The Effects of Management Practices on Grassland Birds— Mountain Plover (*Charadrius montanus*)

Chapter E of

The Effects of Management Practices on Grassland Birds

Professional Paper 1842–E

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Chapter E of

The Effects of Management Practices on Grassland Birds

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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)
Area		
square meter (m ²)	0.0002471	acre
hectare (ha)	2.471	acre
square meter (m ²)	10.76	square foot (ft ²)
hectare (ha)	0.003861	square mile (mi ²)

Abbreviations

BBS Breeding Bird Survey

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

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The Effects of Management Practices on Grassland Birds—Mountain Plover (*Charadrius montanus*)

By Jill A. Shaffer,¹ Lawrence D. Igl,¹ Douglas H. Johnson,¹ Marriah L. Sondreal,¹ Christopher M. Goldade,^{1,2} Melvin P. Nenneman,^{1,3} Travis L. Wooten,^{1,4} and Betty R. Euliss¹

Capsule Statement

The key to Mountain Plover (*Charadrius montanus*) management is maintaining sparsely vegetated grasslands. Grasslands can be made suitable for breeding Mountain Plovers by preserving large prairie dog (*Cynomys* species [spp.]) towns, conducting prescribed burns, or implementing heavy grazing in some situations. Mountain Plovers have been reported to use habitats with 2–38 centimeters (cm) average vegetation height, 14–87 percent grass cover, 2–14 percent forb cover, 4–55 percent shrub cover, 9–72 percent bare ground, 2 percent litter cover, and 4–6 cm litter depth. The descriptions of key vegetation characteristics are provided in table E1 (after the “References” section). Vernacular and scientific names of plants and animals follow the Integrated Taxonomic Information System (<https://www.itis.gov>).

Breeding Range

Mountain Plovers breed from southeastern Alberta and southwestern Saskatchewan through central Montana; south to south-central Wyoming, the southwestern portion of the Nebraska panhandle, east-central Colorado, and northeastern New Mexico; and east to northern Texas, northwestern Oklahoma, and western Kansas (Bly and others, 2008; McConnell and others, 2009; National Geographic Society, 2011). The relative densities of Mountain Plovers in the United States and southern Canada, based on North American Breeding Bird Survey (BBS) data (Sauer and others, 2014), are shown in figure E1 (not all geographic places mentioned in report are shown on figure). Although the Mountain Plover’s entire

Mountain Plover. Illustration by Christopher M. Goldade, U.S. Geological Survey.

breeding range is within in the area covered by the BBS, the species is considered to be poorly monitored by the BBS, with imprecise results largely owing to small sample sizes, a restricted distribution, and poor coverage of their habitats from along roadsides (Sauer and others, 2013). As such, the breeding range map does not depict locations with known but sparse breeding populations of Mountain Plovers in the northern part of the species’ range in Montana, southeastern Alberta, and southwestern Saskatchewan. In recent years, the species has expanded its breeding range into southwestern Nebraska and northwestern Oklahoma (Bly and others, 2008; McConnell and others, 2009).

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Figure E1. Breeding distribution of the Mountain Plover (*Charadrius montanus*) 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.

Suitable Habitat

Mountain Plovers prefer large, flat grassland expanses with sparse, short vegetation and bare ground within short-grass and mixed-grass prairies and shrubsteppe (Giezentanner, 1970; Graul, 1973, 1975; Knowles and others, 1982; Olson, 1984; Olson and Edge, 1985; Shackford, 1987; Wershler and Wallis, 1987; Leachman and Osmundson, 1990; Parrish and others, 1993; Knopf and Miller, 1994; Shackford and Leslie, 1994; Knowles, 1996; Ellison Manning and White, 2001;

Beauvais and Smith, 2003; Goguen, 2012). Within semidesert grasslands, Mountain Plovers use flat, sparsely vegetated habitats with cacti, low shrubs, and an open understory (Tolle, 1976; Day, 1994). Areas disturbed by prairie dogs, fire, or heavy grazing provide suitable habitat (Bradbury, 1918; Finzel, 1964; Giezentanner, 1970; Wallis and Wershler, 1981; Knowles and others, 1982; Knowles and Knowles, 1984; Olson, 1984; Shackford, 1987; Wershler and Wallis, 1987; Leachman and Osmundson, 1990; Knowles, 1996; Tipton and others, 2008; Augustine, 2011; Goguen, 2012). Mountain

Plovers frequently use cultivated fields for nesting and brood rearing (Shackford, 1987, 1991, 1996; Shackford and Leslie, 1994; Knopf, 1996; Knopf and Rupert, 1999; Shackford and others, 1999; Dreitz and others, 2005; Bly and others, 2008; McConnell and others, 2009).

Mountain Plovers tend to place nests in areas of sparse vegetation. The species often nests near rocks, cow dung, or clumps of vegetation (Graul, 1975; Wallis and Wershler, 1981; Olson and Edge, 1985; Parrish, 1988; Parrish and others, 1993; Knopf and Miller, 1994; Knopf, 1996). In Colorado, nest sites had a lower percentage of vegetative cover, more cow dung, and fewer pricklypear (*Opuntia* spp.) plants than nearby random sites (Knopf and Miller, 1994). In Utah shrubsteppe, Mountain Plover nest sites had shorter vegetation than random sites (Ellison Manning and White, 2001). In Montana, mean vegetation height at nest sites was lower than that in the surrounding habitat, although litter cover was higher (Olson, 1984; Olson and Edge, 1985). In northeastern Wyoming, Mountain Plovers nested in areas with shorter grasses (average height of 8.4 cm), forbs (average height of 4.3 cm), shrubs (average height of 3.7 cm), and distances to animal or wheel tracks; higher shrub density (average density of 12.3 shrubs per square meter [m^2]); and taller cacti (average height of 6.7 cm) than random sites (Parrish, 1988; Parrish and others, 1993). Shrubs, primarily birdfoot sagebrush (*Artemisia pedatifida*), in the nesting habitat were small (2–20 cm) in diameter and grew in a mat-like fashion (Parrish and others, 1993). Nest sites had lower forb density and more grass cover than sites where chicks were located (Parrish, 1988; Parrish and others, 1993).

In Colorado, brood rearing occurred in areas with more bare ground and less grass cover than areas used for nesting (Knopf and Rupert, 1999). Mean percentage of bare ground and grass cover on brood rearing areas was 15 and 84 percent, respectively, compared with 9 and 87 percent on nesting areas, respectively. Differences between the two areas were statistically significant. Cover of forbs, pricklypear, and cow dung were similar between the two areas.

Mountain Plovers often are associated with grasslands dominated by blue grama (*Bouteloua gracilis*) or buffalo-grass (*Bouteloua dactyloides*) (Bradbury, 1918; Laun, 1957; Finzel, 1964; Giezentanner, 1970; Graul, 1973, 1975; Graul and Webster, 1976; Wallis and Wershler, 1981; Parrish, 1988; Parrish and others, 1993; Childers and Dinsmore, 2008), but Knopf and Rupert (1999) reported that none of 147 nests in a Colorado study were in buffalograss. In Alberta, the dominant vegetation at nest sites was blue grama, Sandburg's bluegrass (*Poa secunda*), junegrass (*Koeleria macrantha*), and thread-leaf sedge (*Carex filifolia*) (Wershler and Wallis, 1987). In Montana, typical Mountain Plover habitat consisted of a plant community dominated by saltbush (*Atriplex* spp.) (Knowles, 1996). Plovers also were found in wild buckwheat (*Eriogonum* spp.) with 70 percent bare ground including glacial till and rocks. In Wyoming, the species nested in shortgrass pastures dominated by needleandthread (*Hesperostipa comata*), junegrass, and Sandburg's bluegrass (Laun, 1957).

Mountain Plovers occupy areas with moderately flat topography during the breeding season, but soil types vary among nesting areas. In western Wyoming, Beauvais and Smith (2003) reported a strong negative relationship between Mountain Plover presence and slope; at slopes greater than 8 percent, the probability of Mountain Plover presence was zero. In another Wyoming study, Parrish (1988) and Parrish and others (1993) reported that the species occurred on slopes of less than (<) 3 percent and on clay soil. Of 154 nests in Colorado, 65 percent were on slopes of <1 degree (slope of 1.7 percent), 25 percent on slopes of <2 degrees (slope of 3.5 percent), and one nest was on a slope of 5 degrees (slope of 8.7 percent) (presumably, the remaining percentages of nests were on slopes between 2 and 5 degrees) (Graul, 1975). Knowles and others (1982) observed Mountain Plovers in Montana on slopes of <12 percent. Ellison Manning and White (2001) observed plovers in Utah on slopes of less than or equal to 10 percent. In New Mexico, Mountain Plovers used grasslands with slopes of <1.5 degrees (slope of 2.6 percent) (Goguen, 2012). In Oklahoma, Mountain Plovers nested in bare, cultivated fields of <2 percent slope, and their distribution was closely tied to the presence of clay loam soils (McConnell and others, 2009). In Alberta, the species nested on flat mixed-grass pastures with well-drained sandy soil but avoided nesting in areas with poorly drained soil and rolling hills (Wershler and Wallis, 1987). In the northern Great Plains, Mountain Plovers used heavily grazed areas with aridic ustoll soils (Kantrud and Kologiski, 1982). In Montana, the soils within an area designated as critical habitat for Mountain Plovers consisted of hardpan clay and bentonite (Childers and Dinsmore, 2008). Within cultivated fields in Colorado, Kansas, Oklahoma, and Wyoming, soil near nests contained an average of 55 percent sand and 43 percent silt and clay, whereas soil of cultivated fields unoccupied by plovers contained an average of 80 percent sand and 20 percent silt and clay (Shackford and Leslie, 1994).

Prairie dog towns are an important component of Mountain Plover habitat (Childers and Dinsmore, 2008; Augustine and Skagen, 2014). Prairie dog towns may provide greater food resources and more available prey for Mountain Plovers than areas outside of towns (Olson, 1985). In mixed-grass prairies and other areas where vegetation is otherwise too tall, thick, or shrubby, prairie dog towns that are moderately to heavily grazed by livestock provide the mixture of short-statured grass and bare ground suitable for Mountain Plovers (Knowles and Knowles, 1984; Olson, 1984; Olson and Edge, 1985; Leachman and Osmundson, 1990). Prairie dogs within pastures with shrubs can control sagebrush (*Artemisia* spp.) growth and provide suitable nesting habitat (Olson, 1984; Olson and Edge, 1985).

In Montana, Mountain Plovers rarely were observed outside of prairie dog towns, and towns <10 hectares (ha) were considered marginal habitat (Knowles and others, 1982; Olson, 1984). The species used active prairie dog towns in upland areas characterized by heavy grazing and sparse shrub cover (Knowles and others, 1982). Nest sites on prairie

dog towns in Montana had lower mean cover of plants, bare ground, grass, and big sagebrush (*Artemisia tridentata*), and lower vegetation height and density of plains pricklypear than on adjacent areas outside of prairie dog towns (Olson, 1984). Compared to random sites within prairie dog towns, Mountain Plover nest sites in prairie dog towns were characterized by shorter vegetation; lower cover of total plants, grass, and pricklypear; higher cover of bare ground, fringed sagewort (*Artemisia frigida*), and big sagebrush; and higher forb density than at random sites within prairie dog towns (Olson 1984; Olson and Edge, 1985). In another Montana study, the densities of Mountain Plovers were much higher on prairie dog towns than on grasslands without towns (Childers and Dinsmore, 2008). In Colorado shortgrass prairies, prairie dog towns within moderately grazed pastures provided suitable habitat for Mountain Plovers, whereas grasslands without prairie dog towns did not (Augustine and Derner, 2012). The species was most common in burned areas and grasslands that contained active prairie dog towns, was less common in shortgrass prairies with inactive prairie dog towns, and was not found on unburned grasslands with no prairie dog towns (Augustine, 2011). In another Colorado study, Tipton and others (2008) reported that Mountain Plover occupancy was higher in prairie dog towns than in grasslands outside prairie dog towns or agricultural fields.

Prairie dog towns occupied by Mountain Plovers often are associated with stock ponds (Knowles and others, 1982; Olson and Edge, 1985). In Colorado, Knopf and Rupert (1999) examined the presence of Mountain Plovers around stock tanks used by cattle and stock tanks not used by cattle. Plovers were located near 11 of the 28 tanks where cattle were present and were absent at all 28 tanks without cattle. Plovers probably were attracted either to cattle presence or recent site disturbance created by cattle. Cattle-watering tanks were generally devoid of vegetation within 20 meters (m) around the tank.

Mountain Plovers frequently nest in cultivated fields. In Nebraska, Mountain Plovers nested almost exclusively in agricultural fields (98 percent of 278 nests) (Bly and others, 2008). Similarly, 90 percent of known Mountain Plover breeding populations in Oklahoma occurred in agricultural fields (McConnell and others, 2009). In Colorado, the species nested in cultivated fields, especially if native prairie was nearby; in Wyoming, the species nested in plowed river-bottom fields (Shackford, 1996). Of 52 nests within cultivated fields in Colorado, Kansas, Oklahoma, and Wyoming, 26 were located on bare or fallow ground, 13 were in fields of growing wheat (*Triticum* spp.), 7 were in fields of milo (*Sorghum* spp.), 4 were in fields of forbs or forb stubble, and 2 were in fields of sprouting corn (*Zea mays*) (Shackford and others, 1999). Mountain Plovers continued to nest in cropland as the crop increased in height to about 35 cm, including one nest that remained active until vegetation was 38 cm high (Shackford and Leslie, 1994).

Cultivated land also may be used by adults with broods (Shackford, 1987, 1991, 1996; Shackford and Leslie, 1994; Knopf, 1996; Knopf and Rupert, 1999; Shackford and others,

1999; Dreitz and others, 2005; Bly and others, 2008). In Colorado, Knopf and Rupert (1999) determined that adults with broods moved from cultivated land to grazed shortgrass prairie when vegetation in the field reached 20 cm tall.

Area Requirements and Landscape Associations

In Colorado, three male Mountain Plovers defended territories averaging 16 ha, and the minimum area needed to raise a brood was at least 28 ha (Graul, 1973; Knopf and Rupert, 1996). Areas used by different broods often overlapped (Graul, 1973; Knopf and Rupert, 1996). In another Colorado study, Dreitz and others (2005) reported average home-range estimates for adults with broods in three landscapes: 146.1 ha for 12 broods in grasslands, 131.6 ha for 13 broods in agricultural fields, and 243.3 ha for 10 broods in prairie dog towns. The larger home-range estimate for prairie dog towns compared to the other two habitats was attributed to two broods that were raised on a prairie dog complex rather than in isolated towns. Movements (that is, the distance moved by adults and their brood between two consecutive locations collected at 1- or 2-day intervals) were similar across habitats. Adult plovers that nested in grasslands and adults that nested in prairie dog towns did not move their broods to different habitats but rather stayed in the habitat in which they nested. Four adults that nested in agricultural fields remained with their broods in those fields, four adults moved their broods to grasslands, and five adults moved back and forth between these two habitats. In Colorado, Kansas, and Oklahoma, plovers were attracted to large (greater than 30 ha), cultivated fields (Shackford and Leslie, 1994).

The size of prairie dog towns is an important factor that affects Mountain Plover presence and abundance. In New Mexico, Goguen (2012) determined that the probability of Mountain Plovers occupying a prairie dog town increased with increasing area, and in Montana, Dinsmore and others (2005) concluded that the population trend of Mountain Plovers closely matched the trend in the area occupied by black-tailed prairie dogs (*Cynomys ludovicianus*). Mountain Plovers in Montana occurred at highest densities on towns that were 6–50 ha and were less abundant on smaller towns (Knowles and others, 1982; Olson, 1984; Olson-Edge and Edge, 1987). The average size of towns used by Mountain Plovers in north-central Montana was 57.5 ha (Knowles and Knowles, 1984).

Tipton and others (2008) examined the relationship between Mountain Plover occupancy and the amount of prairie dog town, grassland, and dryland agriculture at three spatial scales (a 25-ha plot and its surrounding 203.48 ha; 1,031.35 ha; or 2,064.30 ha). The sampling frame consisted of 500×500-m (25-ha) grid cells of each habitat. Mountain Plover occupancy was positively correlated with increasing amounts of prairie dog town in the immediate surrounding landscape, regardless of plot type (prairie dog town, grassland, or agriculture). The amount of grassland at the largest landscape scale positively

influenced Mountain Plover occupancy in prairie dog towns and agricultural plots, but negatively influenced plover occupancy in grassland plots. The authors surmised that the plot-specific response may reflect Mountain Plover use of one habitat type for nesting and another habitat type for brood rearing.

In Colorado, anthropogenic edges (defined as fence lines, roads, and perimeters of agricultural fields) had no effect on nest success of Mountain Plovers (Mettenbrink and others, 2006). Nest success relative to the distance from the nearest edge was similar between rangeland and cropland, and year-to-year differences were insignificant. In Oklahoma, McConnell and others (2009) found no evidence to indicate that Mountain Plovers were influenced by roads. The 34 plover detections within 200 m of the observer surveying from the road were similar to the 38 plover detections beyond 400 m; no Mountain Plovers were encountered during additional searches in interiors of roadless sections.

Brood Parasitism by Cowbirds and Other Species

No studies have documented brood parasitism by Brown-headed Cowbirds (*Molothrus ater*) (Shaffer and others, 2019). Mountain Plovers are not suitable hosts for Brown-headed Cowbirds because young plovers are precocial and nidifugous. Jojola-Elverum and Giesen (2000) reported a Killdeer (*Charadrius vociferus*) incubating a nest with three Killdeer eggs and three Mountain Plover eggs.

Breeding-Season Phenology and Site Fidelity

Generally, Mountain Plovers arrive on the breeding grounds from mid-March to mid-April and depart for the wintering grounds from early August to late October (Graul, 1973, 1975; Wallis and Wershler, 1981; Olson, 1984; Leachman and Osmundson, 1990; Knopf, 1996; Knopf and Wunder, 2006; Bly and others, 2008). In Colorado, the peak breeding period is mid-April to mid-July (Ball, 1996).

If the first nest fails before June, the female may attempt to reneest (Knopf and Wunder, 2006). Multiple nesting attempts (that is, the male incubates a first clutch while the female incubates a second clutch simultaneously) have been reported (Graul, 1973; Knopf, 1996). Mountain Plovers exhibit fidelity to nest sites used the previous year (Graul, 1973, 1975; Skrade and Dinsmore, 2010).

Species' Response to Management

Burning can benefit Mountain Plovers when used to maintain areas of shorter grass within mixed-grass prairies (Wallis and Wershler, 1981; Knopf and Wunder, 2006). In

shortgrass prairies, dormant-season prescribed burns may provide suitable breeding habitat. In Colorado, Mountain Plover densities in shortgrass prairies that were burned during the dormant season were similar to Mountain Plover densities in shortgrass prairies with active prairie dog towns (Augustine, 2011). Densities in these two habitats were higher than in shortgrass prairies with inactive prairie dog towns, and no Mountain Plovers occurred on unburned grasslands that had no active prairie dog towns owing to an outbreak of epizootic plague. Augustine and Skagen (2014) determined that Mountain Plover densities were similar between grasslands burned during the preceding dormant season and active prairie dog towns, but nest survival was higher on active prairie dog towns than burned sites. Increased time since burning decreased plover densities; densities declined by 78 percent at burned sites between the first and second season post-burn growing season. In comparison, removal of prairie dog disturbance owing to sylvatic plague reduced plover density by 70 percent relative to active prairie dog colonies after 1 year.

Grazed grasslands, especially those containing prairie dog towns, are vital to Mountain Plovers (Ryder, 1980; Kantrud and Kologiski, 1982; Knowles and others, 1982; Wershler and Wallis, 1987; Bock and others, 1993; Knowles, 1996; Dinsmore and others, 2005; Childers and Dinsmore, 2008). Grazing activities that maintain short vegetation and low litter attract Mountain Plovers; the species has been reported inhabiting areas around stock tanks and increasing in numbers where sheep herds and American bison (*Bison bison*) are pastured (Knowles, 1996). In Alberta, heavy grazing in summer or late winter improved habitat for Mountain Plovers by providing short-statured grass in mixed-grass areas (Wallis and Wershler, 1981; Wershler and Wallis, 1987). In Colorado, shortgrass pastures grazed heavily in summer were used by Mountain Plovers for foraging and nesting (Giezen-tanner, 1970). However, Mountain Plovers may be excluded by extreme or long-term overgrazing (Laun, 1957; Wallis and Wershler, 1981). Within Montana shrub grasslands (Olson and Edge, 1985) and Colorado shortgrass prairies (Augustine and Derner, 2012), intensive livestock grazing alone (1.2 animal unit months per ha, which was double the usual stocking rate), without prairie dog towns or burning, did not provide suitable habitat.

Cultivated land may provide suitable habitat in areas where prairie dog towns in grasslands are unavailable. In Oklahoma, Mountain Plovers preferred plowed fields over shortgrass prairies, unless prairie dog towns were present on the prairies (Shackford, 1991, 1996). In Colorado in April, the number of Mountain Plovers within paired plots at a native-prairie and cultivated-field interface did not differ. Mountain Plovers preferred a cultivated field over shortgrass prairie after April (Knopf and Rupert, 1999). After the cultivated field had been planted and chemically treated for weed control in early May, detections of Mountain Plovers were significantly higher on the cultivated field than on the shortgrass prairie. Although a few nests were found, Mountain Plovers appeared to be mainly foraging in the prairie and were nesting primarily in

the field. However, planting and weed control operations probably destroyed nests, because Mountain Plovers began courtship activities for a second time. Broods moved from prairie to fields, as did adults that were unsuccessful breeders.

Mountain Plovers are present in saltbush-dominated habitats in central Montana; Mountain Plovers abandoned an area after the seeding of saltbush habitats to crested wheatgrass (*Agropyron cristatum*) and the development of weedy mudflats owing to damming (Knowles, 1996).

In Montana, Dinsmore (2013) reported a strong negative effect of a pyrethroid insecticide on nest survival of Mountain Plovers. The insecticide contained 0.05 percent deltamethrin and was used to control fleas on prairie dogs to help limit the spread of plague, a flea-borne disease caused by the bacterium *Yersinia pestis*. Although there was no evidence of direct toxicity to nesting Mountain Plovers, Dinsmore (2013) indicated that the insecticide caused lower insect availability for the plovers, resulting in more time off nests or a switch to a less desirable insect prey, which in turn lowered nest survival.

Some oil and gas extraction activities may be compatible with Mountain Plover habitat needs. In Utah, disturbed areas around oil well pads created open habitat with high amounts of bare ground suitable for Mountain Plovers (Day, 1994). Mountain Plovers in southeastern Wyoming did not seem to be disturbed by nearby mining activity (Parrish, 1988).

Management Recommendations from the Literature

Disturbances, such as those created by livestock grazing, burning, or prairie dog activity, provide critical breeding habitat for Mountain Plovers (Finzel, 1964; Wallis and Wershler, 1981; Knowles and Knowles, 1984; Knopf and Wunder, 2006; Augustine and Derner, 2012; Augustine and Skagen, 2014). Because some plovers return to the same breeding sites year after year, several authors emphasized the importance of protecting areas traditionally used by Mountain Plovers, especially within large and active prairie dog towns (Graul, 1973, 1975; Knowles and others, 1982; Olson, 1984; Olson and Edge, 1985; Olson-Edge and Edge, 1987; Dinsmore and others, 2005; Goguen, 2012). Livestock grazing in these areas should be encouraged, because prairie dog towns often are associated with grazed areas (Knowles and others, 1982; Olson and Edge, 1985). Maintaining complexes of prairie dog towns will be more advantageous for successful brood rearing than maintaining isolated prairie dog towns (Dreitz and others, 2005). Management that mitigates or prevents plague outbreaks on large prairie dog towns will help maintain plover habitat (Augustine and Skagen, 2014).

Wershler (1987, 1991) recommended protecting large, unfragmented native grasslands from tillage and from seeding to exotic grasses. Knopf and Rupert (1999) highlighted the importance of using native seed mixtures on Conservation Reserve Program areas. In Colorado, shortgrass prairies

should be managed to maintain vegetation <25 cm in height (Ball, 1996).

Prescribed burns can improve Mountain Plover habitat in native grasslands (Wallis and Wershler, 1981; Eldridge, 1992; Knopf and Wunder, 2006). Burning, however, provides suitable habitat for only about 1 year; in Colorado, plover densities declined by 78 percent between the first and second post-burn growing season (Augustine and Skagen, 2014). Timing of burns and consideration of geographical location and annual precipitation are important. In Alberta, burns conducted in late summer or early fall improved the vegetation structure and composition that is associated with Mountain Plover habitat (Wershler, 1991). In Colorado, Knopf and Rupert (1999) found that Mountain Plovers were attracted to grasslands that had been burned the previous winter or spring. In another Colorado study, Augustine and Skagen (2014) reported that plover density did not differ between sites burned in fall compared to late winter or with burn size (11- to 500-ha burns), suggesting that managers have flexibility in selecting the timing and size of burns. Burning also may help maintain Mountain Plover habitat without adversely affecting forage availability for cattle; in Colorado shortgrass prairies during years with average or above-average precipitation, burning <50 percent of a pasture provided plover habitat (Augustine and Milchunas, 2009; Augustine and others, 2010).

A management approach that combines prairie dog conservation with the strategic use of prescribed burning can be beneficial to Mountain Plovers (Augustine and Skagen, 2014). Conducting burns near prairie dog towns that were recently affected by an outbreak of epizootic plague may help the towns to recover, as well as increase nest survival rate (Augustine, 2011; Augustine and Derner, 2012). In addition, prescribed burning can be used to create nesting habitat in landscapes where disturbances such as prairie dog towns are limited in distribution and size (Augustine and Skagen, 2014). Vegetation structure within prairie dog towns was more stable in space and time than within burned areas; hence, Augustine and Derner (2012) advised that the importance of maintaining active prairie dog towns should not be overlooked.

Suitable Mountain Plover habitat can be created or maintained by varying livestock grazing intensities, ranging from heavily grazed to ungrazed, which may simulate historic grazing pressure by American bison (Wallis and Wershler, 1981). For example, in shortgrass or mixed-grass pastures, grazing at moderate-to-heavy intensities will improve Mountain Plover habitat (Knowles and others, 1982; Eldridge, 1992). Grazing at heavy intensities, however, should occur in summer or late winter (Wallis and Wershler, 1981; Wershler, 1987). Wallis and Wershler (1981) recommended that long-term overgrazing should be avoided in Alberta and Saskatchewan because it may exclude Mountain Plovers. To enhance nesting habitat in Colorado, Knopf and Rupert (1999) suggested moving livestock into native pastures by early May to provide intensive, long-term grazing on grasslands adjacent to cultivated fields.

Cultivated landscapes can provide suitable habitat, but changes in cropland type may alter the suitability of fields

from one year to the next and hence represent population sinks (McConnell and others, 2009). Furthermore, cultivated fields in the northern part of the species' breeding range differ from fields in the southern part with regard to crop type, timing of cultivation, number of disturbances, and length of growing season (Shackford and others, 1999). These factors influence suitability and nest productivity of these habitats for Mountain Plovers, and more research is needed to evaluate the effectiveness of different agricultural practices in conserving populations of plovers. Some general management recommendations can be made. Knopf and Wunder (2006) recommended avoiding plowing operations of nesting areas during the breeding season. Shackford and others (1999) reported that 67 percent of 46 nests were lost to plowing operations. To minimize length of disturbance, Knopf and Rupert (1999) recommended that preparation of cropland fields for planting should be done right before planting rather than a month in advance. To control weeds between May 1 and July 15, Knopf and Rupert (1999) suggested that chemical control, rather than physical types of disturbance, should be used on fields.

Although oil and gas extraction activities may be compatible with Mountain Plover habitat needs, Ball (1996) recommended that extraction-related activities be restricted near Mountain Plover habitat during the peak breeding season (April–July), that production facilities be located in ways that minimize disturbance to plover habitat, and that travel be restricted to existing roads.

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Table E1. Measured values of vegetation structure and composition in Mountain Plover (*Charadrius montanus*) 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; <, less than; ≥, greater than or equal to; ≤, less than or equal to]

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)
Augustine and Derner, 2012 (nests)	Colorado	Shortgrass prairie	Multiple	3.9	--	--	--	--	35.9	--	--
Augustine and Derner, 2012 (foraging locations)	Colorado	Shortgrass prairie	Multiple	3.5	--	--	--	--	34.1	--	--
Ellison Manning and White, 2001 (nests)	Utah	Shrubsteppe	--	23.1	--	31.4	13.6	54.9	--	--	--
Goguen, 2012 (prairie dog towns)	New Mexico	Shortgrass prairie	Grazed	2.3	--	28.5	--	9.2	61.5	--	--
Goguen, 2012 (nests)	New Mexico	Shortgrass prairie	Grazed	1.6	--	29.5	--	3.6	66.1	--	--
Graul, 1973, 1975 (nests)	Colorado	Shortgrass prairie	Grazed	<10	--	--	--	--	--	--	--
Knopf, 1996 (nests)	Colorado	Shortgrass prairie	Multiple	--	--	68	--	--	32	--	--
Knopf and Miller, 1994	Colorado	Shortgrass prairie	Multiple	--	--	--	--	--	≥30	--	--
Knopf and Rupert, 1999 (nests)	Colorado	Shortgrass prairie	Grazed	--	--	87	--	--	9	--	--
Knopf and Rupert, 1999 (broods)	Colorado	Shortgrass prairie	Grazed	--	--	84	--	--	15	--	--
Knowles, 1996	Montana	Shortgrass prairie	Grazed	--	--	--	--	--	70	--	--
Olson, 1984; Olson and Edge, 1985 ^a (nests)	Montana	Shortgrass prairie	Grazed	4.4	--	14.5	--	--	26.9 ^b	31.8	4.4
Olson, 1984; Olson and Edge, 1985 ^a (prairie dog towns)	Montana	Shortgrass prairie	Grazed	6.4	--	14.5	--	--	42.5 ^b	24.7	6.4
Parrish and others, 1993 (nests)	Wyoming	Reclaimed short-grass prairie	Grazed	≤9	--	13.9	2.1	10.4	71.8	1.9	--
Shackford, 1991 (nests)	Oklahoma	Cropland	--	20	--	--	--	--	--	--	--
Shackford and Leslie, 1994 (nests)	Colorado, Kansas, Oklahoma	Cropland	--	<38	--	--	--	--	--	--	--
Wershler and Wallis, 1987 (nests)	Alberta	Mixed-grass prairie	Burned, grazed	--	--	--	--	--	45–50	--	--
Wershler and Wallis, 1987 (nests)	Alberta	Mixed-grass prairie	Unburned, grazed	--	--	--	--	--	15–25	--	--

^aThe sum of the percentages is greater than 100%, based on methods described by the author.

^bErosion pavement cover.

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