12-2008

Density and Abundance of Mountain Plovers in Northeastern Montana

Theresa M. Childers
Iowa State University

Stephen J. Dinsmore
Iowa State University, cootjr@iastate.edu

Density and Abundance of Mountain Plovers in Northeastern Montana

Abstract
Estimates of local abundance for declining species provide important information necessary for conservation measures. We estimated the density and abundance of Mountain Plover (*Charadrius montanus*) in Phillips and Valley counties in north-central Montana in 2004 using distance sampling methodology. Sampling efforts were stratified to include active prairie dog (*Cynomys* sp.) colonies, an Area of Critical Environmental Concern (ACEC) specifically established for Mountain Plover, and all other habitats. The density of plovers was greatest on prairie dog colonies (7.20 ± 0.42 [SE] plovers/km^2) and much lower on both the ACEC (1.60 ± 0.31 plovers/km^2), and all other habitats (0.07 ± 0.01 plovers/km^2). An estimated 1,028 (95% CI = 903–1,153) plovers inhabited this region in 2004, most (74%) on prairie dog colonies. Our results highlight the importance of prairie dog colonies to plovers in this region and suggest that as much as 10% of their continental population may breed in north-central Montana.

Disciplines
Natural Resources Management and Policy | Ornithology

Comments
This article is from *Wilson Journal of Ornithology* 120 (2008): 700, doi:10.1676/07-135.1. Posted with permission.

Density and abundance of Mountain Plovers in northeastern Montana

Author(s): Theresa M. Childers and Stephen J. Dinsmore
Source: The Wilson Journal of Ornithology, 120(4):700-707.
Published By: The Wilson Ornithological Society
DOI: http://dx.doi.org/10.1676/07-135.1
URL: http://www.bioone.org/doi/full/10.1676/07-135.1

The Wilson Journal of Ornithology 120(4):700–707, 2008

DENSITY AND ABUNDANCE OF MOUNTAIN PLOVERS IN NORTHEASTERN MONTANA

THERESA M. CHILDERS[1,2] AND STEPHEN J. DINSMORE[1,3]

ABSTRACT.—Estimates of local abundance for declining species provide important information necessary for conservation measures. We estimated the density and abundance of Mountain Plover (*Charadrius montanus*) in Phillips and Valley counties in north-central Montana in 2004 using distance sampling methodology. Sampling efforts were stratified to include active prairie dog (*Cynomys* sp.) colonies, an Area of Critical Environmental Concern (ACEC) specifically established for Mountain Plover, and all other habitats. The density of plovers was greatest on prairie dog colonies (7.20 ± 0.42 [SE] plovers/km^2) and much lower on both the ACEC (1.60 ± 0.31 plovers/km^2), and all other habitats (0.07 ± 0.01 plovers/km^2). An estimated 1,028 (95% CI = 903–1,153) plovers inhabited this region in 2004, most (74%) on prairie dog colonies. Our results highlight the importance of prairie dog colonies to plovers in this region and suggest that as much as 10% of their continental population may breed in north-central Montana. *Received 10 September 2007. Accepted 14 February 2008.*

The Mountain Plover (*Charadrius montanus*) is a declining species endemic to the western Great Plains and Colorado Plateau (Knopf 1994, Knopf and Wunder 2006). Historically, its breeding range extended from Canada south along the eastern edge of the Rocky Mountains to New Mexico and east to eastern North Dakota and south to western Texas, including a vast region of short grass prairie, denuded plains, and semi-desert areas (Bent 1929, Knopf and Wunder 2006). Breeding Bird Surveys (BBS) indicate Mountain Plover declined in the 1966–1993 period (Knopf 1996, Knopf and Wunder 2006), although there are no other continent-wide monitoring data for comparison. The Mountain Plover was proposed in 1999 for federal listing as threatened due to concerns over population decline as a result of continued critical habitat loss; listing was denied in 2003 (USDI 2003). However, Mountain Plovers are still considered a species of special concern throughout much of their breeding range (USDA 1994, USDI 2000, Brown et al. 2001) and are one of a suite of the Great Plains ecosystem indicator species that include black-footed ferret (*Mustela nigripes*) and Burrowing Owl (*Athene cunicularia*).

Concerns with continental declines of Mountain Plovers have focused monitoring efforts on estimating their abundance at breeding (Dinsmore et al. 2003, Wunder et al. 2003, Dreitz et al. 2006) and wintering (Knopf and Wunder 2006) sites. The current continental Mountain Plover population estimate is 11,000–14,000 birds (Plumb et al. 2005). Estimates of local abundance are available for key breeding sites and are usually extrapolated from density estimates. Adult density was 2.0 ± 0.46 (SE) plovers/km^2 at the Pawnee National Grasslands, Colorado from 1990 to 1994 (Knopf and Wunder 2006) and an estimated 4,850 adult Mountain Plovers occur in eastern Colorado east of the Front Range (USDI 2003). Plover density on select prairie dog colonies in Phillips County, Montana ranged from 6.80 ± 1.61 (SE) plovers/km^2 in 1991 to 1.28 ± 0.06 (SE) plovers/km^2 in 1995 with an estimated 175 breeding adult Mountain Plovers (Dinsmore 2001, Dinsmore et al. 2003). The density of adult plovers in South Park, Colorado was 7.90 ± 0.90 (SE) plovers/km^2 and an estimated 2,310 breeding adult plovers (Wunder et al. 2003). Plumb et al. (2005) estimated there were 4.47 ± 0.55 (SE) plovers/km^2 in Wyoming and a statewide adult population of 3,393 plovers. Populations in Colorado, Wyoming, and Montana combined comprise the majority of all known breeding Mountain Plovers (Knopf and Miller 1994, USDI 2003).

Estimating and monitoring local abundance of Mountain Plovers throughout their range is important because it identifies concentrations of plovers, helps focus conservation efforts, and aids land management planning by natural

[1] Department of Natural Resource Ecology and Management, 339 Science II, Iowa State University, Ames, IA 50011, USA.

[2] Current address: 24830 West Highway 50, #EC1-E, Gunnison, CO 81230, USA.

[3] Corresponding author; e-mail: cootjr@iastate.edu

resource agencies. Our objectives were to: (1) estimate Mountain Plover density and abundance in 2004 in three habitat strata in southern Phillips and Valley counties, Montana, and (2) suggest how this information can aid management and conservation planning activities to benefit Mountain Plovers.

METHODS

General Study Area.—We studied Mountain Plovers during the 2003 and 2004 breeding seasons in a 7,162-km^2 area in Phillips and Valley counties, Montana (Fig. 1). We used the 2003 breeding season to calculate sampling effort from a pilot study and identify the sampling frame, and then conducted surveys during the 2004 breeding season. Mountain Plovers in Montana primarily select active black-tailed prairie dog (*Cynomys ludovicianus*) colonies for nesting (Knowles et al. 1982, Olson and Edge 1985, Dinsmore 2001). Prairie dog colonies are one of the few remaining suitable habitat types for Mountain Plovers in Montana, and have experienced declines throughout the last century due to large-scale poisoning and sylvatic plague (Olson and Edge 1985, Knowles 1999). Other habitats inhabited by breeding plovers in Montana include areas heavily grazed by domestic sheep in central Montana, and hardpan drainages and a former bentonite mining area in Valley County (Prellwitz 1993, Knowles and Knowles 1998). Plovers are either absent or occur in low densities in Montana outside of these habitats. Our study area consisted primarily of federal lands managed by the Bureau of Land Management (BLM, Glasgow Field Station and Malta Field Office) and the U.S. Fish and Wildlife Service (USFWS, Charles M. Russell National Wildlife Refuge).

We divided the study area into three strata to facilitate surveying plovers. The strata were: (1) a Mountain Plover Area of Critical Environmental Concern (ACEC) in Valley County, (2) all active black-tailed prairie dog colonies in Phillips County (there was none in Valley County), and (3) all other habitats surrounding these strata south of U.S. Highway 2, east of Montana Highway 191, north of the Missouri River, and west of Montana Highway 24 (Fig. 1). Prior research suggested these areas were occupied by plovers at differing densities and stratification was necessary to generate valid estimates of plover abundance.

Mountain Plover ACEC.—The BLM (Glasgow Field Station) established an Area of Critical Environmental Concern in the Little Beaver Creek drainage of Valley County to protect plover breeding habitat and considers the plover a species of special concern (USDI 2000). The ACEC stratum consisted of 10,007 ha delineated by existing roads and property lines, and managed by the BLM to protect Mountain Plover breeding habitat (USDI 2000). The ACEC was comprised of two primary habitats: sparsely vegetated hardpan clay and bentonite soils in drainage bottoms, and densely vegetated gentle rises on either side of the drainages. Mountain Plovers inhabit hardpan soil valley bottoms within the ACEC, where dominant vegetation includes Nuttall's saltbush (*Atriplex nuttallii*), Sandberg bluegrass (*Poa secunda*), western wheatgrass (*Pascopyrum smithii*), plains prickly pear (*Opuntia polycantha*), wild onion (*Allium* spp.), and wild parsley (*Lomatium foeniculaceum*) (USDI 2000). Plovers also use bentonic soils dominated by knotweed (*Polygonum* spp.), Sandberg bluegrass, blue grama (*Bouteloua gracilis*), and western wheatgrass. Gentle rises on either side of valley bottoms are dominated by wild buckwheat (*Polygonum convolvulus*), horizontal juniper (*Juniperus communis*), basin big sagebrush (*Artemisia tridentata tridentata*), and western wheatgrass and are generally not used by Mountain Plovers.

Prairie Dog Colonies.—Breeding Mountain Plovers in north-central Montana are known to selectively inhabit prairie dog colonies and are thought to be restricted to these sites in Phillips County (Knowles et al. 1982, Olson 1984, Dinsmore 2000). Our prairie dog colony stratum consisted of 334 active black-tailed prairie dog colonies ranging from <1 to 308 ha in size comprising a total of 10,515 ha in 2002 (the most recent year colonies were surveyed; J. J. Grensten, pers. comm.). Dominant vegetation in this stratum included fringed sagewort (*Artemisia frigida*), buffalograss (*Buchloe dactyloides*), club moss (*Selaginella densa*), plains prickly pear, blue grama, needle-and-thread grass (*Stipa comata*), and Sandberg bluegrass.

Other Habitats.—All habitat types sur-

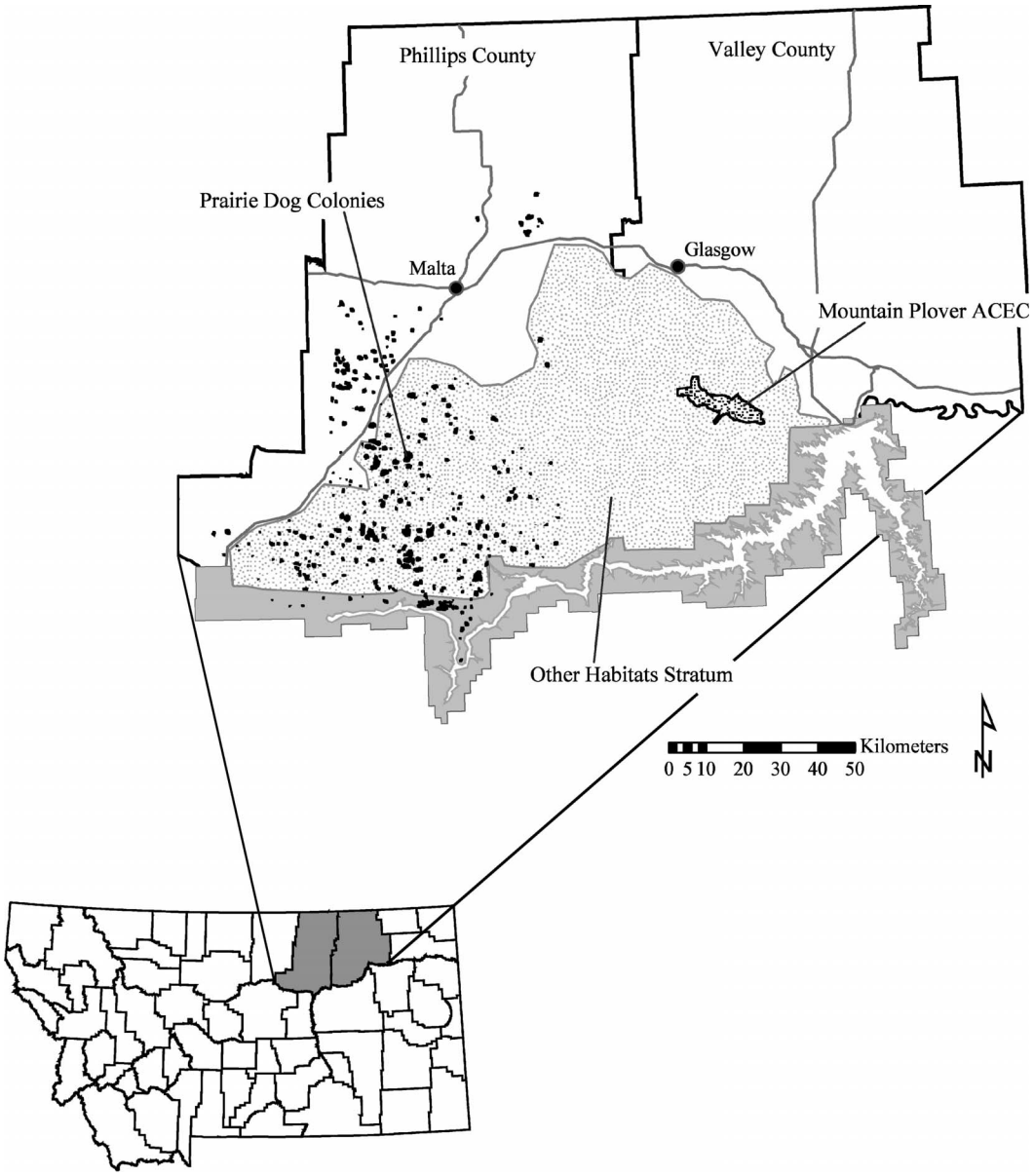

FIG. 1. Phillips and Valley counties, Montana showing strata where breeding Mountain Plovers were surveyed during the 2004 nesting season. The three strata consisted of the Mountain Plover Area of Critical Environmental Concern (ACEC) in Valley County (dark gray stippling), active black-tailed prairie dog colonies in Phillips County (black areas), and all other habitats surrounding the prairie dog colony and ACEC strata (light gray stippling).

rounding the prairie dog colony and ACEC strata in southern Phillips and Valley counties were included in the 'other habitats stratum' (716,241 ha). We sampled all habitats in this stratum and made no attempt to partition the sample based on suitable habitat because: (1) we did not have access to GIS information with sufficient detail to identify suitable plover habitat, and (2) logistical constraints prevented us from mapping suitable habitat in the

field during this study. Our purpose for sampling this region was to provide baseline information about Mountain Plover density outside the other two strata. The other habitats strata varied in topography from the rolling Larb Hills to relatively flat open rangeland. Vegetation was generally taller and denser compared to that of the other two strata, but comprised of the same species. Small areas of habitat similar to those in the ACEC were scattered throughout both counties.

Statistical Analyses.—We used radial distance point count surveys (Buckland et al. 2001) to sample Mountain Plovers in each of the three strata. We used data from pilot studies to calculate a suitable sample of points given a 15% desired coefficient of variation (CV). Distance sampling encounter rates from the 1991–2000 breeding seasons (SJD, unpubl. data) for the prairie dog colony stratum were used to calculate a suitable survey sample ($n = 105$ points). We conducted randomly located point count surveys in early May 2004 in the ACEC stratum and used the resulting encounter rates to delimit the survey sample for the ACEC ($n = 110$ points).

The number of sample points in the other habitats strata was chosen to be logistically feasible and to provide baseline evidence regarding plover density. We knew this stratum supported a low density of Mountain Plovers, based on personal observation and consultation with regional biologists, and concluded that an excessive number of sample points was needed to generate a precise abundance estimate. Generating a plover abundance estimate with reliable precision was not possible in this stratum given time, personnel, and logistical constraints. However, we believed it was necessary to provide some evidence regarding Mountain Plover density in the other habitats stratum. A generally recommended sample size for areas with relatively good probability of detection of animals is 40 (Buckland et al. 2001). We believed probability of detecting plovers was low to moderate in this stratum due to shrub cover and rolling topography. We chose to survey slightly more ($n = 50$ points) than the recommended number of sample points to provide evidence, rather than a precise estimate, of Mountain Plover density for this stratum.

We overlaid a 500 × 500 m grid with a random starting point on the ACEC and other habitats strata, and randomly selected grid center point coordinates for survey points. We chose survey points differently for the prairie dog stratum because of how colonies were distributed on the landscape. The borders of all colonies were mapped in 2002 with GPS units by the BLM (Malta Field Office). We selected colonies at random with replacement, assigned survey points proportional to colony size, and spaced points equidistant within a colony if it included >1 point.

One observer (TMC) visited all points in the ACEC (mid-May through mid-Jun) and other habitats strata (mid-Jun through early Jul) while a second observer (SJD) visited all points on prairie dog colonies (mid-May through early Jun) to minimize observer bias. Timing of all surveys coincided with the nesting season in Montana (Dinsmore et al. 2002) but we visited the ACEC and other habitats strata at slightly different seasons for logistical reasons. Individual points were located on the ground using a Garmin Explorer V GPS unit and were approached by vehicle. Plovers actively avoid a person on foot but appear to ignore vehicles (pers. obs.). We minimized violation of the assumption that there was no avoidance behavior by approaching survey points in a vehicle. All surveys were conducted during daylight hours (0500 to 1200 hrs MDT) during standardized weather conditions (0–24 km/hr wind speed, no precipitation, and temperature <27° C). Surveys were conducted in the early portion of the breeding season to ensure that only breeding adults were included, and there were no problems with post-breeding dispersal. We visited each point for 5 min, surveyed for plovers using 10 × 40 binoculars, and measured the distance (m) to each Mountain Plover using a NewCon Optic LRM 1500 laser rangefinder. All measurements were exact and we used actual distances rather than placing observations into distance groups. Observations were treated as statistically independent events, which is reasonable given that 43% of sightings were of a single bird.

We used Program DISTANCE (Version 3.5; Thomas et al. 1998) to model detection rates of plovers and calculate stratum-specific density estimates. We considered the four robust models best suited for detection functions sug-

TABLE 1. Model selection results from Program DISTANCE, and density ($\hat{D}$; birds/km^2) and abundance ($\hat{N}$) estimates for Mountain Plovers on the Area of Critical Environmental Concern (ACEC) and active black-tailed prairie dog colonies in north-central Montana, 2004.

Model, expansion	AIC	ΔAIC	$\hat{D}$	$\hat{N}$	CV
ACEC					
Uniform, cosine[a]	658.76	0.00	1.60	160	24%
Half-normal, hermite	666.74	7.98			
Uniform, simple polynomial	751.16	92.40			
Hazard rate, cosine	777.27	118.51			
Prairie dog colonies					
Hazard rate, cosine[b]	3792.75	0.00	7.20	758	6%
Half-normal, hermite	3796.22	3.47			
Uniform, simple polynomial	3870.75	78.00			
Uniform, cosine	17,453.01	13,660.26			

[a] Four cosine expansion terms.
[b] Zero cosine expansion terms.

gested by Buckland et al. (2001:155): (1) uniform key function with a cosine expansion, (2) uniform key function with a simple polynomial expansion, (3) half-normal key function with a hermite expansion, and (4) hazard rate key function with a cosine expansion. All models exhibit properties that meet the distance sampling assumption that probability of detection of an animal declines with increasing distance from the point. Model fit was assessed using the Chi-square goodness-of-fit test in Program DISTANCE. We used AIC model selection (Burnham and Anderson 2002) to select the best approximating model for each stratum.

There were insufficient plover detections (1 detection in 50 point surveys) in the other habitats stratum, and density and abundance estimates were calculated using the ACEC detection function. We chose this approach for three reasons: (1) we wanted to generate an estimate of abundance for this stratum for planning purposes and were unable to entirely ignore the small sample size; (2) both the ACEC and other habitats strata surveys were conducted with the same observer, and pooling these data into a single detection function seemed reasonable; and (3) portions of these two regions had similar habitat types, making them more similar than the other habitats stratum was to the prairie dog colony stratum.

Abundance.—Plover density estimates in the prairie dog colony and ACEC strata were multiplied by their known areas to calculate stratum-specific estimates of Mountain Plover abundance. We estimated plover abundance differently for the other habitats stratum. Rather than estimate abundance for all habitats in this stratum, we chose to focus only on suitable habitat. We used previously classified (shrub, non-shrub, bare ground, and water) Landsat 7 (14 May 2003, path 37, rows 26 and 27) satellite imagery to identify potential Mountain Plover habitat. We considered potential Mountain Plover habitat at this scale to consist of either non-shrub or bare ground patches. Olson-Edge and Edge (1987) observed that Mountain Plovers in Montana select prairie dog colonies >6 ha in size. Thus, we restricted potential habitat by selecting patches >6 ha (area = 157,573 ha). The vegetation structure of non-shrub patches could not be calculated from satellite images, and not all of the area identified actually contained suitable plover nesting habitat. We estimated that 22% (157,573 ha) of this stratum contained suitable Mountain Plover habitat based on these criteria.

RESULTS

Model Selection and Detection Function.—The best model selected for the ACEC was a uniform key function with a cosine expansion and for the prairie dog colony stratum it was the hazard rate key function with a cosine expansion (Table 1); no other models were considered competing ($\Delta AIC < 2$). Both of these models fit the data well ($P > 0.15$). We were unable to develop a detection function for the

other habitats stratum due to the low detection rate (1 detection in 50 points).

Density and Abundance Estimates.—The density of Mountain Plovers was greater in the prairie dog colony stratum ($\hat{D}$ = 7.20 plovers/km^2, 95% CI = 0.064–0.082, 6.41% CV) than in the ACEC stratum ($\hat{D}$ = 1.60 plovers/km^2, 95% CI = 0.010–0.025, 24.03% CV). The majority (74%) of the Mountain Plovers within the study area occurred in the prairie dog colony stratum ($\hat{N}$ = 758, 95% CI = 668–860) with smaller numbers in the ACEC ($\hat{N}$ = 160, 95% CI = 100–285). The density of Mountain Plovers in the other habitats stratum was two orders of magnitude less than the density in the other two strata ($\hat{D}$ = 0.07 plovers/km^2, 95% CI = 0.0005–0.0010, 16.54% CV). An optimistic estimate of Mountain Plover abundance in this stratum was relatively low for such a large area ($\hat{N}$ = 110, 95% CI = 78–154).

DISCUSSION

We estimated Mountain Plover density in three habitats in north-central Montana. The density estimate for the prairie dog colony stratum had good precision (6.41% CV) due to robustness of the data used to generate the detection function. The precision of the ACEC density estimate was less than expected (24% CV vs. a desired 15% CV) and may have resulted because suitable habitat occurred in small and unevenly distributed patches. The density of Mountain Plovers in the other habitats stratum was thought to be low prior to this survey, and an infeasible number of point counts would have been necessary to produce an estimate with good precision. Our result for this stratum should be interpreted with caution.

Sampling issues caused us to make key assumptions about plover detection rates and suitable plover habitat in the other habitats strata. The ACEC and other habitats strata shared some habitat characteristics, e.g., densely vegetated low ridges interspersed with irregular patches of suitable Mountain Plover habitat. Thus, the calculated density for the other habitats stratum appeared to realistically represent Mountain Plover density in regions similar to the ACEC. The scale and frequency of suitable habitat patches varied between strata, and we corrected for an inflated abundance estimate in the other habitats stratum by constricting the inferential space to only the area of potential plover habitat. It is unlikely that all identified potential plover habitat (22%, or 157,573 ha) is actually suitable for nesting.

There are few rigorous estimates of Mountain Plover abundance in Montana. A specific sampling protocol has been used on a portion of prairie dog colonies in southern Phillips County (Dinsmore 2001), but our study presents the first formal sample of Mountain Plover density and abundance throughout a significant proportion of its northeastern Montana breeding range. Mountain Plover density in the prairie dog stratum was much greater than densities reported for grasslands in Colorado (2.0 ± 0.46 birds/km^2 to 4.7 ± 1.20 birds/km^2; Knopf and Wunder 2006), and for grasslands (5.17 ± 1.06 birds/km^2) and shrub-steppe habitats (4.23 ± 0.67 birds/km^2) in Wyoming (Plumb et al. 2005). Our density estimates were similar to those reported from Phillips County in the early 1990s (SJD, pers. obs.), despite an outbreak of sylvatic plague in the mid-1990s that decimated prairie dogs (and affected plover habitat) throughout this region (Dinsmore et al. 2005). The majority of Mountain Plovers currently breeding in southern Phillips and Valley counties (74%) inhabit active black-tailed prairie dog colonies. The strong link between plovers and prairie dogs in Montana (Dinsmore et al. 2005), which is not as prevalent elsewhere in the plover's range suggests that size and mosaic of suitable plover habitat patches may be more dynamic in short-grass prairie habitats at other sites. Other forms of disturbance such as fire and grazing by ungulates creates suitable plover nesting habitat in areas where prairie dogs do not constantly maintain low vegetation.

Our investigation of Mountain Plover abundance outside prairie dog colonies and ACEC strata partially confirms biologists' contention that the other habitats stratum is mostly uninhabited by plovers. An optimistic estimate of plover abundance in all potential nesting habitat within the other habitats stratum is 110 plovers, which may comprise up to 10% of the breeding population in southern Phillips and Valley counties.

Our study revealed that plovers breeding

near the northern limit of their range in Montana constitute a significant proportion of this species' overall population and should remain a conservation priority. The total population estimate of Mountain Plovers in southern Phillips and Valley counties was 1,028 adults (95% CI = 903–1,153, 6.18% CV), or less than 10% of the estimated 11–14,000 Mountain Plovers in North America (USDI 2003, Plumb et al. 2005). Most inhabit active prairie dog colonies in Phillips County. With removal of large-scale grazers and increased fire control, sites maintained by prairie dog activities and unproductive soils have become the only suitable areas available to breeding Mountain Plovers in much of Montana.

CONSERVATION IMPLICATIONS

Our study provides critical baseline information about plover density and occurrence in Phillips and Valley counties in north-central Montana, but more investigation of plovers in this region is needed. Patches of breeding habitat outside of the prairie dog colony and ACEC strata should be identified and sampled more intensively to gain a more precise estimate of plover abundance. Our investigation of the other habitats stratum suggests it may support up to 10% of the Mountain Plover population in Phillips and Valley counties. Much of the suitable plover habitat in this stratum appears to be near the ACEC, suggesting that Mountain Plovers may benefit from an expansion of the ACEC. Mountain Plover abundance within the prairie dog colony and ACEC strata should be monitored at regular intervals. Plovers in both of these regions represent important contributions to the continental population, are considered indicators of the health of their respective habitats (Dinsmore 2000), and should continue to be the focus of local monitoring efforts and management.

Regional population estimates of breeding Mountain Plovers contribute useful information for conservation planning at both the regional and continental levels. Recently, researchers have estimated abundance of Mountain Plovers in South Park, Colorado (Wunder et al. 2003), eastern Colorado (Tipton 2007), and in Wyoming (Plumb et al. 2005). These estimates, combined with information from other breeding populations, suggest the continental population of Mountain Plovers is greater than previously believed (Plumb et al. 2005, Knopf and Wunder 2006). The previous continental population estimate based on samples of wintering plovers was 5,000–10,000 individuals; Plumb et al. (2005) suggests a revised population estimate of 11,000–14,000 individuals.

The ACEC and active prairie dog colonies provide nesting habitat for the majority of Mountain Plovers in north-central Montana. Local managers should continue to (1) protect the ACEC and active prairie dog colonies on public lands from major human disturbances, such as mining, during the plover breeding season, and (2) monitor the size and health of suitable plover habitat in each region (hardpan flats in Valley County and active prairie dog colonies in Phillips County).

ACKNOWLEDGMENTS

We thank the U.S Bureau of Land Management (Glasgow Field Office) for funding this study. David Waller, John Carlson, John Fahlgren, and many other staff from the Glasgow Field Office provided field assistance. J. J. Grensten and C. T. Wilcox helped with fieldwork in Phillips County and M. D. Smith provided assistance with GIS work.

LITERATURE CITED

BENT, A. C. 1929. Life histories of North American shorebirds. U.S. National Museum Bulletin 146: 263–269.

BROWN, S., C. HICKEY, B. HARRINGTON, AND R. GILL (Editors). 2001. The U.S. Shorebird Conservation Plan. Second Edition. Manomet Center for Conservation Sciences, Manomet, Massachusetts, USA.

BUCKLAND, S. T., D. R. ANDERSON, K. P. BURNHAM, J. L. LAAKE, D. L. BORCHERS, AND L. THOMAS. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press, Oxford, United Kingdom.

BURNHAM, K. P. AND D. R. ANDERSON. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second Edition. Springer-Verlag, New York, USA.

DINSMORE, S. J. 2000. Mountain Plover. Pages 213–218 *in* Endangered animals: a reference guide to conflicting issues (R. P. Reading and B. Miller, Editors). Greenwood Press, Westport, Connecticut, USA.

DINSMORE, S. J. 2001. Population biology of Mountain Plovers in southern Phillips County, Montana. Dissertation. Colorado State University, Fort Collins, USA.

DINSMORE, S. J., G. C. WHITE, AND F. L. KNOPF. 2002.

Advanced techniques for modeling avian nest survival. Ecology 83:3476–3488.

DINSMORE, S. J., G. C. WHITE, AND F. L. KNOPF. 2003. Annual survival and population estimates of Mountain Plovers in southern Phillips County, Montana. Ecological Applications 13:1013–1026.

DINSMORE, S. J., G. C. WHITE, AND F. L. KNOPF. 2005. Mountain Plover population responses to black-tailed prairie dogs in Montana. Journal of Wildlife Management 69:1546–1553.

DREITZ, V. J., P. M. LUKACS, AND F. L. KNOPF. 2006. Monitoring low density avian populations: an example using Mountain Plovers. Condor 108:700–706.

KNOPF, F. L. 1994. Avian assemblages on altered grasslands. Studies in Avian Biology 15:247–257.

KNOPF, F. L. 1996. Prairie legacies—birds. Pages 135–148 *in* Prairie conservation: preserving North America's most endangered ecosystem (F. B. Samson and F. L. Knopf, Editors). Island Press, Covelo, California, USA.

KNOPF, F. L. AND B. J. MILLER. 1994. *Charadrius montanus*—montane, grassland, or bare-ground plover? Auk 111:504–506.

KNOPF, F. L. AND M. B. WUNDER. 2006. Mountain Plover (*Charadrius montanus*). The birds of North America. Number 211.

KNOWLES, C. J. 1999. Selective use of black-tailed prairie dog colonies by Mountain Plovers—a second look. USDI, Bureau of Land Management, Malta Field Office, Malta, Montana, USA.

KNOWLES, C. J. AND P. R. KNOWLES. 1998. The historic and current status of the Mountain Plover in Montana. USDI, Bureau of Land Management, Malta Field Office, Malta, Montana, USA.

KNOWLES, C. J., S. P. STONER, AND S. P. GIEB. 1982. Selective use of black-tailed prairie dog towns by Mountain Plovers. Condor 84:71–74.

OLSON, S. L. 1984. Density and distribution, nest site selection, and activity of the Mountain Plover on the Charles M. Russell National Wildlife Refuge. Thesis. Montana State University, Bozeman, USA.

OLSON, S. L. AND D. EDGE. 1985. Nest site selection by Mountain Plovers in north central Montana. Journal of Range Management 38:280–282.

OLSON-EDGE, S. L. AND W. D. EDGE. 1987. Density and distribution of the Mountain Plover on the Charles M. Russell National Wildlife Refuge. Prairie Naturalist 19:233–238.

PLUMB, R. E., F. L. KNOPF, AND S. H. ANDERSON. 2005. Minimum population size of Mountain Plovers breeding in Wyoming. Wilson Bulletin 117:15–22.

PRELLWITZ, D. M. 1993. Additional Mountain Plover sightings in Montana. Prairie Naturalist 25:23–26.

THOMAS, L., J. L. LAAKE, J. F. DERRY, S. T. BUCKLAND, D. L. BORCHERS, D. R. ANDERSON, K. P. BURNHAM, S. STRINDBERG, S. L. HEDLEY, M. L. BURT, F. F. C. MARQUES, J. H. POLLARD, AND R. M. FEWSTER. 1998. Distance 3.5. Release 6. Research Unit for Wildlife Population Assessment, University of St. Andrews, St. Andrews, United Kingdom.

TIPTON, H. C. 2007. Occupancy, abundance, and density of Colorado breeding grassland birds: estimation and habitat correlations. Thesis. Colorado State University, Fort Collins, USA.

U.S. DEPARTMENT OF AGRICULTURE (USDA). 1994. Final environmental impact statement for management strategy for Mountain Plover. USDA, Forest Service, Pawnee National Grasslands, Greeley, Colorado, USA.

U.S. DEPARTMENT OF INTERIOR (USDI). 2000. Bitter Creek and Mountain Plover areas of critical environmental concern plan amendment and environmental assessment. MT-096-99-04. USDI, Bureau of Land Management, Glasgow Field Station, Glasgow, Montana, USA.

U.S. DEPARTMENT OF THE INTERIOR (USDI). 2003. Endangered and threatened wildlife and plants: withdrawal of the proposed rule to list the Mountain Plover as threatened. Federal Register 68:53083–53101.

WUNDER, M. B., F. L. KNOPF, AND C. A. PAGUE. 2003. The high-elevation population of Mountain Plovers in Colorado. Condor 105:654–662.