

EFFECTS OF MANAGEMENT PRACTICES ON GRASSLAND BIRDS: BREWER'S SPARROW



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This report is one in a series of literature syntheses on North American grassland birds. The need for these reports was identified by the Prairie Pothole Joint Venture (PPJV), a part of the North American Waterfowl Management Plan. The PPJV recently adopted a new goal, to stabilize or increase populations of declining grassland- and wetland-associated wildlife species in the Prairie Pothole Region. To further that objective, it is essential to understand the habitat needs of birds other than waterfowl, and how management practices affect their habitats. The focus of these reports is on management of breeding habitat, particularly in the northern Great Plains.

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Species for which syntheses are available:

American Bittern	Sprague's Pipit
Mountain Plover	Grasshopper Sparrow
Marbled Godwit	Baird's Sparrow
Long-billed Curlew	Henslow's Sparrow
Willet	Le Conte's Sparrow
Wilson's Phalarope	Nelson's Sharp-tailed Sparrow
Upland Sandpiper	Vesper Sparrow
Greater Prairie-Chicken	Savannah Sparrow
Lesser Prairie-Chicken	Lark Sparrow
Greater Sage-Grouse	Field Sparrow
Northern Harrier	Brewer's Sparrow
Swainson's Hawk	Clay-colored Sparrow
Ferruginous Hawk	Chestnut-collared Longspur
Golden Eagle	McCown's Longspur
Prairie Falcon	Dickcissel
Merlin	Lark Bunting
Short-eared Owl	Bobolink
Burrowing Owl	Eastern Meadowlark
Horned Lark	Western Meadowlark
Sedge Wren	Brown-headed Cowbird
Loggerhead Shrike	

EFFECTS OF MANAGEMENT PRACTICES ON GRASSLAND BIRDS:

BREWER'S SPARROW

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ORGANIZATION AND FEATURES OF THIS SPECIES ACCOUNT

Information on the habitat requirements and effects of habitat management on grassland birds were summarized from information in more than 5,500 published and unpublished papers. A **range map** is provided to indicate the relative densities of the species in North America, based on Breeding Bird Survey (BBS) data. Although birds frequently are observed outside the breeding range indicated, the maps are intended to show areas where managers might concentrate their attention. It may be ineffectual to manage habitat at a site for a species that rarely occurs in an area. The species account begins with a brief **capsule statement**, which provides the fundamental components or keys to management for the species. A section on **breeding range** outlines the current breeding distribution of the species in North America, including areas that could not be mapped using BBS data. The **suitable habitat** section describes the breeding habitat and occasionally microhabitat characteristics of the species, especially those habitats that occur in the Great Plains. Details on habitat and microhabitat requirements often provide clues to how a species will respond to a particular management practice. A **table** near the end of the account complements the section on suitable habitat, and lists the specific habitat characteristics for the species by individual studies. A special section on **prey habitat** is included for those predatory species that have more specific prey requirements. The **area requirements** section provides details on territory and home range sizes, minimum area requirements, and the effects of patch size, edges, and other landscape and habitat features on abundance and productivity. It may be futile to manage a small block of suitable habitat for a species that has minimum area requirements that are larger than the area being managed. The Brown-headed Cowbird (*Molothrus ater*) is an obligate brood parasite of many grassland birds. The section on **cowbird brood parasitism** summarizes rates of cowbird parasitism, host responses to parasitism, and factors that influence parasitism, such as nest concealment and host density. The impact of management depends, in part, upon a species' nesting phenology and biology. The section on **breeding-season phenology and site fidelity** includes details on spring arrival and fall departure for migratory populations in the Great Plains, peak breeding periods, the tendency to renest after nest failure or success, and the propensity to return to a previous breeding site. The duration and timing of breeding varies among regions and years. **Species' response to management** summarizes the current knowledge and major findings in the literature on the effects of different management practices on the species. The section on **management recommendations** complements the previous section and summarizes specific recommendations for habitat management provided in the literature. If management recommendations differ in different portions of the species' breeding range, recommendations are given separately by region. The **literature cited** contains references to published and unpublished literature on the management effects and habitat requirements of the species. This section is not meant to be a complete bibliography; a searchable, annotated bibliography of published and unpublished papers dealing with habitat needs of grassland birds and their responses to habitat management is posted at the Web site mentioned below.

This report has been downloaded from the Northern Prairie Wildlife Research Center World-Wide Web site, www.npwrc.usgs.gov/resource/literatr/grasbird/grasbird.htm. Please direct comments and suggestions to Douglas H. Johnson, Northern Prairie Wildlife Research Center, U.S. Geological Survey, 8711 37th Street SE, Jamestown, North Dakota 58401; telephone: 701-253-5539; fax: 701-253-5553; e-mail: Douglas_H_Johnson@usgs.gov.

BREWER'S SPARROW
(*Spizella breweri breweri*)

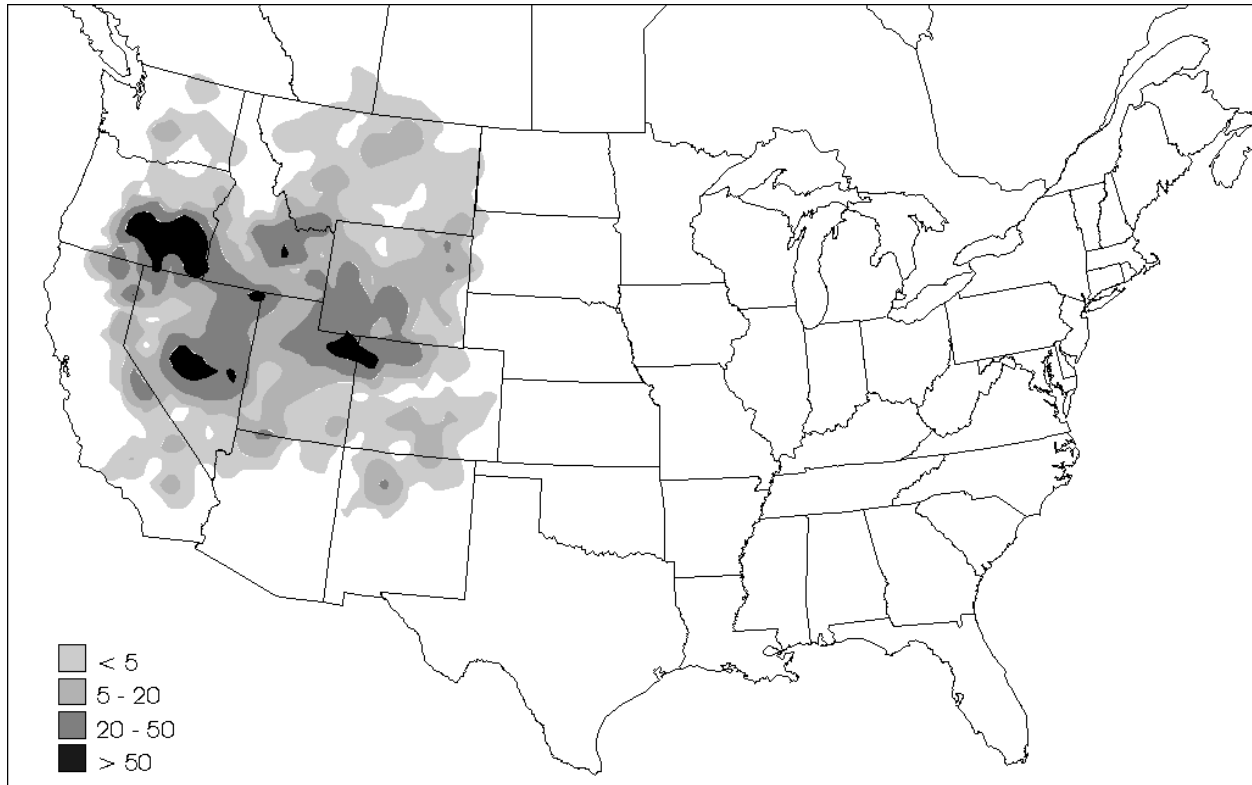


Figure. Breeding distribution of Brewer's Sparrow in the United States and southern Canada, based on Breeding Bird Survey data, 1985-1991. Scale represents average number of individuals detected per route per year. Map from Price, J., S. Droege, and A. Price. 1995. The summer atlas of North American birds. Academic Press, London, England. 364 pages.

Keys to management include maintaining extensive areas of suitable habitat (sagebrush-dominated shrublands with average shrub cover of 10-30%, average shrub height of 0.4-1.5 m, and an understory of native grasses and forbs [percent understory cover depends on region]), preventing the invasion of conifers and non-native plants, especially cheatgrass (*Bromus tectorum*), minimizing disturbance to soil, and restricting the use of pesticides and herbicides during the breeding season (April-August).

Breeding range:

Two subspecies of Brewer's Sparrows breed in North America: the "sagebrush" Brewer's Sparrow (*S. b. breweri*) and the "timberline" Brewer's Sparrow (*S. b. 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 Great Basin, and not with the timberline subspecies, which breeds from northwestern Montana north through the Canadian Rockies to eastcentral Alaska (Doyle 1997, Griffin et al. 2003). The two subspecies differ in habitat use, vocalizations, morphology, plumage characteristics, and genetics. These differences may warrant a future decision to split the Brewer's Sparrow into two distinct species (Klicka et al. 1999, 2001; but see Mayr and Johnson 2001).

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. The species regularly breeds east to northwestern New Mexico, eastern Colorado, northwestern Nebraska, 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 et al. 1987, Faanes and Lingle 1995, National Geographic Society 1999, Rotenberry et al. 1999). It is unclear whether individuals breeding in high-elevation subalpine habitats in the western U.S. are taxonomically closer to *S. b. breweri* or to *S. b. taverneri* (Rising 2002). (See Figure for the relative densities of Brewer's Sparrows in the United States and southern Canada, based on Breeding Bird Survey data).

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, Rotenberry et al. 1999). Sagebrush habitats vary with local changes in soil, precipitation, topography, and elevation, and range from grasslands with scattered sagebrush to dense shrublands with a sparse understory (Paige and Ritter 1999). Because these habitats often are not clearly delineated in the literature, we adhere to the following general definitions. "Shrubsteppe" is characterized by the co-dominance of sagebrush and native bunchgrasses (West 1996, Paige and Ritter 1999) and moderate shrub cover (10-20%) (Montana PIF 2000), by moderate shrub cover (10-20%), moderate precipitation, and a significant understory component of grasses and forbs (West 1996, Paige and Ritter 1999, Montana PIF 2000). Shrubsteppe is found in the western Great Plains, Rocky Mountains, and the Columbia and Snake river basins. "Arid sagebrush shrublands" typical of the Great Basin are characterized by denser shrub cover (20-80%), less precipitation, and a sparser understory of grasses and forbs than true shrubsteppe (West 1988, Montana PIF 2000). In this account, both shrubsteppe and arid sagebrush shrublands are simply referred to as "shrubsteppe." Local areas and transition zones where sagebrush mixes with shrubs that are more typical of arid or semiarid deserts, particularly in the southern Great Plains (Johnsgard 1979), Great Basin (Wiens and Rotenberry 1981), and Southwest (Larson and Bock 1986), are designated "semidesert shrubsteppe."

Brewer's Sparrows breed in shrubsteppe, transitions between shrubsteppe and shortgrass prairie, and semidesert shrubsteppe (Fautin 1946, Stewart 1975, Johnsgard 1979, Rotenberry and Wiens 1980a, Kantrud and Kologiski 1983, Wiens et al. 1987a, Faanes and Lingle 1995, Rotenberry et al. 1999). Suitable habitat includes sagebrush-dominated shrublands with >10% average shrub cover and an average shrub height of 0.5 - 1.5 m (Larson and Bock 1986, Dobler et al. 1996, Sarell and McGuinness 1996, Rotenberry et al. 1999). In general, Brewer's Sparrow abundance decreases as average shrub cover decreases below 10-13%, and Brewer's Sparrows disappear entirely when average shrub cover decreases below 3-8% (Dobler et al. 1996, Larson and Bock 1986). Brewer's Sparrow abundance may decrease if shrub cover exceeds 50% (Sarell and McGuinness 1996).

Brewer's Sparrow habitats typically are dominated by one or more subspecies of big sagebrush, including basin big sagebrush (*A. tridentata tridentata*), mountain big sagebrush (*A. t. vaseyana*), and Wyoming big sagebrush (*A. t. wyomingensis*) (Rotenberry et al. 1999). Other dominant or co-dominant shrubs in Brewer's Sparrow habitat may include threetip sagebrush (*A. tripartita*), silver sagebrush (*A. cana*), black sagebrush (*A. nova*), little sagebrush (*A. arbuscula*), white sagebrush (*A. ludoviciana*), Bigelow sage (*A. bigelovii*), tarragon (*A. dracunculus*), yellow (or green) rabbitbrush (*Chrysothamnus viscidiflorus*), rubber rabbitbrush (*Ericameria nauseosa*), and antelope bitterbrush (*Purshia tridentata*) (Baldwin 1956, Biermann et al. 1987, Faanes and Lingle 1995, Rotenberry et al. 1999). Brewer's Sparrows also occur in transition areas where big sagebrush is adjacent to, or intermixed with, scabland sagebrush (*A. 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*), black greasewood (*Sarcobatus vermiculatus*), and curl-leaf mountain mahogany (*Cercocarpus ledifolius*) (Walcheck 1970, Hill 1980, Larson and Bock 1986, Knopf et al. 1990, Medin 1990a, Faanes and Lingle 1995, Rotenberry et al. 1999). Brewer's Sparrows less commonly breed in other shrub-dominated habitats lacking sagebrush, including brushy slopes and regenerating clearcuts and burns with greenleaf manzanita (*Arctostaphylos patula*), snowbrush ceanothus (*Ceanothus velutinus*), shrubby cinquefoil (*Dasiphora floribunda*), golden currant (*Ribes aureum*), antelope bitterbrush, curl-leaf mountain mahogany (*Cercocarpus ledifolius*), serviceberry (*Amelanchier* spp.), and snowberry (*Symphoricarpos* spp.) (Grinnell et al. 1930, Burleigh 1972, Beaver 1976, Cannings et al. 1987, Knopf et al. 1990, Kingery 1998, Wisdom et al. 2000). Rarely, Brewer's Sparrows breed in patches of russet buffaloberry (*Shepherdia canadensis*) (Saunders 1914), in creosote (*Larrea tridentata*) desert (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 abundant in shrubsteppe of central and northern Wyoming and southcentral Montana, common in transition zones between shrubsteppe and shortgrass prairie in southern Alberta, central and southeastern Montana, the western Dakotas, and eastern Wyoming, and uncommon in local areas of semidesert shrubsteppe (Feist 1968a,b; Walcheck 1970; Best 1972; Fautin 1975; Kantrud and Kologiski 1983; Biermann et al. 1987; Faanes and Lingle 1995; Logan 2001). In transition habitats between shrubsteppe and shortgrass prairie, Brewer's Sparrows use areas with a denser understory of grasses and forbs (64-73%), less sagebrush cover (5-10%), and shorter sagebrush (0.25-1.0 m) than in shrubsteppe (Feist 1968a,b; Best 1972; Logan 2001).

In the Intermountain West, Rocky Mountains, Columbia and Snake river basins, and Sierra Nevada, Brewer's Sparrows breed over a wide range of elevation (100-3150 m), but are most abundant in broad, flat valleys with extensive shrubsteppe habitat and minimal soil disturbance (Grinnell and Miller 1944; Baldwin 1956; Huey and Travis 1961; Olson 1974; Schroeder and Sturges 1975; McGee 1976; O'Meara et al. 1981; Krementz and Sauer 1982; Larson and Bock 1986; Rotenberry 1986; Wiens et al. 1986, 1987a; Sedgwick 1987; Rotenberry and Wiens 1989, 1991; Knick and Rotenberry 1995; Sarell and McGuinness 1996; Welch 2002). In southern British Columbia, Brewer's Sparrows usually occurred in sagebrush with 10-20% average shrub cover and a high forb component and avoided sagebrush areas surrounded by orchards, vineyards, and pasture (Paczek 2002). In eastern Washington, Brewer's Sparrows were

significantly more abundant in shrubsteppe with deep, loamy soils and above-average precipitation, plant productivity, and shrub cover (Vander Haegen et al. 2000, 2001). 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 et al. 1993). In southwestern Idaho, percentage of shrub cover was the most important local vegetation feature predicting presence or absence of Brewer's Sparrows at a site (Knick and Rotenberry 1995), and 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 southeastern Oregon and northern Nevada, a significant negative association existed between Brewer's Sparrow abundance and habitat features associated with transitions between shrubsteppe and more arid habitats (e.g., the diversity of shrub species present, and the percent cover of spiny hopsage, bud sagebrush, and bare rock) (Wiens and Rotenberry 1981). 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 transitions that occasionally support bird species, such as Western Meadowlark (*Sturnella neglecta*), for which shrubsteppe is a secondary habitat (Rotenberry and Wiens 1980b).

In the Great Basin, Brewer's Sparrows occur in sagebrush habitats with similar shrub cover, but a sparser understory than "true" shrubsteppe farther north. In central Nevada, Brewer's Sparrows were 1.8 times more abundant, on average, in undisturbed shrubsteppe with 18-21% shrub cover and a sparse understory than in 20- to 30-year-old crested wheatgrass (*Agropyron smithii*) plantings recolonized by sagebrush with 1-12% shrub cover (McAdoo et al. 1989). In southeastern Idaho and northcentral Utah, Brewer's Sparrows were most common in undisturbed shrubsteppe (12-49% shrub cover), less common in crested wheatgrass seedings recolonized by sagebrush (3-40% shrub cover), rare in sagebrush/saltbush (*Atriplex* sp.) transition zones, and absent from recent crested wheatgrass seedings (Olson 1974). In eastcentral 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 desert, and absent from pinyon (*Pinus*)/juniper (*Juniperus*) woodlands (Medin 1990a,b, 1992; Medin et al. 2000). In Utah, Brewer's Sparrows nested in black greasewood on alkali bottomlands but were absent from adjacent dry hillsides with stunted pinyon/juniper woodland (Hardy 1945). In mountains of southeastern California, Brewer's Sparrows nested in tracts of sagebrush within singleleaf pinyon (*Pinus monophylla*) and limber pine (*Pinus flexilis*) woodland (Fisher 1893 in Wauer 1964).

Brewer's Sparrows most often build nests in sagebrush, although they occasionally will nest in other shrubs with similar vegetation structure, including spiny hopsage, antelope bitterbrush, yellow rabbitbrush, rubber rabbitbrush, black greasewood, and western snowberry (*Symphoricarpos occidentalis*) (Fautin 1946; Petersen and Best 1985; Rotenberry et al. 1999; Mahony 2003; D. Humple, Point Reyes Bird Observatory [PRBO], Bolinas, California, *unpublished data*; W. M. Vander Haegen, Washington Department of Fish and Wildlife, Olympia, Washington, *unpublished data*). Rarely, Brewer's Sparrows build nests in Douglas-fir (*Pseudotsuga menziesii*) saplings, hawthorn (*Crataegus*), wild rose (*Rosa*), spotted knapweed (*Centaurea biebersteinii*), or giant wildrye (*Leymus condensatus*) (Tyler 1910, Fautin 1946, Sarell and McGuinness 1996, Rotenberry et al. 1999, Mahony 2003). After a fire, birds may nest in large perennial forbs for several years until sagebrush regenerates (Mahony 2003).

Nest heights range from 7-104 cm, and nest-shrub heights range from 24-191 cm (Table 1). When shrubs of different heights are available for nesting, Brewer's Sparrows prefer to nest in medium-sized shrubs (i.e., 50-90 cm tall) rather than in taller or shorter shrubs (Petersen and Best 1985).

Brewer's Sparrows prefer nest sites surrounded by relatively dense (26%-42%) shrub cover, but the percentage of shrub cover near nests varies (Petersen and Best 1985, Larson and Bock 1986) (Table 1). In areas with sparse, low-growing shrubs, Brewer's Sparrows usually select nest sites in denser, taller patches of shrubs (Castrale 1982, Petersen and Best 1985, Bock and Bock 1987, Rotenberry et al. 1999). When shrub cover is uniformly tall, birds may prefer areas with below-average shrub cover and higher grass and forb cover (Rotenberry et al. 1999).

Brewer's Sparrows prefer to nest in shrubs that are alive or mostly alive (Winter 1984, Petersen and Best 1985, Rotenberry et al. 1999). Nest shrubs averaged 81% live foliage in both western Montana (n=74, range 0-100%; B. Walker, *unpublished data*) and northern Wyoming (n=153, range 5-100%; A. Holmes, PRBO, Bolinas, California, *unpublished data*). In southeastern Idaho, 71% of nests (n=58) were in shrubs with 100% live foliage, 93% of nests were in shrubs with >75% live foliage, and all nests were in shrubs with >50% live foliage (Petersen and Best 1985). Brewer's Sparrows show no preference for nesting in shrubs with denser-than-average foliage unless the shrub is dead (Best 1972, Rotenberry et al. 1999). 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).

While foraging, Brewer's Sparrows spend most of their time (75%) in tall, live sagebrush and less time (25%) on the ground (Winter 1984, Wiens et al. 1987b, Rotenberry and Wiens 1998). They prefer to forage in tall, live shrubs, particularly big sagebrush, rather than in dead shrubs or small, live shrubs of other species (e.g., yellow rabbitbrush, rubber rabbitbrush). Tall, live sagebrush may provide more food resources, or alternatively, because males often sing from and forage in the same shrub, birds may prefer elevated song perches instead of specific foraging sites (Castrale 1983, Knopf et al. 1990, Rotenberry and Wiens 1998). Table 2 near the end of the account lists specific habitat characteristics for Brewer's Sparrow by study.

Area requirements:

Brewer's Sparrows are not known to be area sensitive, as they successfully breed in small patches (e.g., 6 ha) of suitable shrubsteppe habitat within a larger unsuitable matrix of agricultural lands (Wisdom et al. 2000; W. M. Vander Haegen, *unpublished data*). However, evidence suggests that fragmented landscapes may act as population sinks. In disturbed landscapes of southwestern Idaho, isolated patches of sagebrush were occupied less often than those in more continuous shrubsteppe, suggesting that smaller patches of habitat are of marginal suitability (Knick and Rotenberry 1995). Disturbance by livestock grazing, military activities, and frequent burning converted shrubsteppe to monocultures of cheatgrass and Russian thistle (*Salsola tragus*). In a three-year study in shrubsteppe of eastern Washington, nesting success and season-long productivity of Brewer's Sparrows were lower in fragments (median size 146 ha) than in continuous shrubsteppe (W. M. Vander Haegen, *unpublished data*). Predation of

both real and artificial nests was higher in fragments (median size 146 ha) than in areas of continuous shrubsteppe (median size 115,368 ha) (Vander Haegen et al. 2002).

Territory size varies among regions, among sites, and among years, but is usually about 0.5-2.0 ha (Wiens et al. 1985, Cannings et al. 1987). Territory size decreases with increased density of pairs and increases in unsaturated habitats. Territory density varies from 0.34 to 2.5 males (or pairs) per ha (Schroeder and Sturges 1975, Wiens et al. 1985, Rotenberry and Wiens 1989, Dobler et al. 1996, Rotenberry et al. 1999, Walker 2000).

Brown-headed Cowbird brood parasitism:

The Brewer's Sparrow is an uncommon host of the Brown-headed Cowbird (*Molothrus ater*) (Friedmann 1963, Rotenberry et al. 1999). Rates of cowbird parasitism varied from 0 to 60%, with most studies reporting little or no parasitism (Rich 1978; Reynolds 1981; Biermann et al. 1987, Cannings et al. 1987; Rotenberry and Wiens 1989; Vander Haegen and Walker 1999, Logan 2001; Mahony 2003; A. Chalfoun, University of Montana, Missoula, Montana, *unpublished data*; A. Holmes, *unpublished data*; D. Humple, *unpublished data*; N. Mahony, University of British Columbia, Vancouver, British Columbia, *unpublished data*; B. Walker, *unpublished data*). 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 et al. 1987, Freeman et al. 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 et al. 1987). Logan (2001) reported no cowbird parasitism of 44 Brewer's Sparrow nests in uniform shrubsteppe habitats of central Montana but found high rates of parasitism (about 50% of nests) of nests of other bird species in nearby riparian areas. In eastern Washington, cowbirds were more abundant in fragmented shrubsteppe than in more continuous landscapes (Vander Haegen et al. 2000). Cowbird parasitism also was higher in fragments (7.9% of 178 nests) than in continuous shrubsteppe (2.2% of 186 nests) (W. M. Vander Haegen, *unpublished data*).

Hatching and fledging success of cowbirds in Brewer's Sparrow nests generally is poor because Brewer's Sparrows often 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 et al. 1987, Vander Haegen and Walker 1999, Mahony 2003). In contrast, five of 267 unparasitized nests were abandoned in eastern Washington (Vander Haegen and Walker 1999). Biermann et al. (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 two years in eastern Washington. Only one cowbird fledged from 22 parasitized nests over four years in southern British Columbia (Mahony 2003).

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, SDOU 1991, Kingery 1998). In other parts of their breeding range, males arrive between mid-April and mid-June (Cannings et al. 1987, Sarell and McGuinness 1996, Rotenberry et al. 1999, Walker 2000). Birds generally arrive earlier at lower latitudes and at lower elevations, and males generally arrive earlier than females (Rotenberry et al. 1999). The mean arrival date of females may vary by up to 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 24 May through 3 July in western South Dakota (SDOU 1991) and from 26 May through 27 June in southern Alberta (Biermann et al. 1987). In other regions, breeding occurs from early April through early August, with a peak between early May and late July (Tyler 1910, Fautin 1946, Rich 1980, Howe et al. 1996, Rotenberry et al. 1999, Vander Haegen and Walker 1999, Walker 2000). Dates of nest initiation may vary by up to two 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 et al. 2002). Second and subsequent nesting attempts are initiated between early June and mid-July (Rotenberry et al. 1999, Walker 2000). Latest known dates of nest initiation are 20 July in southern British Columbia (Mahony 2003) and 22 July in Oregon (Rotenberry et al. 1999). Young birds generally remain within 200 m of the nest until they become independent from their parents about 30 days after fledging (Yu 1999). Males exhibit site fidelity to breeding territories (Petersen and Best 1987, Rotenberry et al. 1999, Walker 2000). Estimates of site fidelity range from 25% of 12 males in southeastern Idaho (Petersen and Best 1987, Rotenberry et al. 1999) to 50% of 24 males in eastern Washington (Walker 2000). Little is known about site fidelity of females, other than that pair bonds sometimes persist from year to year (B. Walker, *unpublished data*). Brewer's Sparrows are not known to show fidelity to natal sites (Rotenberry et al. 1999).

Species' response to management:

Habitat for Brewer's Sparrows has been and continues to be substantially altered by management practices. Sagebrush often is removed via burning, spraying, chaining, or plowing, and treated areas are planted with non-native species (e.g., crested wheatgrass, alfalfa [*Medicago sativa*]) to increase forage for livestock (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 commonly are used in shrubsteppe to reduce shrub cover and create habitat mosaics for other species (Petersen and Best 1987, 1999; Connelly et al. 2000). Large areas of sagebrush are treated annually with insecticides to control unwanted insects such as mosquitoes (Culicidae) and grasshoppers (Orthoptera) (George et al. 1995, Howe et al. 1996). Although it is clear that complete removal of sagebrush eliminates suitable breeding habitat, our understanding of how other management practices affect Brewer's Sparrows is relatively poor. The following is a review about what is known concerning the effects of sagebrush removal, burning, grazing, and spraying on populations and individuals. Several authors emphasized the need in future studies to study post-treatment responses for longer than 3 yr to overcome problems associated with site fidelity of individuals and masking of treatment effects by natural fluctuations in abundance (Wiens and Rotenberry 1985, Wiens et al. 1986, Rotenberry 1998, Petersen and Best 1999). It is recommended that future researchers estimate

demographic rates from studies of marked individuals rather than relying on indices of abundance based on singing males (Thompson 2002, Knick et al. 2003).

Brewer's Sparrows dramatically decrease in abundance or disappear entirely after complete removal of sagebrush (Best 1972, Schroeder and Sturges 1975, Bock and Bock 1987, Welch 2002). Planting of non-native grass 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 et al. 1989). 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 yr after treatment, but the effect of partial sagebrush removal on reproductive success and survival is unclear (Castrale 1982). Brewer's Sparrows continued to nest in areas sprayed with an herbicide that retained some live shrubs for at least 2 yr after treatment (Beaver 1976). The long-term effects of partial sagebrush removal are unknown.

Partial removal of sagebrush reduces foraging opportunities for individuals. In central Oregon, experimental reductions of sagebrush cover from 22 to 14% 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 et al. 1986). Within the treatment area, birds spent proportionally more time in unmanipulated blocks (those with no shrubs removed) than in blocks in which shrubs had been removed.

Burning of sagebrush generally decreases the abundance of Brewer's Sparrows. In a study of 13 pairs of transects conducted on adjacent burned and unburned shrubsteppe throughout the Intermountain West, Brewer's Sparrows were present on 12 of 13 unburned transects but absent on transects in burned areas that had been seeded with non-native grasses (Welch 2002). In shrubsteppe of southcentral Wyoming, indices of abundance were four times higher on untreated control plots with 37% average sagebrush cover and mean shrub height of 31 cm than on burned areas with 6% average sagebrush cover and mean shrub height of 20 cm (Kerley and Anderson 1995). In southcentral Montana, Brewer's Sparrows were absent from a site 2-3 yr after a fire eliminated all sagebrush cover, even though grass and forb cover were similar on burned and unburned plots (Bock and Bock 1987). Castrale (1982) compared indices of Brewer's Sparrow abundance on a regenerating 4-yr-old burn, a regenerating 4-yr-old chained site, and a regenerating 17-yr-old plowed site. Brewer's Sparrows were absent from burned areas, except in intact remnants of sagebrush, and they occurred at relatively low densities (about 0.4 pairs/ha) on chained and plowed sites. Partial burns may have little or no long-term effects on populations. In southeastern Idaho, an incomplete (45% of the area was burned) prescribed burn resulted in significantly lower densities in the 2 yr following the burn, but densities exceeded those on control plots during the third and fourth years after burning (Petersen and Best 1987). In the 4 yr 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 7 yr indicated that prescribed burning by itself did not have any long-term effects on abundance (Petersen and Best 1999). However, burning may negatively affect populations by promoting the spread of non-native weeds and the subsequent conversion of shrubsteppe to non-native annual grassland (Knick and Rotenberry 1995, 1997, 1999, 2000, 2002).

Partial burns are less detrimental to Brewer's Sparrows than complete burns. In burned mountain big sagebrush of western Wyoming, Brewer's Sparrows continued to nest in remaining patches of unburned shrubs (McGee 1976). Arthropods make up the majority (70-80%) of the adult diet and 100% of the nestling diet during the breeding season (Feist 1968a, Best 1972, Petersen and Best 1986, Rotenberry et al. 1999, Howe et al. 2000). 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 1986). Although nesting Brewer's Sparrows spend 40-50% 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 the nest to forage, but this did not change the duration of their foraging bouts (Winter 1984). In southern British Columbia, birds continued to nest in burns that were 4 yr old, but they used a much greater diversity of plant species for nesting, including large perennial forbs (Mahony 2003). Six years after burning, birds switched back to nesting in sagebrush that had germinated after fire (Mahony 2003).

Information regarding the effects of grazing on Brewer's Sparrow populations is limited to descriptive or correlative data. In the northern Great Plains, 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 prairie, abundance was highest in moderately grazed and lightly grazed areas, most likely because grazing resulted in higher shrub density (Kantrud and Kologiski 1983). 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, 86% of breeding territories were located in areas with >25% cover of native, climax vegetation (i.e., those in "fair" to "good" range condition), whereas only 14% occurred in areas with <25% cover of native, climax vegetation (i.e., those in "poor" range condition) (Sarell and McGuinness 1996). In the Columbia River Basin of eastern Washington, indices of Brewer's Sparrow abundance were significantly higher on plots with >25% cover of native, climax vegetation (Dobler et al. 1996, Vander Haegen et al. 2000). Individual-level effects of grazing on Brewer's Sparrows are poorly known. Cattle occasionally trample low-lying Brewer's Sparrow nests or dislodge them from nest shrubs (N. Mahony, *unpublished data*, in Paczek 2002; B. Walker, *unpublished data*).

Spraying of herbicides usually reduces Brewer's Sparrow abundance. Brewer's Sparrows generally prefer to nest and forage in live shrubs (Wiens et al. 1987b, Rotenberry and Wiens 1998, Rotenberry et al. 1999). In central Montana, indices of abundance declined 54% after 1 yr 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 kg/ha (Best 1972), and birds still were absent from these plots after 5 yr (Pyrah and Jorgensen 1974 in Braun et al. 1976). In this case, total sagebrush cover decreased from 21 to 0%, forb cover decreased from 25 to 2%, and grass cover increased from 39 to 71% 1 yr after spraying. In contrast, indices of Brewer's Sparrow abundance on partial-kill plots did not change after 1 yr. In shrubsteppe of southcentral Wyoming, indices of abundance were four times higher on untreated control plots with 37%

sagebrush cover and mean shrub height of 31 cm than on sprayed areas with 15% sagebrush cover and mean shrub height of 22 cm (Kerley and Anderson 1995). At high-elevation sites in Wyoming, indices of abundance were 67% lower on treated sites 1 yr after spraying with 2,4-D at 3.4 kg/ha, and 99% lower 2 yr after spraying; Brewer's Sparrows remained abundant (0.75 to 1.1 nesting pairs/ha) on nearby unsprayed control sites (Schroeder and Sturges 1975). No Brewer's Sparrow nests were found on sprayed plots, and adults were only seen in areas with intact patches of live sagebrush. Spraying active nests with 2,4-D at concentrations of 3.4 kg/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. In southcentral Oregon, estimates of Brewer's Sparrow density fluctuated dramatically and unpredictably in response to a 2,4-D spraying and reseedling treatment in which not all shrubs were killed (application rate not reported) (Wiens and Rotenberry 1985). Densities during the 3 yr before the treatment were estimated as 1.5, 2.8, and 3.4 individuals/ha. In the 3 yr following the treatment, densities were estimated as 2.0, 0.7, and 3.4 individuals/ha. These fluctuations were comparable to those on other, unmanipulated sites in the Great Basin. Treatment effects were confounded by site fidelity of individuals, and annual variation in breeding phenology may have contributed to fluctuations in density estimates. On brush-covered mountain slopes in eastcentral California, the number of territorial pairs of Brewer's Sparrows did not change in response to spraying of the herbicide 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) 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 include shifts in nest placement, diet, and parental behavior. In central Montana, Brewer's Sparrows switched to nesting in larger, denser shrubs after sagebrush was killed by spraying (Best 1972). In shrubsteppe of southeastern Idaho, ultra-low volume aerial spraying of Malathion, a broad-spectrum insecticide, during the breeding season reduced insect densities on the study plot but resulted in no immediate mortalities 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 et al. 1996). Nestling growth rates and mass at fledging were significantly reduced on sprayed plots in 1 yr of the 2-yr study (Howe et al. 1996). Reduced food availability due to spraying caused feeding trips away from the nest to last an average of 5 minutes longer on treated sites than on untreated sites, but the mass of food delivered to nestlings did not differ, and adults partially compensated for the reduction in food by shifting the composition of their diet (Howe et al. 2000). In central Montana, the proportion of arthropods in adult diets decreased from 71 to 81% before treatment with the herbicide 2,4-D at 3.4 kg/ha to 38-53% after treatment, suggesting that defoliation of sagebrush reduced arthropod availability (Best 1972). On untreated control plots, Brewer's Sparrow diets consisted of 76% arthropods and 12% plant foods (12% other), whereas on sprayed plots, diets consisted of 46% arthropods and 39% plant foods (15% other) (Best 1972). 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.

Management Recommendations:

Major threats to Brewer's Sparrow populations are similar to those faced by other declining sagebrush-obligate species and include conversion of sagebrush to agriculture or pasture, invasion by non-native plants, altered fire regimes, livestock overgrazing, habitat fragmentation, conifer encroachment, soil disturbance, energy development and conversion to urban or residential housing (Vale 1974, Sarell and McGuinness 1996, Rotenberry 1998, Knick 1999, Paige and Ritter 1999, Connelly et al. 2000, Wisdom et al. 2000, Knick and Rotenberry 2002, Knick et al. 2003). These processes often act synergistically (Knick and Rotenberry 2000). Although some shrubsteppe habitat remains in relatively pristine condition, much has been moderately or heavily disturbed and may require intensive management to restore conditions suitable for Brewer's Sparrows (Knick and Rotenberry 2002, Knick et al. 2003). Management strategies must be tailored to local conditions. Paige and Ritter (1999) review specific strategies for managing sagebrush habitat for Brewer's Sparrows and other sagebrush-obligate birds. Management recommendations include:

Identify and protect remaining intact sagebrush habitats, especially those with high biological diversity, an intact understory of native grasses and forbs, and an intact cryptobiotic soil crust (Paige and Ritter 1999). Cryptobiotic soil crusts prevent erosion and hinder the establishment of non-native weeds. Because disturbance from livestock grazing is ubiquitous in shrubsteppe habitats, cryptobiotic soil crust and native understory may need to be restored or allowed to regenerate in many areas (Saab et al. 1995).

Coordinate management of existing sagebrush areas at the landscape level among private landowners and federal and state resource agencies so that large, continuous blocks of suitable, intact sagebrush are conserved (Montana PIF 2000, Knick et al. 2003). The size of such areas depends on the suitability of remaining sagebrush habitat for breeding and population goals for the region.

Maintain large, intact sagebrush stands with an average shrub cover of 10-30%, an average shrub height of 0.4-1.5 m, and a diverse understory of grasses and forbs native to the local area (Petersen and Best 1985, 1987; Larson and Bock 1986; Dobler et al. 1996; Rotenberry et al. 1999; Montana PIF 2000). Within each stand, maintain areas with relatively dense sagebrush cover (25-40%) and medium-sized shrubs (0.5-0.9 m) that Brewer's Sparrows prefer for nesting (see Table 1). 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) (e.g., Feist 1968b, Best 1972, Schroeder and Sturges 1975, Logan 2001). In shrubsteppe and transitions between shrubsteppe and shortgrass prairie in the northern Great Plains, Brewer's Sparrows may prefer areas with high grass and forb cover (e.g., 30-80%), whereas a sparser ground cover of grasses and forbs (e.g., 10-30%) may be appropriate in the Great Basin (Paige and Ritter 1999).

Avoid the complete removal of sagebrush, as it eliminates suitable nesting habitat for Brewer's Sparrows and promotes the spread of invasive plants (Rotenberry 1998, Paige and Ritter 1999). Reseeding with non-native grasses further delays recolonization by sagebrush, thereby reducing habitat quality for Brewer's Sparrows (e.g., Reynolds and Trost 1981, McAdoo et al. 1989). Overgrazed stands with extremely dense sagebrush (>50%) may need to be thinned to re-

establish 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, do so before birds return in April or after birds have left the area in August (Castrale 1982). If possible, leave large patches of intact sagebrush suitable for nesting (see Suitable habitat, above). Spraying, chaining, and incomplete burning allow faster regeneration of suitable nesting habitat for Brewer's Sparrows and are preferred over plowing or complete burning (Braun et al. 1976, Castrale 1982, Winter 1984, Peterson 1995). Sagebrush regenerates within 5-10 years after spraying or chaining, and it reinvades burned or plowed areas, reestablishing the original cover (but not the original height) within about 35 years (Harniss and Murray 1973). All removal methods run the risk of promoting the spread of invasive plants adapted to disturbance (Rotenberry 1998).

Eliminate and control non-native grasses and forbs, especially those that are invasive or highly flammable (e.g., cheatgrass). Identify and control non-native plants most likely to become a problem in the local area. The ecological effects of introducing non-native species are unpredictable and often cause permanent, undesirable changes to the landscape and to populations of native plants and animals. Loss of sagebrush habitat appears to be irreversible after invasion by non-native weeds alters fire regimes (Knick and Rotenberry 1995, 1997, 1999). Historically, sagebrush steppe burned every 60-100 years. Cheatgrass reduces fire-return intervals to 3-5 years, a time frame in which sagebrush cannot regenerate. Restore shrubsteppe that has been burned or planted using native shrubs, grasses, and forbs (Saab et al. 1995, Knick et al. 2003).

Manage stocking rates of livestock so as to reduce impacts on the grass and forb understory and to reduce soil compaction and disturbance (Saab et al. 1995). Eliminating livestock grazing altogether or significantly reducing stocking rates reduces the risk of non-native plant invasions and is expected to improve habitat quality (Saab et al. 1995). Manage livestock facilities near sagebrush plots to reduce food resources for Brown-headed Cowbirds. For example, eliminate waste grain in or near corrals, feedlots, and stock tanks (Paige and Ritter 1999). Situate new livestock facilities in areas surrounded by existing agricultural land rather than near sagebrush.

Reduce soil disturbance from livestock trampling and farm and recreational vehicle use. Disturbing the soil breaks up and eliminates cryptobiotic soil crusts and facilitates invasions by non-native plants (Paige and Ritter 1999).

Avoid pesticide use in sagebrush habitats. If insecticides or herbicides are used, delay spraying until September to avoid peak periods of nesting and fledgling development. Only use chemicals that rapidly degrade and have low toxicity to non-target organisms, and broadcast them at the lowest application rates possible. Explore non-toxic options for controlling unwanted pests (Paige and Ritter 1999).

For information on managing sagebrush for bird communities, please see Paige and Ritter (1999), Peterson (1995), and Rotenberry (1998).

Table 1. Nest-site characteristics of Brewer's Sparrow by region.

Location	n ¹	Nest height ² (cm)	Height of nest shrub ² (cm)	Shrub cover near nest ³ (%)	Reference
central MT	27	15 (9-22)	41 (26-50)	31	Feist 1968a
central MT	40	14 (8-21)	- (24-55)	-	Best 1972
central MT	44	19 (7-37)	50 (14-110)	-	Logan 2001
southcentral MT	133	27 (13-86)	68 (29-164)	30 (6-78)	A. Chalfoun, <i>unpublished data</i>
western MT	79	30 (11-51)	90 (60-133)	42 (23-70)	B. Walker, <i>unpublished data</i>
northern WY	153	30 (7-71)	55 (30-140)	27 (8-60)	A. Holmes/PRBO, <i>unpublished data</i>
southcentral WY	7	24 (15-36)	50 (32-67)	-	Schroeder & Sturges 1975
central UT	3	31 (22-40)	-	-	Fautin 1946
northcentral UT	12	20 (13-30)	69 (48-120)	-	Castrale 1982
southeastern ID, northcentral UT	19	26	-	-	Olson 1974
southeastern ID	7	25	65	-	Reynolds 1981
southeastern ID	27	32	67	-	Rich 1980
southeastern ID	58	39 (90% btw. 20-50)	69 (42-104)	29	Petersen & Best 1985
southeastern ID	11-26	34 unburned	61-65 unburned	26-31 unburned	Petersen & Best 1987
southeastern ID	11-26	41 pre-burn	74 pre-burn	32 preburn	Petersen & Best 1987
southeastern ID	11-26	32 postburn	64 postburn	15 postburn	Petersen & Best 1987
southern B.C.	21	30 (15-100)	-	-	Cannings et al. 1987
southern B.C.	25	49 (12-104)	110 (64-170)	-	Sarell & McGuinness 1996
southern B.C.	114	35 (11-82)	86 (39-152)	34 (0-76)	Mahony 2003
eastern WA	471	31 (7-84)	85 (31-191)	26	W. M. Vander Haegen, <i>unpublished data</i>
northeastern CA	17	40 (20-65)	83 (52-140)	26 (4-66)	D. Humple/PRBO, <i>unpublished data</i>
central OR, northern NV	89	35 (14-67)	-	-	Rotenberry et al. 1999

¹ number of nests.

² mean (range). A dash indicates that data were not available. Nest height is the distance from the ground to the top rim of the nest.

³ mean (range). A dash indicates that data were not available.

Table 2. Brewer's Sparrow habitat characteristics (see Table 1 for details of nest height, nest-shrub height, and % shrub cover around nests).

Author(s)	Location(s)	Habitat(s) Studied*	Species-specific Habitat Characteristics
Baldwin 1956	Montana	Shrubsteppe	Nested in areas dominated by white sagebrush (<i>Artemisia ludoviciana</i>) and tarragon (<i>Artemisia dracunculus</i>) between 0.3 and 0.9 m tall in a mid-elevation valley in the Rocky Mountains
Beaver 1976	California	Burned montane shrublands	Nested in brush on mountainsides in the Sierra Nevada consisting of greenleaf manzanita (<i>Arctostaphylos patula</i>), snowbrush ceanothus (<i>Ceanothus velutinus</i>), and golden currant (<i>Ribes aureum</i>)
Best 1972	Montana	Shrubsteppe-shortgrass transition	All nests (n=40) were in big sagebrush (<i>Artemisia tridentata</i>); 72% of 39 nests were in shrubs with >75% green foliage; dead or partially-dead shrubs used for nesting were larger and denser than live shrubs used for nesting; grass cover was greater at nests placed in dead sagebrush, either because Brewer's Sparrows preferred this character or because grass cover was greater in sprayed areas; densities were reduced when sagebrush was killed by spraying with 2,4-D
Biermann et al. 1987	Alberta	Shrubsteppe	Nested in silver sagebrush (<i>Artemisia cana</i>) with an understory of grass
Bock and Bock 1987	Montana	Shrubsteppe	Were found in areas with big sagebrush and a dense understory of native grasses and Japanese brome (<i>Bromus japonicus</i>), a non-native annual grass; birds preferred areas of denser-than-average sagebrush (3425 shrubs/ha) within the plot (the plot averaged 1225 shrubs/ha); birds were absent in June in the first year of a 2-yr study
Burleigh 1972	Idaho	Shrubland	Were uncommon as a breeding bird in patches of serviceberry (<i>Amelanchier</i>)
Cannings et al. 1987	British Columbia	Shrubsteppe	Nested in areas with extensive tracts of big sagebrush
Castrale 1982	Utah	Regenerating burned, chained, and plowed shrubsteppe	Several years prior to the study, sagebrush was removed via one of three treatment methods: partial burning, chaining, or plowing; birds were restricted to post-treatment areas that still contained dense stands of big sagebrush; nests occurred in areas with an average density of 7605 shrubs/ha; no data were presented on differences in nest density among

			treatments
Castrale 1983	Utah	Regenerating burned, chained, and plowed shrubsteppe	Song perches were primarily in big sagebrush (93.6%) but Utah juniper (<i>Juniperus osteosperma</i>) was used more than expected (5.5%) based on availability (1%); males preferred to sing from tall, live shrubs; this may be because males alternate foraging and singing and prefer to forage in tall live shrubs; mean perch height was 85 cm (n=110); the height, width, and perpendicular width of shrubs used as song perches were significantly greater than shrubs surrounding the song perch; the availability of song perches is probably less important in habitat selection than the availability of suitable nesting or foraging sites
Dobler et al. 1996	Washington	Shrubsteppe	Were most abundant in areas with 3-19% shrub cover (measured via the line-intercept method); the density of birds increased as shrub cover approached the historic level of 10% and remained high as shrub cover approached 19%
Faanes and Lingle 1995	Nebraska	Shrubsteppe-shortgrass transition	Were found at low densities in prairie dominated by black greasewood (<i>Sarcobatus vermiculatus</i>)
Fautin 1946	Utah	Semidesert shrubsteppe	Nested at low densities in areas with sagebrush and black greasewood
Fautin 1975	Wyoming	Shrubsteppe	Were found in areas with Wyoming big sagebrush (<i>Artemisia tridentata wyomingensis</i>) and silver sagebrush
Feist 1968a,b	Montana	Shrubsteppe-shortgrass transition	Were common (0.62-0.98 pairs/ha) in shrubsteppe habitats with 15-29% sagebrush cover, 32-49% grass cover, and 5-18% forb cover; all nests (n=27) were in low-growing big sagebrush
Fisher 1893	California	Shrubsteppe	Bred in patches of sagebrush within singleleaf pinyon (<i>Pinus monophylla</i>) woodland
Hardy 1945	Utah	Semidesert shrubsteppe	Nested in stands of black greasewood but were absent from adjacent, stunted twoneedle pinyon (<i>Pinus edulis</i>)/Utah juniper woodland
Hill 1980	Nevada	Creosote bush desert	In years with high precipitation, Brewer's Sparrows nested in creosote bush (<i>Larrea tridentata</i>) desert
Howe et al. 1996, 2000	Idaho	Shrubsteppe	Were present in big sagebrush with 22-25% sagebrush cover and an

			understory of 14-19% grass cover and 2-15% forb cover
Huey and Travis 1961	New Mexico	Shrubsteppe	Reported as a common nesting species in stands of big sagebrush on hillsides surrounding a high-elevation lake
Kantrud and Kologiski 1983	Colorado, Montana, Nebraska, North Dakota, South Dakota, Wyoming	Shrubsteppe, shrubsteppe-grassland	In shrubsteppe of central and northern Wyoming and southcentral Montana, Brewer's Sparrows were most abundant in lightly grazed areas and least abundant in heavily grazed areas; in transition zones between shrubsteppe and grassland in western North and South Dakota, eastern Wyoming, and southeastern, southcentral, and central Montana, Brewer's Sparrows were common (72% of 155 units sampled) in heavily, moderately, and lightly grazed areas; sagebrush in transition zones was more patchily distributed and smaller in size, and was often more dense in grazed areas; Brewer's Sparrows were rare in grassland-dominated areas of the northern, eastern, and southern portions of the northern Great Plains.
Kerley and Anderson 1995	Wyoming	Burned shrubsteppe, shrubsteppe, sprayed shrubsteppe	Were found in high-elevation Wyoming big sagebrush shrubsteppe with an understory of native grasses; indices of abundance were four times higher in intact shrubsteppe (37% sagebrush cover, mean shrub height 31 cm) than in sprayed shrubsteppe (15% shrub cover, 22 cm high) or burned shrubsteppe (6% shrub cover, 20 cm high)
Knick and Rotenberry 1995	Idaho	Shrubsteppe	Were more common in large, unfragmented areas of sagebrush with above-average sagebrush cover and relatively little disturbed ground; no estimates were presented for minimum patch size or minimum shrub cover required
Knick and Rotenberry 1999	Idaho	Shrubsteppe	Brewer's Sparrow distribution was accurately predicted by mapping the distribution of large, intact patches of sagebrush
Knick and Rotenberry 2000	Idaho	Shrubsteppe	Over a 13-yr period, the abundance of Brewer's Sparrows declined in areas where turnover of habitat was greatest because of fire, grazing, and soil disturbance
Knopf et al. 1990	Colorado, Nevada, Utah	Shrubsteppe	Were most closely associated with homogenous patches of big sagebrush; at two locations in Nevada, males preferred to sing from elevated perches in mountain mahogany (<i>Cercocarpus ledifolius</i>); singing males preferred live shrubs

Krementz and Sauer 1982	Wyoming	Idle tame, shrubsteppe	Were abundant in areas of undisturbed shrubsteppe; were absent as a breeding bird in adjacent reclaimed mine spoils dominated by common halogeton (<i>Halogeton glomeratus</i>), a non-native annual forb
Larson and Bock 1986	New Mexico	Semidesert shrubsteppe	Of nine study sites, Brewer's Sparrows were only found on the five sites with the highest total shrub cover; big sagebrush dominated three of the five sites, and rubber rabbitbrush (<i>Ericameria nauseosa</i>) dominated the other two sites; preferred areas with above-average shrub cover (median shrub cover 32%), above-average shrub height (median shrub height about 60 cm), and below-average bare ground (median 45% bare ground); males held territories in areas with 15-45% shrub cover, 25-60% bare ground, 10-40% grass cover, and shrubs 20-60 cm tall; were absent from lowland areas dominated by four-wing saltbush (<i>Atriplex canescens</i>) and cholla (<i>Opuntia imbricata</i>) and from sites with <8% shrub cover; models suggested that Brewer's Sparrow abundance decreases with shrub cover <13%
Logan 2001	Montana	Grazed shrubsteppe, ungrazed shrubsteppe	Were present at low to moderate densities (0.20-0.55 nests/ha) in both grazed and ungrazed shrubsteppe with 16-26% sagebrush cover from 20-50 cm tall and 28-40% sagebrush cover from 0-20 cm tall
McAdoo et al. 1989	Nevada	Regenerating tame pasture, semidesert shrubsteppe, tame pasture	Relative abundance was positively associated with increasing shrub cover and was highest in undisturbed shrubsteppe (17-21% shrub cover averaging 35-52 cm tall), lower in crested wheatgrass (<i>Agropyron smithii</i>) seedlings being reclaimed by sagebrush (8-12% shrub cover averaging 26-44 cm tall), and lowest in crested wheatgrass monocultures (1-5% shrub cover averaging 44-51 cm tall)
McGee 1976	Wyoming	Burned shrubsteppe, shrubsteppe	Occurred at moderate densities (0.38-0.65 pairs/ha) in mountain big sagebrush (<i>Artemisia tridentata vaseyana</i>) in only one of 3 yr; birds nested in unburned control plots and in remaining patches of unburned sagebrush within areas burned the preceding year
Medin 1990a	Nevada	Shadscale saltbush desert	Within shadscale saltbush (<i>Atriplex confertifolia</i>) habitat, Brewer's Sparrows were restricted to shrubby areas along dry washes with black greasewood, four-wing saltbush, and rubber rabbitbrush

Medin 1990 <i>b</i> , 1992	Nevada	Shrubsteppe	Was most abundant breeding species in mountain big sagebrush
Medin et al. 2000	Nevada	Pinyon/juniper woodland, semidesert shrubsteppe, shrubsteppe	Were abundant in extensive stands of Wyoming and mountain big sagebrush; were less abundant in transition zones between sagebrush and other vegetation zones; were absent from pinyon (<i>Pinus</i>)/juniper (<i>Juniperus</i>) woodlands
Olson 1974	Idaho, Utah	Shrubsteppe	Were most abundant (1.39-2.23 birds/ha) in pure sagebrush stands with 12-49% shrub cover, less abundant (0.56-1.72 birds/ha) in regenerating sagebrush shrubland with 3-40% cover, and least abundant (0.31-0.72 birds/ha) in stands of mixed sagebrush (3-16%) and saltbush (<i>Atriplex</i> sp.) (5-18%)
O'Meara et al. 1981	Colorado	Chained pinyon/juniper woodland, pinyon/juniper woodland	Were found at relatively low densities (0.6-0.3 pairs/ha) at two sites with 5-17% shrub cover where pinyon/juniper woodland with a sagebrush understory had been chained 8 yr and 15 yr prior to the study; Brewer's Sparrows were absent from nearby pinyon/juniper woodland with 3% shrub understory (including some sagebrush)
Paczek 2002	British Columbia	Shrubsteppe	Avoided sagebrush areas surrounded by orchards, vineyards, and pasture and were more likely to occur in moderately dense sagebrush with a high forb component; were generally absent from plots with a northern exposure and flora characteristic of drier, disturbed areas, such as pricklypear (<i>Opuntia</i>) and sand dropseed grass (<i>Sporobolus cryptandrus</i>); were present more often in higher-elevation sagebrush with deep soils, less bare ground, intact cryptobiotic crusts, and an understory of silky lupine (<i>Lupinus sericeus</i>), parsnip-flowered buckwheat (<i>Eriogonum heracleoides</i>), and junegrass (<i>Koeleria macrantha</i>); within plots, birds were most abundant in areas with concentrations of threetip sagebrush, buckwheat, lupine, and leaf litter
Petersen and Best 1985	Idaho	Shrubsteppe	All nests were in big sagebrush; mean sagebrush cover (29%) and mean height of surrounding shrubs (54 cm) were greater, and the percentage of bare ground (46%) was lower, around nests than within the study plot, which averaged 26% cover, shrubs 43 cm tall (range 8-127), and 54% bare

			ground; although 70% of all shrubs available were <50 cm tall, 93% of 58 nests were in shrubs >50 cm tall; 71% of nests were in shrubs with 100% live foliage, 93% were in shrubs with >75% live foliage, and all nests were in shrubs with >50% live foliage; nesting birds did not show a preference for nest shrubs with denser-than-average foliage or with a continuous canopy; nests were situated, on average, 18 cm from the edge and 24 cm from the top of nest shrubs; nest height increased an average of 6 cm over the course of the breeding season, but height from the nest to the top of the nest shrub did not change; birds selected nest shrubs of medium density and did not nest in shrubs >104 cm in height
Petersen and Best 1987, Idaho 1999		Burned shrubsteppe, shrubsteppe	Following an incomplete (45% of the area was burned) prescribed burn, mean nest height (n = 11-26) decreased 10 cm and nest-shrub height decreased 10 cm; after the burn, the height of shrubs decreased 14 cm, sagebrush cover decreased (32% to 15%), and the amount of bare ground increased (48% to 58%) in the vicinity of nests; densities measured via territory mapping were 50% of pre-burn levels for the first 2 yr following the burn, but exceeded those on control plots in the third and fourth years after the burn; continued monitoring through 1988 revealed that the 2-yr decrease in abundance after fire was short-lived; they suggested that prescribed burning had no long-term effects on population size
Reynolds 1981; Reynolds and Trost 1980, 1981	Idaho	Grazed shrubsteppe, tame pasture, ungrazed shrubsteppe	Were absent from areas planted with crested wheatgrass; three nests were found on nearby shrubsteppe plots grazed by sheep that had 65% sagebrush cover, and four nests were found on ungrazed shrubsteppe plots with 41% sagebrush cover
Rich 1980	Idaho	Shrubsteppe	All nests were in big sagebrush; mean nest-to-crown distance was 39 cm
Rotenberry 1986	Nevada, Oregon, Washington	Shrubsteppe	Were most abundant in broad, flat, mid-elevation valleys dominated by sagebrush and were rarely found in areas with low-growing, spiny shrubs characteristic of arid or semiarid deserts
Rotenberry and Wiens 1980a	Montana, Oregon, Washington,	Shrubsteppe	In a large-scale study across the western U.S., Brewer's Sparrows were most abundant at sites with highest shrub cover (i.e., in shrubsteppe) than in areas with higher grass cover (i.e., in prairie)

Wyoming			
Rotenberry and Wiens 1980b	Nevada, Oregon	Shrubsteppe	Abundance was negatively correlated with grass cover and with turnover in the composition of bird species between years
Rotenberry and Wiens 1989,1991	Nevada, Oregon	Shrubsteppe	Were consistently abundant at a site with 32% total shrub cover (19% sagebrush, 13% other shrubs) and 24% grass cover; were present and abundant in only one of 2 yr at a site with 25% total shrub cover (23% sagebrush, 2% other shrubs) and 39% grass cover
Rotenberry and Wiens 1998	Oregon	Shrubsteppe	Preferred to forage in large, live big sagebrush rather than in dead shrubs or yellow or rubber rabbitbrush, which were usually smaller; however, this may be because males prefer to sing from high, exposed perches and often alternate singing and foraging bouts from the same shrub
Sarell and McGuinness 1996	British Columbia	Shrubsteppe	At 25 sites where Brewer's Sparrows were detected in the Okanagan Valley, sagebrush height averaged 110 cm (range 64-170 cm); 32% of nesting pairs were found in sparse sagebrush (<10% shrub cover), 48% were in moderately dense sagebrush (10-30% shrub cover), and 20% were in dense sagebrush (>30% shrub cover); only inhabited extensive tracts of big sagebrush with a bluebunch wheatgrass (<i>Pseudoroegneria spicata</i>) understory; all nests were found in big sagebrush; density decreased when shrub cover exceeded 20%
Saunders 1914	Montana	Idle shortgrass	One pair consistently found in a patch of russet (or Canada) buffaloberry (<i>Shepherdia canadensis</i>) throughout the summer breeding season
Schroeder and Sturges 1975	Wyoming	Shrubsteppe, sprayed shrubsteppe	Abundant (0.75 to 1.10 nesting pairs/ha) in undisturbed sagebrush during a 2-yr study; no nests were found in adjacent areas sprayed with 2,4-D; the only birds found in sprayed areas were within remaining patches of live sagebrush
Schuler et al. 1993	Washington	Tame burned shrubsteppe, semidesert shrubsteppe, shrubsteppe	Occurred only rarely in mixed shrublands with big sagebrush, spiny hopsage (<i>Grayia spinosa</i>), yellow rabbitbrush (<i>Chrysothamnus viscidiflorus</i>), and rubber rabbitbrush and an understory of cheatgrass (<i>Bromus tectorum</i>) and Sandberg's bluegrass (<i>Poa secunda</i>)
Sedgwick 1987	Colorado	Pinyon/juniper woodland,	Were most abundant in uniform patches of big sagebrush within larger openings in pinyon/juniper woodland; preferred open areas with large

		shrubsteppe	shrubs, gradual slopes, and low shrub species richness (i.e., areas dominated by big sagebrush); were most abundant in areas away from woodland edges
Tyler 1910	California	Vineyards	Were found nesting in vineyards
Vander Haegen et al. 2000	Washington	Semidesert shrubsteppe, shrubsteppe	Were most common on wetter, more productive sites in the northern part of the Columbia River Basin, in areas with greater shrub cover and deep, loamy soils, and in areas in good to fair range condition (those with >25% total cover of native, climax vegetation); were least abundant in areas of poor range condition; despite high shrub densities, birds avoided low-elevation sites with low precipitation and sandy soils; these areas were primarily in the southern part of the Columbia River Basin
Walcheck 1970	Montana	Pine/juniper woodland, shrubsteppe	Occurred at low density (0.13 pairs/ha) in mixed shrublands with an average shrub cover of 17% (9% big sagebrush, 8% black greasewood), but densities were much higher (1.2 pairs/ha) in nearby stands of silver sagebrush (total shrub cover 53%) with an understory of cheatgrass and western wheatgrass; were absent from nearby woodlands of limber pine (<i>Pinus flexilis</i>) and Rocky Mountain juniper (<i>Juniperus scopulorum</i>) with an understory of common juniper (<i>Juniperus communis</i>), big sagebrush, and skunkbush sumac (<i>Rhus trilobata</i>)
Welch 2002	Idaho, Montana Oregon, Utah, Wyoming	Burned shrubsteppe, shrubsteppe	Were found exclusively in stands dominated by big sagebrush; were present on 12 of 13 transects in undisturbed shrubsteppe; they were absent on 13 of 13 transects in adjacent shrubsteppe that had been burned and seeded with non-native grasses
Wiens and Rotenberry 1981	Nevada, Oregon	Shrubsteppe	Were less abundant in areas with spiny hopsage and bud sagebrush (<i>Picrothamnus desertorum</i>), with high shrub species diversity (indicating transition areas between pure sagebrush and other habitats or vegetation types), and with a higher percentage of bare rock (i.e., rock outcroppings); appeared to first select breeding habitat based on the presence of shrubs; they then selected territories within breeding habitat based on species composition (i.e., they preferred big sagebrush) and the suitability of shrubs and shrub cover for nesting and foraging
Wiens and Rotenberry	Oregon	Shrubsteppe,	Were found in pure stands of big sagebrush with 19-24% shrub cover, 1-

1985		sprayed shrubsteppe	4% grass cover, 70-75% bare ground, and few forbs; after spraying, birds were still present (although populations fluctuated) in areas with 4-12% sagebrush cover and 10-57% grass cover
Wiens et al. 1986	Oregon	Shrubsteppe	Were abundant (1.2-2.2 individuals/ha) in shrubsteppe dominated by big sagebrush
Wiens et al. 1987a	Nevada, Oregon	Shrubsteppe	Abundance was highest in areas with tall, moderately dense sagebrush; Brewer's Sparrows were present at sites with 23-37% shrub cover (2-32% sagebrush cover); individual birds occupied patches with higher vegetation density from 0-30 cm and higher sagebrush cover
Winter 1984	Idaho	Burned shrubsteppe, shrubsteppe	Were found in unburned stands of big sagebrush averaging 30% shrub cover (26% big sagebrush, 4% rabbitbrush), 8% grass cover, 60% bare ground, and 4% forbs; after prescribed fire, birds primarily foraged in unburned patches with 25% shrub cover (20% sagebrush, 5% rabbitbrush), 9% grass, 5% forbs, and 65% bare ground; preferred to forage in areas with greater sagebrush cover and on plants in better condition

* In an effort to standardize terminology among studies, various descriptors were used to denote the management or type of habitat. "Shrubsteppe" typical of the western Great Plains, Rocky Mountains, and Columbia and Snake river basins is characterized by moderate shrub cover (10-20%), moderate precipitation, and a significant understory component of grasses and forbs. Sagebrush shrublands typical of the Great Basin are characterized by relatively dense shrub cover (>20%), low precipitation, and a sparse understory of grasses and forbs. In this account, we refer to both sagebrush shrublands and shrubsteppe simply as "shrubsteppe." Local areas with sandy or rocky soils and transition zones where sagebrush mixes with shrubs more typical of arid or semiarid deserts, particularly in the southern Great Plains, Great Basin, and Southwest, are designated "semidesert shrubsteppe" "Burned" includes habitats that were burned intentionally or accidentally or those burned by natural forces (e.g., lightning).

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