentata*) and green rabbitbrush (*Chrysothamnus viscidiflorus*) cover combined.

[i]The sum of the percentages is >100%, based on the modified point-quadrant technique of Wiens (1969).

[j]Effective vegetation height.

[k]The authors monitored breeding bird populations in a large sagebrush-dominated rangeland 3 years prior to and 3 years following alteration (that is, spraying the area with the herbicide 2,4–Dichlorophenoxyacetic acid, removing the dead shrubs, and then planting to crested wheatgrass [*Agropyron cristatum*]).

[l]The sum of the percentages >100%, based on methods described by the author.

Table AA2. Nest-site characteristics of Brewer's Sparrow (*Spizella breweri breweri*) by State or province.

[*n*, number of nests; cm, centimeter; %, percent; --, no data; n.d., no date]

Study	State or province	*n*	Mean nest height (range) (cm)[a]	Mean height of nest shrub (range) (cm)[a]	Mean shrub cover near nest (range) (%)[a]
Cannings and others, 1987	British Columbia (southern)	21	30 (15–100)	--	--
Sarell and McGuinness, 1996	British Columbia (southern)	25	49 (12–104)	110 (64–170)	--
Mahony, 2003	British Columbia (southern)	114	35 (11–82)	86 (39–152)	34 (0–76)
D. Humple, written commun. [n.d.]	California (northeastern)	17	40 (20–65)	83 (52–140)	26 (4–66)
Olson, 1974	Idaho (southeastern), Utah (north-central)	19	26	--	--
Reynolds, 1981	Idaho (southeastern)	7	25	65	--
Rich, 1980	Idaho (southeastern)	27	32	67	--
Petersen and Best, 1985	Idaho (southeastern)	58	39 (90% between 20–50)	69 (42–104)	29
Petersen and Best, 1987	Idaho (southeastern)[b]	11–26	34	61–65	26–31
Petersen and Best, 1987	Idaho (southeastern)[c]	11–26	41	74	32
Petersen and Best, 1987	Idaho (southeastern)[d]	11–26	32	64	15
Feist, 1968a	Montana (central)	27	15 (9–22)	41 (26–50)	31
Best, 1972	Montana (central)	40	14 (8–21)	-- (24–55)	--
Logan, 2001	Montana (central)	44	19 (7–37)	50 (14–110)	--
A. Chalfoun, written commun. [n.d.]	Montana (south-central)	133	27 (13–86)	68 (29–164)	30 (6–78)
Abe, 2007	Montana (western)[e]	219	--	--	42
Abe, 2007	Montana (western)[f]	146	--	--	32
B. Walker, unpub. data	Montana (western)	79	30 (11–51)	90 (60–133)	42 (23–70)
Rotenberry and others, 2020	Oregon (central), Nevada (northern)	89	35 (14–67)	71 (50–107)	--
Fautin, 1946	Utah (central)	3	31 (22–40)	--	--
Castrale, 1982	Utah (north-central)	12	20 (13–30)	69 (48–120)	--
W.M. Vander Haegen, written commun. [n.d.]	Washington (eastern)	471	31 (7–84)	85 (31–191)	26
A. Holmes, written commun. [n.d.]	Wyoming (northern)	153	30 (7–71)	55 (30–140)	27 (8–60)
Ruehmann and others, 2011	Wyoming (northwestern)[g]	55	34	--	32
Ruehmann and others, 2011	Wyoming (northwestern)[h]	57	33	--	43
Schroeder and Sturges, 1975	Wyoming (south-central)	7	24 (15–36)	50 (32–67)	--
Barlow and others, 2020	Wyoming (northeastern)	73	22 (5–80)	61 (30–108)	26 (1–56)

[a]Mean (range). Mean nest height is the average distance from the ground to the top rim of the nest.

[b]Unburned.

[c]Preburn.

[d]Postburn.

[e]Grazed study areas.

[f]Ungrazed study areas.

[g]Nests with native grass understory.

[h]Nests with smooth brome (*Bromus inermis*) understory.

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