Mountain Plover (*Charadrius montanus*): A Technical Conservation Assessment

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COVER PHOTO CREDIT

Mountain plover (*Charadrius montanus*). Photo taken by author.

Summary of Key Components for Conservation of the Mountain Plover

The mountain plover (*Charadrius montanus*) is a local and declining bird throughout its range. It was proposed for listing under the Endangered Species Act by the U.S. Fish and Wildlife Service in 1999, but was withdrawn in 2003. The mountain plover is one of a small number of endemic Great Plains birds, and its status may be one indicator of the health of this ecosystem. Mountain plovers nest locally in the western Great Plains from Montana south to New Mexico, in Utah, and in Mexico, and they winter in a broad band from Texas west and north to the Central Valley of California. The mountain plover has an interesting life-history strategy that includes multiple clutches per pair, moderate fidelity to nesting sites, and relatively low adult annual survival. The current continental population is thought to number between 8,000 and 10,000 birds, and the best data available suggest they are experiencing a significant long-term decline. This decline may be the result of a loss of nesting habitat, habitat alterations due to the loss of primary grazers, and a possible reproductive sink created by plovers nesting on agricultural lands. Several threats, particularly the loss of nesting habitat and threats to prairie dogs, are the focus of broader conservation efforts in the Great Plains that will benefit the plover and a host of other species. The conservation of mountain plovers hinges on the protection of high quality nesting habitat, the conservation of prairie dogs, and the use of proactive plover management with fire, rotational grazing, and protection of known nesting sites.

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Introduction

This assessment is one of many being produced to support the Species Conservation Project for the U.S. Forest Service (USFS), Rocky Mountain Region (**Figure 1**). The mountain plover (*Charadrius montanus*) is the focus of an assessment because it is a sensitive species in the Rocky Mountain Region (Region 2) and a Management Indicator Species (MIS) on three forests in the region. Within the National Forest system, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of a significant current or predicted downward trend in abundance or in habitat capability that would reduce its distribution (FSM 2670.5(19)). A sensitive species may require special management, so knowledge of its biology and ecology is critical. A MIS serves as a barometer for species viability at the Forest level and has two functions: 1) to estimate the effects of planning alternatives on fish and wildlife populations (36 CFR 219.19 (a) (1)); and 2) to monitor the effects of management activities on species via changes in population trends (36 CFR 219.19 (a) (6)).

This assessment addresses the biology of the mountain plover throughout its range but focuses on Region 2. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed

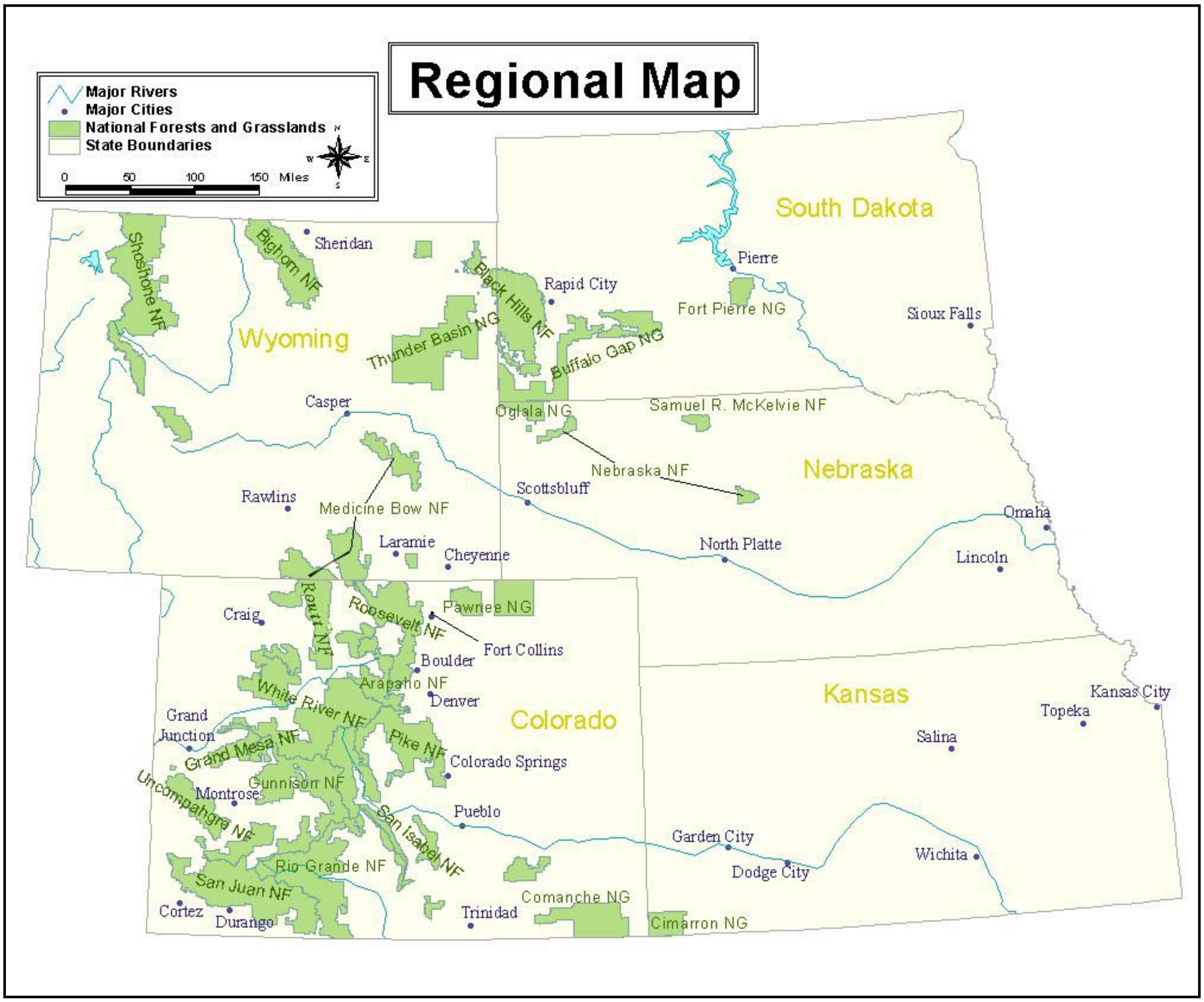

Figure 1. Map showing the boundaries of the U.S. Forest Service, Rocky Mountain Region and the lands they administer.

to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations but provides the ecological background upon which management must be based. However, it does focus on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere and, when management recommendations have been implemented, the assessment examines the success of the implementation.

Scope

This mountain plover assessment examines the biology, ecology, conservation status, and management of this species with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although some of the literature on this species originated from field investigations outside this region, this document places that literature in the ecological and social contexts of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of mountain plovers in the context of the current habitat rather than under historical conditions. The evolutionary habitat occupied by this species is considered in conducting the synthesis, but placed in a current context.

In producing this assessment, I reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies, and I initiated direct contacts with researchers. Not all publications on mountain plover are referenced in the assessment, nor was all published material considered equally reliable. The assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications or reports were regarded with greater skepticism. I chose to use some non-refereed literature in the assessment, however, when information was unavailable elsewhere. Unpublished data (e.g., annual research reports) were important in estimating geographic distribution and provided the only information on some aspects of mountain plover ecology. These data required special attention because of the diversity of persons and methods used to collect these data and because of proprietary rights.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and observations limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, strong inference, as described by Platt, suggests that experiments will produce clean results (Hilborn and Mangel 1997), as may be observed in certain physical sciences. Chamberlain (1897) suggested an alternative approach to science where multiple competing hypotheses are confronted with observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools (experiments, modeling, logical inference). Ecological science is, in some ways, more similar to geology than physics because of the difficulty conducting critical experiments and the reliance on observation, inference, good thinking, and models to guide understanding of the world (Hilborn and Mangel 1997).

Confronting uncertainty, then, is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted and alternative explanations described when appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observation, and inference are accepted as sound approaches to understanding.

Publication of Assessment on the World Wide Web

To facilitate use of species assessments in the Species Conservation Project, assessments are being published on the Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, it facilitates revision of the assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer-reviewed prior to release on the Web. This report was reviewed through a process administered by the Society for Conservation Biology which chose two recognized experts to provide critical input on the manuscript. Peer review was designed to improve the quality of communication and increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

The mountain plover is a North American shorebird of high conservation concern. It is a localized breeding bird of the western Great Plains, where it is considered one of 12 endemic birds (Mengel 1970). The mountain plover is classified as a sensitive species in Region 2 by the USFS, and it is a MIS on the Arapaho and Roosevelt national forests and the Pawnee National Grassland (U.S. Forest Service 1994a). In 1999, the mountain plover was proposed for listing as a threatened species under the Endangered Species Act by the U.S. Fish and Wildlife Service (USFWS; (U.S. Department of the Interior 1999a). Higher priority listings precluded further action, until several groups submitted a 60-day Notice of Intent to sue the Secretary of the Department of the Interior for failure to comply with legal deadlines established under the Act for completing listing actions. In response, USFWS re-examined the case. On September 9, 2003, the agency published a notice in the Federal Register (60 FR 53083) withdrawing its proposed rule to list the mountain plover as a threatened species (U.S. Department of the Interior 2003). Following further review and examination of new data, USFWS determined that the mountain plover was not warranted for federal listing because threats to the species were "not as significant as earlier believed". Mountain plovers are designated High Priority on the Partners in Flight WatchList (score = 26 High Priority, National Audubon Society 2001).

The mountain plover receives special management attention in some of the Region 2 states. It is a species of Special Concern in Colorado (Colorado Division of Wildlife 2001), a Species in Need of Conservation in Kansas (Collins et al. 1995), and a Threatened species in Nebraska (Nebraska Game and Parks Commission 2002). This species receives no special protection in Wyoming and is extirpated in South Dakota (South Dakota Ornithologists' Union 1991).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

As described later in this assessment, the major threats to mountain plovers are the loss of primary nesting habitat, a reduction in the number of native grazers, a possible reproductive sink for birds nesting on agricultural lands, and the alteration of vegetative characteristics on remaining native landscapes that makes them less suitable for plovers. From a management perspective, little has been done to counter the negative effects of these factors, so existing regulatory mechanisms are limited and, in some cases, inadequate for mountain plovers.

There are few existing regulatory mechanisms that specifically protect mountain plovers, and those that do, address issues related to providing nesting habitat and reducing disturbance during the nesting season. Mountain plovers receive full protection under the U.S. Migratory Bird Treaty Act and subsequent amendments (see U.S. Department of the Interior 1999a for a complete summary of these laws). More locally, the USFS has implemented a mountain plover management strategy on the Pawnee National Grassland in Colorado (U.S. Forest Service 1994a, 1994b); similar regulations protect plovers on U.S. Bureau of Land Management (BLM) lands in this same area (U.S. Department of Interior 1994). The Pawnee National Grassland in Colorado also has a plan for late winter/early spring burns on its lands to provide high quality nesting habitat for plovers. This burn plan was initiated in 1997, and USFS burned four sections (1,024 ha; allocation of the area burned has varied between years) in 2002 (U.S. Forest Service 2002). These plans include provisions to use grazing to improve nesting habitat, to protect nesting plovers between 10 April and 10 July, to actively manage prairie dog colonies, and to restrict oil and gas development during the plover nesting season. The USFS and the BLM also have enacted broader plans to protect known plover nesting areas between 1 April and 30 June in Colorado, Wyoming, and Utah (U.S. Department of the Interior 1999a). These dates were chosen to accommodate the courtship, nesting, and fledging periods for most plovers nesting in these areas. In addition to these management actions, there was an unsuccessful attempt to re-introduce mountain plovers in Wallace County, Kansas in 1982 (Ptacek and Schwilling 1983). There are no known regulatory mechanisms that specifically protect mountain plovers during migration or on their wintering grounds.

The impact of these existing regulations on mountain plovers in Region 2 is not fully understood and has not been formally studied or monitored. On the Pawnee National Grassland plovers readily respond to burns and use them for nesting (F. L. Knopf personal communication 2002), although there is not yet sufficient information to suggest whether the burns are beneficial to plovers. The effects of the mountain plover Management Strategy on nesting plovers on the Pawnee National Grassland have not been specifically addressed, and the overall effectiveness of this plan is unknown.

There are currently no detailed plans for managing mountain plovers on either their nesting or wintering grounds. Such plans would include clearly stated objectives (i.e., a target number of nesting adults), management actions that are based on the results of sound scientific studies (i.e., burns for nesting areas), and a formal means of evaluating the results of these actions (i.e., carefully designed monitoring surveys). There are, however, regional plans that specifically include the mountain plover as a key Great Plains species. The Nature Conservancy, under the Prairie Wings initiative, specifically targets land acquisitions that have the potential for supporting nesting and wintering mountain plovers.

Biology and Ecology

Systematics and species description: The mountain plover is a medium-sized plover of the Order Charadriiformes and Family Charadriidae (**Figure 2**). Its closest relatives, the Caspian plover (*Charadrius asiaticus*) and Eurasian dotteral (*Eudromias morinellus*), occur in the Old World. Mean mass (± SD) of adult plovers was 107.1 ± 8.2 g (*n* = 431; SJD, unpublished data) during the nesting season in Montana and 95.1 ± 6.5 (*n* = 26 males) and 96.4 ± 8.7 (*n* = 13 females) in California during winter (Knopf 1996a). Like most plovers, the plumage is drab (see Knopf 1996a for a more detailed description). Alternate plumage, acquired by early March and retained through at least late June (later at more northerly latitudes), is typified by a black crown patch of variable extent, a white supercilium, and variable buff or orange-buff color on the mantle, upper breast, and flanks. Basic plumage, acquired as early as mid-June and retained through late February, is similar to alternate plumage but the head pattern is less distinct and there is no buff color on the body. Juvenile plumage, acquired at about 33 days of age (Knopf 1996a) and held through early spring, is typified by bright orange-buff color on the head, neck, mantle, and upper breast, and an indistinct head pattern.

Mountain plovers are monomorphic, both sexes have similar plumage, and the sexes can be reliably distinguished only by observing courtship activities (Knopf 1996a) or with the use of molecular techniques (Dinsmore 2001). However, there are subtle plumage differences between the sexes. Males generally have a brighter plumage with a more striking head pattern and brighter buff or golden color on the head and mantle.

There is little geographic variation in mountain plovers. Preliminary molecular research across the breeding range of the mountain plover found considerable mixing between populations and high genetic variability within populations (S. Oyler-McCance, personal communication 2002). This could indicate that the North American population, at least in those areas sampled for genetic study, behaves as a single unit.

Distribution and abundance

Mountain plovers breed primarily in eastern Colorado, central Wyoming, and eastern Montana (Knopf 1996a) and more locally in northern Mexico (state of Nuevo León; Knopf and Rupert 1999b, Desmond and Ramirez 2002), Texas (Davis Mountains), northeastern New Mexico (Hubbard 1978, Sager 1996), western Oklahoma (primarily the Panhandle; Shackford 1991), southwestern Kansas (primarily Morton County; Fellows and Gress 1999), southwestern Nebraska (Kimball County; Dinsmore 1997), northeastern Utah (Myton Bench area; Day 1994, Ellison-Manning and White 2001a), Arizona (U.S. Department of the Interior 1999a), and southeastern Alberta (Wallis and Wershler 1981, Knopf 1996a) (**Figure 3**). Their abundance varies within their range, although these widely separated breeding sites share several key habitat features (see Habitat section). They are common nowhere, but probably reach their greatest abundance in the central portions of the breeding range in eastern Colorado and Wyoming. They are scarce on the periphery of their breeding range, especially in Mexico, Texas, Utah, and Alberta. Northeastern Colorado, and especially Weld County, has long been considered the center of the mountain plover breeding range (Graul and Webster 1976) although other areas of Colorado (especially South Park and southeastern Colorado) may currently have greater numbers of nesting mountain plovers (Carter et al. 1996, Kingery 1998). Detailed studies to estimate abundance within portions of Region 2 (Colorado and Wyoming) are on-going and preliminary estimates are not yet available (F. L. Knopf and M. B. Wunder, personal communication, 2002). In terms of total numbers,

Figure 2. Adult mountain plover on the breeding grounds in Phillips County, Montana (June 2003). Photo by Stephen J. Dinsmore.

recent surveys suggest that the South Park region in Park County, Colorado may have the greatest number of nesting plovers (Carter et al. 1996, Wunder et al., in prep.). The highest densities of nesting plovers occur on prairie dog colonies in Montana, where densities range from 0.20 plovers per km^2 (Knowles et al. 1982) to 0.28 plovers per km^2 (Olsen-Edge and Edge 1987) at selected sites. Because of limited habitat, however, the total number of nesting plovers at these locations is low.

The historic breeding distribution of mountain plovers extended eastward from their present range to include central Kansas, western Nebraska, extreme western South Dakota, possibly southwestern North Dakota, and southwestern Saskatchewan (Knopf 1996a). This was a region of vast prairies that was frequently disturbed by fire and primary grazers, such as prairie dogs (*Cynomys* spp.) and bison (*Bison bison*). This mosaic of disturbed prairies was apparently favored by plovers and was their preferred nesting habitat. The greatest change in their breeding distribution, in addition to the westward contraction noted above, has been the degree to which the present breeding range has become fragmented. Areas of native prairie now occur

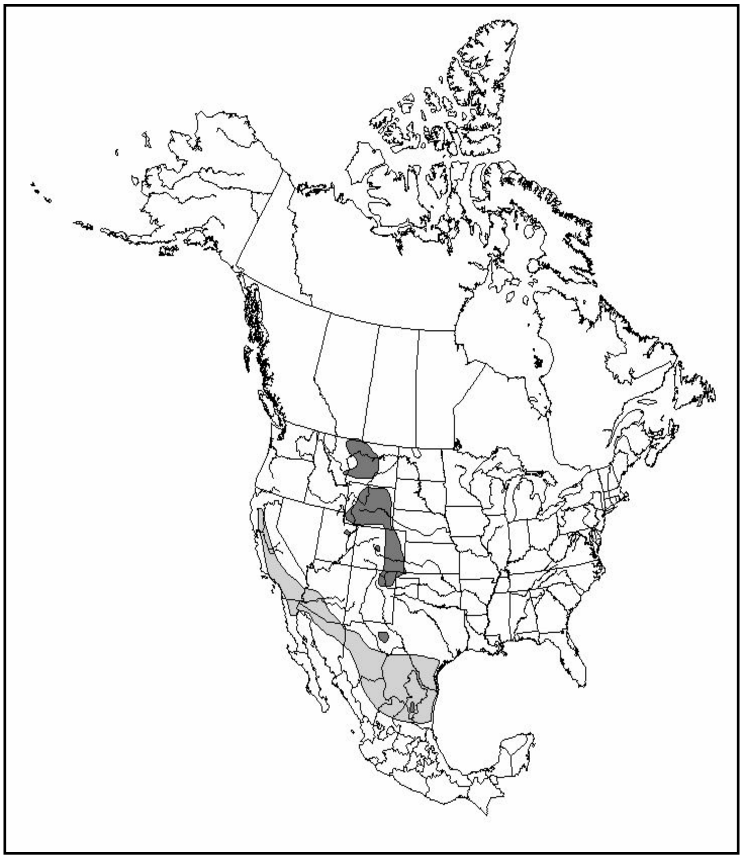

Figure 3. Breeding and wintering distribution of the mountain plover. The breeding range is in dark gray (note the isolated breeding population in Mexico) and the wintering area is shown in light gray. Breeding is localized within this range and the limits of the wintering range are approximate and reflect some uncertainty about their actual distribution at this season.

in patches of variable size throughout the former range of the plover, and the pattern of natural disturbance of this habitat is reduced. Fire suppression, the loss of bison, and the conversion of land for agriculture have all resulted in a fragmented landscape for the plover.

Mountain plovers have a localized distribution within their present breeding range compared to their more widespread historical distribution. In the northern reaches of their range, suitable nesting habitat is scarce and they are extremely localized, occurring primarily in areas with black-tailed prairie dogs (*Cynomys ludovicianus*; Dinsmore 2000). In the southern reaches of their breeding range, the suitable habitat is more abundant and they breed at low densities over a much larger area, although there are still "hotspots" for nesting such as the Pawnee National Grassland and South Park.

The mountain plover is a short-distance migrant and its wintering range is broad, extending from the Central Valley of California south through the Imperial Valley, then eastward across northern Mexico and southern Texas (Howell and Webb 1995, Knopf 1996a). Smaller numbers regularly over-winter in southern Arizona and central Texas. Most plovers are thought to winter in the Imperial Valley in southern California, which may represent a southward shift in range from previously occupied areas in the Central Valley (Wunder and Knopf 2003). They formerly wintered more widely in coastal California, especially the Los Angeles area, but they no longer occur there (Small 1994). The distribution and relative abundance of wintering plovers is well understood from widespread surveys targeting this species, and it is unlikely that any major wintering areas remain undiscovered. A few plovers from Region 2 have been found in winter in southern California, but it is not known if this is the primary wintering locale for these birds.

The degree to which various populations of breeding mountain plovers are isolated is unknown. The molecular evidence discussed earlier (S. Oyler-McCance personal communication 2002) supports interchanges between these populations, so some dispersal occurs. Mountain plovers are short-distance migrants, but they are capable of relatively longer movements so physical barriers to dispersal appear minimal. Yet, they show a limited ability to occupy new breeding areas, especially in the northern part of their range. For example, the enormous prairie dog colonies in southwestern South Dakota are unoccupied (South Dakota Ornithologists' Union 1991), and several prairie dog colonies restored in the late 1990s in southwestern Saskatchewan, less than 150 kilometers from plover nesting areas in Montana, are also unoccupied. There are no records of plovers from the South Dakota colonies, but a single plover was seen at the Saskatchewan site in May 2000. Both of these regions may have been occupied by plovers historically, although specific records to document this are lacking.

Population trend

There is limited evidence, most of it anecdotal, supporting a long-term decline in numbers of mountain plovers. Several late nineteenth century reports noted that large numbers of mountain plovers were killed for food in the Great Plains, and they were especially numerous in Wyoming and Colorado around the turn of the century (see Knopf 1996a). These reports suggest that this species was generally widespread and rather common historically. Given that plovers were more widespread and abundant historically, the current range contraction provides additional support for a concurrent decline in abundance.

Early anecdotal reports provide some indication of their former abundance, but information about the magnitude of population changes to the present day is lacking. It was not until the 1970s that they were studied in detail, and rigorous information on population trends was not available until the 1990s. Early attempts to make inference about total numbers of plovers were highly speculative. Graul and Webster (1976) estimated a minimum continental population of 214,200 plovers in 1976, but this estimate was too high; it was calculated using densities from the Pawnee National Grassland and those densities are among the highest range-wide. Over most of their range, plovers occur in very low densities, so Graul and Webster's estimate of the total number of plovers was grossly inflated. Knopf (1996a) estimated a continental population of between 8,000 and 10,000 plovers in 1996 by combining best "guesstimates" from major breeding areas and a single-day count on the wintering grounds. In addition, there have been several attempts to count local numbers of mountain plovers. A preliminary estimate, using distance sampling, of the number of mountain plovers nesting in the South Park region of Colorado was 2,200 birds (95 percent CI is 1,768, 2,772; Wunder et al., in prep.). In the Imperial Valley, Imperial County, California, winter surveys found 3,346 plovers during a 1-day count in January 1994 (Knopf 1996a) and 4,037 plovers during an 11-day count in January 2001 (Wunder and Knopf 2003). Wintering grounds surveys such as these may not suffice for monitoring because not all mountain plovers winter in the Imperial Valley and trends in these counts may not be correlated with continental population trends. Thus, the degree of uncertainty in such counts is high, and they probably provide a poor index of continental population trends unless the spatial distribution of wintering plovers is better known.

There have been only four formal attempts to monitor population trends of mountain plovers as follows:

1. **North America.** Breeding Bird Survey (BBS) data for several time periods have been analyzed for trends in mountain plover numbers. Knopf (1994) reported a 3.7 percent annual decline for the period 1966 to 1993, which translated into a 63 percent decline in plover numbers continentally during this period (Knopf 1996a). This overall decline is computed as $1 - [(1 - 0.037)^{27}] = 0.63$. More recent analyses of BBS data have reported the following trends: a 2.7 percent (*P*=0.02, significant at *a*=0.05) annual decline for the period 1966 to 1996 (Sauer et al. 1997), a 1.2 percent (*P*=0.54, not significant at *a*=0.05) annual decline for the period 1966 to 1998 (Sauer et al. 1999), a 0.9 percent (*P*=0.64, not significant at a=0.05) annual decline for the period 1966 to 1999 (Sauer et al. 2001), and a 1.2 percent (*P*=0.51, not significant at *a*=0.05) annual decline for the period 1966 to 2000 (Sauer et al. 2001). The BBS is a road-based survey run annually, typically in June (Peterjohn 1994). Routes follow a stratified random sampling design within specific habitat strata throughout the U.S. Each route is 24.5 miles in length and includes 50 stops spaced 0.5 mile apart. The observer pauses at each stop for 3 minutes and records all birds seen or heard within 0.5 mile. The many sources of bias associated with the BBS (roadside nature of the survey, huge numbers of observers, failure to estimate detection probabilities, differences in weather, etc.) have led to

considerable discussion regarding the value of the population trends they estimate (Link and Sauer 1998, O'Connor et al. 2000). The variability in the trends for mountain plovers, and the fact that a 27-year significant negative trend became non-significant with the addition of one year of data, illustrates the tenuous nature of BBS trends for some species. Sadly, this is the only dataset with decent coverage of most of the plover's breeding range. Thus, the degree of uncertainty in trends detected using BBS data is moderate at best, and these trends should be interpreted with caution if they are used.

2. **U.S. Fish and Wildlife Service Region 6.** This region includes all of the USFS Region 2, plus Montana, North Dakota, and Utah and is the closest representation to a Region 2 mountain plover trend analysis. Breeding Bird Survey data for the period 1966 to 2000 indicate a 0.48 percent annual increase (P=0.92, not significant at a=0.05) in mountain plover numbers (Sauer et al. 2001). These data are subject to the same cautionary statements listed in number 1 above.

3. **Pawnee National Grassland, Weld County, Colorado.** Since 1990, Fritz L. Knopf has conducted an annual plover survey on the Pawnee National Grassland in Weld County, Colorado. This is a road-based survey, run during the last 10 days of June, and it consists of 112 point counts to detect plovers throughout the grassland. The point counts employ distance-sampling theory (Buckland et al. 2001), which is used to estimate an annual density of plovers in the study area. The density of plovers in this area was high through 1994 and then crashed with few plovers detected since then (F. L. Knopf personal communication 2002). Distance-sampling theory is sound and well developed, and since all surveys were conducted by the same observer there is no observer bias. A source of potential bias is the road-based nature of this survey, but this is minimized by the secondary nature of these roads. Thus, the degree of uncertainty with this survey is low. This is also the only formal monitoring attempt for mountain plovers within Region 2.

4. **Southern Phillips County, Montana.** For the period 1995 to 2000, annual population trends of mountain plover in a portion of southern Phillips County were estimated using capture-recapture data. During this period, mountain plovers declined from 1995 to 1996, presumably as a result of concurrent declines in black-tailed prairie dogs. Populations then steadily increased through 1999 and stabilized (Dinsmore et al. 2003). This nesting population numbers about 175 adults and has fluctuated in response to changes in the area occupied by black-tailed prairie dogs (Dinsmore 2001). These trends were estimated using extensive capture-recapture data and Pradel lambda models (Pradel 1996); temporary emigration was incorporated into the estimates. This study did not violate any of the model assumptions and conditional capture probabilities were >0.9, so the degree of certainty in these trends is high and these estimates should be considered reliable.

Except for the surveys on the Pawnee National Grassland, noted above, there is no information to assess fine scale patterns of abundance for mountain plovers within Region 2. Numbers at specific sites fluctuate temporally, although such fluctuations appear to be small, based on observational studies. Mountain plovers do not appear to exhibit the classical cyclical patterns of some organisms, and their numbers are best considered relatively constant through time in areas not impacted by any major threats (see Threats section).

Activity pattern

The mountain plover is a migratory bird that undergoes an annual, short distance migration between its northern breeding grounds and wintering grounds farther south. Most birds depart the wintering grounds between mid-February and early March (Knopf and Rupert 1995, Knopf 1996a). Arrival dates on the breeding grounds vary latitudinally with northbound plovers arriving in southeastern Colorado during the first or second week of March (Knopf 1996a), in northeastern Colorado by mid- to late March (Graul 1975, Knopf and Rupert 1996), in Wyoming by late March to early April, and in north-central Montana by early April (J. J. Grensten personal communication 2002.). Departure from the breeding grounds also varies latitudinally with southbound plovers exiting north-central Montana by late September (J. J. Grensten personal communication 2002), Wyoming (SJD Personal observation) and northeastern Colorado by mid-October (Knopf and Rupert 1996), and southeastern Colorado by late October (Andrews and Righter 1992). In Montana, adult plovers will often return to the same or an adjacent prairie dog colony to nest in subsequent years (SJD, unpublished data). The specific dispersal patterns of juvenile plovers are unknown, although some return to nest in the same region where they were banded (SJD, unpublished data).

Migration routes of the mountain plover are poorly understood. Departure from the California wintering grounds is nearly complete by early March (Knopf 1996a), and most plovers are thought to fly non-stop from there to their nesting areas (Knopf and Rupert 1995). Arrival on the nesting grounds ranges from early March in southern Colorado to early April in Montana. There is some indication that migrant plovers may stage along the Lower Colorado River Valley and in southeastern Colorado (Knopf 1996a), although the frequency and extent of this pattern are unknown. A plover color-banded in Montana was resighted in southeastern Colorado in early April and had returned to its Montana nesting grounds by mid-May (SJD, unpublished data).

Little is known about seasonal movements. Within Region 2, there is a noticeable exodus of breeding birds from the Pawnee National Grassland in late summer, usually by mid-July (Knopf and Rupert 1996). Concurrent with this exodus, the number of plovers in southeastern Colorado, especially Baca County, increases as large post-breeding flocks form on agricultural lands (Knopf 1996a). Whether this pattern represents a seasonal shift in their local distribution (e.g., the flocks are local nesting plovers) or results from larger regional movements (e.g., post-breeding migrants from northeastern Colorado and possibly other areas) is unknown. Other nesting areas appear to be occupied by plovers for the duration of the nesting season (see dates above), and there do not appear to be any extended stops during migration.

There is no evidence supporting sex-specific differences in migration patterns, although this is hampered by an inability to readily sex plovers in the field. Similarly, there is no evidence supporting age differences in migration patterns. In Montana, post-breeding flocks comprised of adults and juveniles are present across the entire migration window in fall with no obvious age-related patterns (J. J. Grensten personal communication 2002). However, such patterns have not been formally studied.

It is unknown if mountain plovers exhibit a meta-population pattern or instead occur as a patchy population in an environment where they formerly occurred as a large, connected population. Dispersal in plovers has not been studied. As stated earlier, mountain plovers are physically capable of dispersing to new habitats, but a tendency to remain faithful to nesting areas could limit their dispersal capabilities (see later section on Site fidelity).

Habitat

Mountain plovers are a disturbed-prairie or semidesert species rather than a grassland species (Knopf and Miller 1994), and they are often characterized as a breeding bird of high plains and desert tablelands (Graul 1975, Knopf 1996a, 1996b). They prefer disturbed habitats for nesting, including areas formerly occupied by bison (Knopf 1996a) and prairie dogs (Knowles et al. 1982, Samson and Knopf 1994, Knopf 1996a) and agricultural fields (Knopf and Rupert 1999a, Shackford et al. 1999).

Breeding habitat

Most members of the Charadriidae, including the mountain plover, are associated with areas of disturbance for nesting. Disturbance, like fire or grazing, seems necessary to meet the specific habitat requirements of the plover, and may provide secondary benefits such as increased food resources. Areas used for nesting include four broad habitat associations as follows:

1. **Native short- and mixed-grass prairie (<u>Figure 4</u> and <u>Figure 5</u>).** This is one of the principle nesting habitats for mountain plovers and occurs mainly in the southern reaches of their range, especially in eastern Colorado, where they are often associated with prairies dominated by blue grama (*Bouteloua gracilis*; Knopf and Miller 1994). In this region, plovers prefer sites that are heavily grazed by cattle (Graul 1975, Graul and Webster 1976, Knopf and Miller 1994) and sheep (Knowles and Knowles 1993), although they will use ungrazed sites.

2. **Semi-desert sites.** On the western periphery of their range, primarily in Utah and western Wyoming, plovers also nest in semi-desert habitats on high tablelands, generally in areas dominated by saltbush (*Atriplex* spp.) and sagebrush (*Artemisia* spp.) (Parrish et al. 1993, Day 1994, Ellison-Manning and White

Figure 4. Typical mountain plover habitat on the Pawnee National Grassland in Weld County, Colorado (June 1991). Photo by Stephen J. Dinsmore.

Figure 5. Typical mountain plover habitat in the South Park area in Park County, Colorado (June 2000). Photo by Michael B. Wunder.

2001a). In Utah, plovers nest at very low densities in shrub-steppe habitats with taller vegetation, usually in areas also occupied by white-tailed prairie dogs (*Cynomys leucurus*) (Ellison-Manning and White 2001a). Semi-desert sites occupied by plovers contain taller vegetation than occupied sites in other parts of their range, although plovers always select nest sites with shorter vegetation than the surrounding landscape.

3. **Prairie dog colonies (Figure 6).** Throughout their range, mountain plovers selectively nest on active prairie dog colonies, especially those of black-tailed prairie dogs (Knowles et al. 1982, Olsen-Edge and Edge 1987, Dinsmore 2001), but also occasionally those of the white-tailed prairie dog (Ellison-Manning and White 2001a). The black-tailed prairie dog has experienced precipitous declines in the last century, mostly due to poisoning and sylvatic plague (Knowles 1999). As part of recent conservation efforts, several Great Plains states initiated comprehensive inventories of active prairie dog colonies (see Van Pelt 1999). The most recent estimates of active prairie dog colony areas for states comprising Region 2 include 86,870 ha in 2000 in Colorado (EDAW 2000), 146,674 ha in 1998 in Wyoming (Van Pelt 1999), 98,996 ha in 1998 in South Dakota (Van Pelt 1999), 32,955 (SE = 7,247) ha in 1999 in Nebraska (Nebraska Game and Parks Commission 2001), and 18,843 ha in a 1990 to 1992 survey in Kansas (Vanderhoof and Robel 1994). In each of these states, the current estimates represent a small fraction of what existed historically; although the exact magnitude of the decline is unknown (see Van Pelt 1999). Data for these estimates come from a wide range of sources (actual mapping with Global Positioning System units, measurements from aerial photos, estimated areas from surveys) and with unknown accuracy, so these represent minimum estimates of the surface area occupied by prairie dogs at the time of the survey. Furthermore, the total area occupied by prairie dogs may not be the best characterization of plover habitat because habitat quality may vary among colonies. Detailed information on

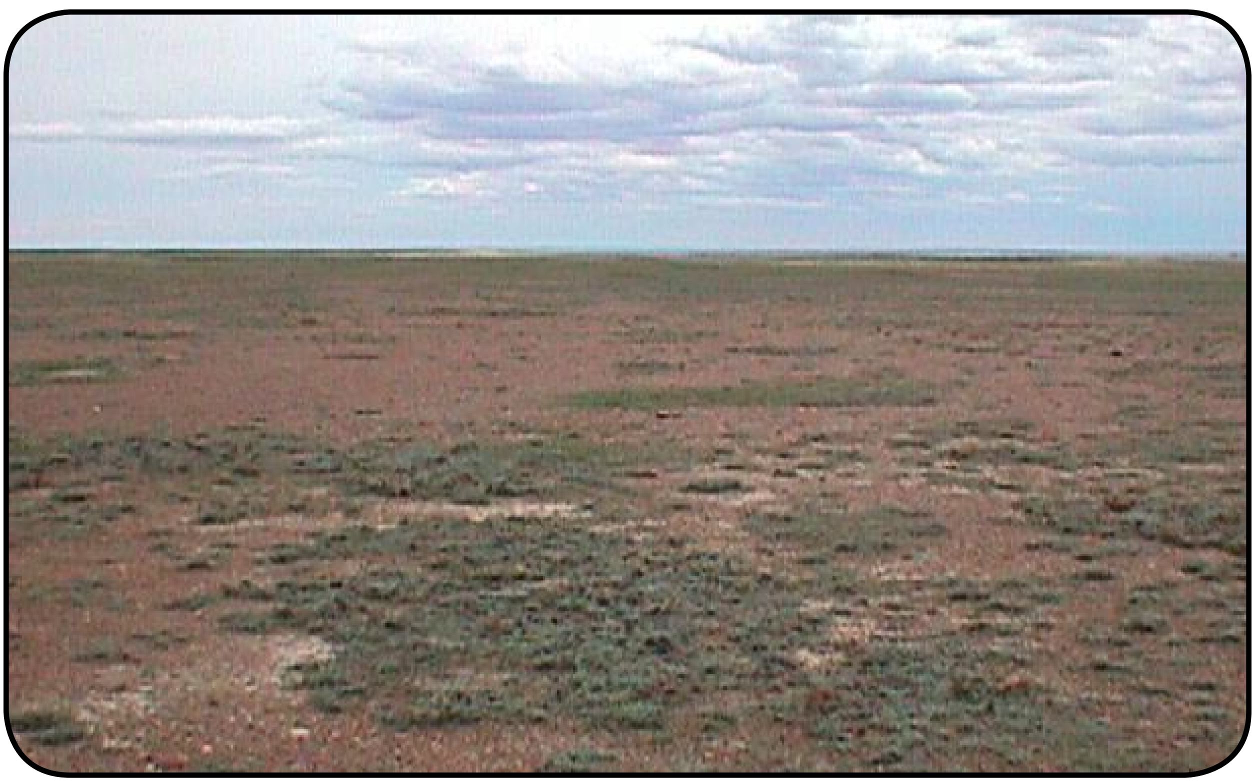

Figure 6. A black-tailed prairie dog colony used by mountain plovers in southern Phillips County, Montana (June 1999). Photo by Stephen J. Dinsmore.

the relationship between plovers and prairie dogs is limited to studies in Phillips County, Montana where plovers selectively nest on black-tailed prairie dog colonies (Knowles et al. 1982, Knowles and Knowles 1984, Olson and Edge 1985, Dinsmore 2001). Olson (1984) reported that 98 percent of all plover sightings were on prairie dog colonies, and mountain plovers in Montana selected mid-sized prairie dog colonies between 6 and 50 ha in size (Olson-Edge and Edge 1987). In Montana, some plovers continue to use inactive prairie dog colonies, although colony suitability for plovers varies and often lasts <2 years (SJD, unpublished data).

4. **Agricultural lands (Figure 7).** Mountain plovers are widespread breeders on agricultural lands in the southern part of their range from essentially the Colorado-Wyoming border southward (Shackford 1991, Shackford et al. 1999, Knopf and Rupert 1999a). They do not appear to use these habitats as frequently in the northern part of their range, perhaps because of the shorter growing season and more frequent disturbance to nest sites (Shackford et al. 1999). Although plovers are known to use fields planted to a variety of crops, they are most often noted in fallow wheat fields. Fields used for nesting are typically fallow, although they will nest in fields planted in wheat, milo, and corn (Shackford et al. 1999). Shackford et al. (1999) located 52 nests in agricultural fields; 50 percent were in fallow fields and another 38 percent were in wheat fields.

Regardless of the nesting habitat used, specific nesting sites share several general microhabitat characteristics. Mountain plovers select nest sites that include short vegetation (typically <5 cm; Graul 1975, Olsen and Edge 1985, Parrish et al. 1993, Ellison-Manning and White 2001b), a bare-ground component (typically >30 percent; Knopf and Miller 1994), some history of disturbance (e.g., grazing or fire; Olsen and Edge 1985, Day 1994, Knopf 1996a, Ellison-Manning and White 2001a), and flat or gently sloping landscapes (Graul 1975). Soil type is not known to be a factor in nest-site selection. Nesting habitat selection or preference at scales larger than the nest-site is not thoroughly understood, although plovers do appear to

Figure 7. A fallow agricultural field used by nesting mountain plovers in Baca County, Colorado (June 1991). Photo by Stephen J. Dinsmore.

select prairie dog colonies and other disturbed sites and generally prefer areas that share the key habitat features listed above.

Winter habitat

On the wintering grounds in California, plovers prefer native grasslands to agricultural fields, and within native grasslands they show a preference for burned areas and alkali flats (Knopf and Rupert 1995). In favored wintering areas in California, plovers spend about 75 percent of their time using plowed agricultural fields (Knopf and Rupert 1995), perhaps because native habitats are scarce. Knopf (1996a) notes that plovers wintering in California and Texas have used Bermuda grass fields and grazed and burned agricultural fields. Wunder and Knopf (2003) studied winter habitat use of mountain plovers in the Imperial Valley of California. They found that most plovers were seen in idle fields or in alfalfa fields (71 percent of all observations) with less use of wheat fields and burns. Furthermore, plovers used only grazed or sprouting alfalfa fields and avoided fields with vegetation taller than 20 cm (Wunder and Knopf 2003). The specific microhabitat used by wintering plovers within these broad habitats is unknown. Wunder and Knopf (2003) concluded that grazed alfalfa fields and fields that were burned after harvest were both critical to plovers wintering in the Imperial Valley. Because this is thought to be the primary wintering site for this species, activities in this region can substantially impact the entire mountain plover population.

Broad-scale habitat associations

The general habitat associations of mountain plovers range-wide are reasonably well known, but the importance of habitat juxtaposition is still unknown. Minimum-area requirements for plover broods are 28 ha, as measured during the fledgling period in Colorado (Knopf and Rupert 1996). Little is known of space requirements for adult plovers. The territories of three males nesting in Colorado averaged 16 ha during a portion of the nesting period (Graul 1973a). In Montana, the nest and brood always occupy a single prairie dog colony (SJD, unpublished data). The area of a colony occupied by a plover or its brood can vary from a few to more than 100 hectares (SJD, unpublished data). This suggests that area requirements on prairie dog colonies differ from those in other areas. Daily space requirements for broods and adults are unknown.

The plover's ability to occupy a wide range of habitat associations, which share several key features (e.g., bare ground component, disturbance, etc.), makes it difficult to predict broad-scale habitat associations. Habitat availability for mountain plovers range-wide cannot be reliably assessed at this time. Current spatial technologies can estimate the area of several habitat types used by plovers, but availability must also be measured at much finer scales. For example, plovers are known to selectively use active prairie dog colonies throughout much of their breeding range (Knowles et al. 1982, Olsen-Edge and Edge 1987, Dinsmore 2001). Total colony area can be reasonably estimated, although the fraction of the colonies on the landscape that plovers will actually use cannot be predicted.

The optimal spatial arrangement(s) of disjunct areas of suitable plover nesting habitat have not been studied. While it may be possible to identify *potential* plover habitat, there is still no information available to make firm predictions about *how* individual patches of habitat should be arranged spatially to benefit the plover. Future studies of plovers using prairie dog colonies may provide insight into how the size and arrangement of colonies influences occupancy by nesting plovers. This, in turn, will provide some information about broad-scale habitat use by plovers, although information from other habitats is still needed.

Site fidelity

Information on site fidelity is limited to a single study in Montana, which documented that many adult plovers returned to nest on the same or a nearby prairie dog colony in subsequent nesting seasons (Dinsmore 2001). Thus, at least in this part of their breeding range, mountain plovers exhibit moderate site faithfulness among years. Little is known about the factors influencing site fidelity in this species, although males may exhibit greater fidelity than females to nesting areas in Montana (SJD, unpublished data). It is not known if a pair bond lasts more than a single breeding season.

Food habits

The mountain plover is insectivorous, although its specific food habits have been studied very little. They feed on ground-dwelling invertebrates, primarily beetles (Coleoptera), grasshoppers and crickets (Orthoptera), and ants (Hymenoptera) (Stoner 1941, Baldwin 1971, Knopf 1996a, Knopf 1998). Baldwin (1971) studied their diet on the nesting grounds in Colorado and found that 99.7 percent of the food items were arthropods (60 percent Coleoptera, 25 percent Orthoptera, and 6 percent Hymenoptera). Plovers wintering in California also foraged primarily on arthropods (Knopf 1998), although different orders dominated the diet at each site where they were collected. Age-specific differences in diet are not known, and chicks tend to capture slightly smaller prey (Knopf 1996a).

Typical foraging behavior involves short runs of 1 m or more in search of insects (Knopf 1996a). Once a prey item is spotted, the bird makes a quick run to capture the prey; they do not capture prey in flight. Most foraging occurs in the early morning, presumably because prey is more sluggish as a result of cooler temperatures (Knopf 1996a).

To date, the limited work on food habits has only investigated their principal diet and proportions of major items found therein. Olsen (1985) noted that the principle food items taken by the mountain plover were more abundant on active prairie dog colonies in Montana than off colonies. There is no information to assess geographic or temporal differences in diet, or to draw conclusions about food preferences. Dietary flexibility has been demonstrated and the breadth of their diet (Knopf 1998) may indicate an ability to forage on specific items during periods of local abundance and an ability to rapidly shift to other food items when necessary. This would seem to suggest that plovers might respond quickly to insect irruptions such as the periodic grasshopper irruptions in the Great Plains. The energetic value of various food items taken by plovers is unknown.

Breeding biology

The breeding biology of mountain plovers has been studied extensively, especially in northeastern Colorado (Graul 1975, Miller and Knopf 1993, Knopf and Rupert 1996). They are generally considered monogamous (Knopf 1996a). Their mating system has been described as rapid multiple-clutch where females lay two clutches, the first incubated by the male and the second by the female, with a single adult plover tending each nest (Graul 1973a). Graul (1976) speculated this was a response to variable food resources with some females laying more than two clutches in good years. Current research suggests that multiple clutches are normal, and there is increasing evidence that polyandry may occur (SJD, unpublished data). Graul (1973a) documented one instance of polyandry; this is the only documented occurrence of polyandry in this species.

The spacing behavior of mountain plovers has been studied very little. Graul (1973a) reported a mean territory size of 16 ha during the nesting season in Colorado. In Montana, where nesting habitat is limited, territories may be smaller but have not been measured. Nesting plovers exhibit some clumping on prairie dog colonies (SJD, unpublished data), but this may be the result of limited nesting habitat rather than a social behavior. Clumping has not been noted in other habitats used for nesting.

Mountain plovers initiate nesting by mid-April in the southern reaches of the breeding range, and by early May farther north. Small numbers of nests are regularly initiated into late June, and exceptional nests may be initiated well into July. Many late nesting attempts represent re-nesting efforts. Dinsmore et al. (2002) found no sex-specific differences in observed or expected mean nest initiation dates (includes all nesting attempts) for a study of mountain plovers in Montana; observed dates (31 May for females and 2 June for males) did not differ from expected dates (27 May for females and 26 May for males). Expected nest initiation dates were computed using a model of daily nest survival and calculating the date a nest would have been initiated, given that it survived to be discovered. Most mountain plovers are thought to breed at age one (Graul 1973a), and color banding work in Montana has documented large numbers of plovers nesting at this age (SJD, unpublished data).

Courtship activities were described in detail by Graul (1973a) and consist of at least three specific displays. The pair-bond forms >18 days before copulation (Graul 1973a), so courtship is lengthy. The timing of courtship activity, coupled with the fact that each sex incubates a single nest, suggests that any monitoring should be timed to avoid peak incubation periods when most adults will be incubating nests (see Management of the Mountain Plover in Region 2).

The nest consists of a simple scrape on the ground, lined with lichen, club moss, gravel, bits of dried cow manure, and other items (**Figure 8**; Knopf 1996a). Clutch size is normally three eggs (range 1 to 6 eggs; Knopf 1996a, Dinsmore and Knopf 1999). Reported clutch sizes (mean ± SD) are 2.9 ± 0.4 (n = 152; Graul 1975) and 2.9 ± 0.3 (n = 108; Knopf 1996a), both in northeastern Colorado. The incubation period lasts an average of 29 days (range 28 to 31 days; Graul 1975).

Nest success of mountain plovers varies geographically and temporally. Most published information comes from long-term studies in Colorado, although there are also estimates from Wyoming and Montana. Published apparent nest success estimates (the proportion of a sample of nests that hatched) from the Pawnee National Grassland include 65 percent (n=80; Graul 1975), 48 percent (n=21; Graul 1975), 45 percent in 1983 (n=23; McCaffery et al. 1984), 50 percent in

Figure 8. Mountain plover nest on a prairie dog colony in Phillips County, Montana (June 2003). Photo by Stephen J. Dinsmore.

1992 (*n*=14; Miller and Knopf 1993), 26 percent in 1993 (*n*=34; Knopf and Rupert 1996), and 37 percent in 1994 (*n*=54; Knopf and Rupert 1996). Interpretation of apparent nesting success estimates is difficult; they can overestimate true nesting success because nests that are lost early in incubation are likely to be underrepresented in the sample (Mayfield 1961). Potential biases in estimates of nesting success can be addressed by calculating daily nest survival estimates and then using a product of these estimates to calculate total nesting success. Dinsmore et al. (2002) modeled the daily nest survival rates of 432 mountain plover nests in Montana and estimated that 49 percent of male-tended nests hatched, compared to only 33 percent of female-tended nests. They also found that daily nest survival increased with the age of the nest, was unaffected by maximum daily temperature, and was negatively affected by daily precipitation. Clutch and brood sizes do not show any obvious geographic variation, although variation resulting from differences in local weather conditions and predator community dynamics occurs.

The hatching period varies latitudinally with a peak in early to mid-June in Colorado (Knopf 1996a) and in mid- to late June in Montana (Dinsmore 2001). The young leave the nest within three hours of hatching (Graul 1973b) and fledge at approximately 33 to 36 days of age (Graul 1975, Miller and Knopf 1993). The young are precocial and receive limited care from the parent. Uniparental care of the brood is typical, although biparental care may occasionally result when broods are split (Knopf 1996a). Chicks can feed on their own within a few hours of hatching (Graul 1973b). Chicks disperse from the nest site rapidly after hatching, sometimes up to 2 km in the first 2 to 3 days (Knopf 1996a) with average daily movements >300 m (Knopf and Rupert 1996). Brood rearing home ranges in Colorado averaged 56.6 ha (SE = 21.5, range 28 to 91 ha; Knopf and Rupert 1996). In Montana, broods reared on prairie dog colonies do not disperse to other colonies (SJD, unpublished data), but dispersal has not been investigated for plovers nesting on prairie dog colonies elsewhere. The mobility of the chicks minimizes potential disturbance of the brood, although undisturbed brood-rearing areas may be preferred.

Little work has been done on the post-hatching survival of mountain plovers. Knopf and Rupert (1996) reported a fledging rate of 0.26 chicks per nesting attempt on the Pawnee National Grassland. After accounting for post-fledging predation, 0.17 (Knopf and Rupert 1996) to 0.70 (Miller and Knopf 1993) chicks per nesting attempt left the breeding grounds.

Demography

Basic life-history summary

Demographic information is only available for a single population of mountain plovers in Montana; no detailed information is available for plovers nesting in Region 2. All known demographic data are summarized in **Table 1**. There have been few attempts to estimate survival rates of mountain plovers. Annual survival rates have been estimated only in Montana; information on seasonal variation in survival is scarce but is available from both the breeding and wintering grounds. Annual survival rates for plovers in Montana were 0.48 (SE = 0.07) for juveniles (from about age 10 days to age 1) and 0.68 (SE = 0.03) for adults (Dinsmore et al. 2003). The survival of 24 adult plovers during the nesting season (14 May to 28 July) was 100 percent in northeastern Colorado (Miller and Knopf 1993). The over winter (1 November to 15 March) survival rate of 44 adult plovers in California was 0.95 (Knopf and Rupert 1995). These are the only estimates of survival for the species. Knopf (1996a) reported a maximum known age to band recovery of 6 years and 7 days, but a male in Montana reached the age of 9 years (SJD, unpublished data). The estimated mean life span of a mountain plover in southern Phillips County, Montana was 1.92 years (SE = 0.19) (Dinsmore et al. 2003) and is estimated for birds of about 10 days of age. Specific ecological factors influencing survival have not been studied and are unknown.

The only estimates of emigration rates are from Montana, where annual emigration rates were 0.24 (SE = 0.06) for juvenile plovers and 0.22 (SE = 0.04) for adult plovers (Dinsmore et al. 2003). Nearly half of all emigrants returned in a subsequent year, and it is possible that some plovers never actually left and simply went undetected. Thus, the probability of emigration for mountain plovers was low, and about half of all emigrants eventually returned to the study area. Dispersal of juvenile mountain plovers is probably low. During a 6-year color banding study in Montana (Dinsmore 2001), 246 juvenile plovers were individually color-banded. Of this total, 41 returned to the study area and nested during a subsequent nesting season, two were found nesting at Fort Belknap Indian Reservation in adjacent Blaine County, Montana (approximately 75 km distant), and one was seen on

Table 1. Summary of demographic parameters for the mountain plover.

Parameter	Estimate	Reference
Proportion of females on nests	Unknown	
Proportion of males on nests	Unknown	
Re-nesting rate	Unknown	
Fecundity	Unknown	
Eggs per clutch	2.90	SJD, unpublished data
Hatching rate of eggs	Unknown	
Fledging rate (chicks per nest)	0.26	Knopf and Rupert (1996)
Fledgling survival rate	Unknown	
Juvenile annual survival rate	0.48	Dinsmore et al. (2003)
Adult annual survival rate	0.68	Dinsmore et al. (2003)
Adult survival rate during breeding season	1.00	Miller and Knopf (1993)
Over-winter survival rate	0.95	Knopf and Rupert (1995)
Juvenile emigration rate	0.24	Dinsmore et al. (2003)
Adult emigration rate	0.22	Dinsmore et al. (2003)
Mean lifespan (years)	1.92	Dinsmore et al. (2003)
Longevity record (years)	9	SJD, unpublished data

the wintering grounds in Imperial County, California 3 years after banding (but was never again seen on the breeding grounds) (SJD, unpublished data). No plovers were found nesting in other states despite extensive surveys in some of those areas, especially the Pawnee National Grassland and the South Park region in Colorado. There are no known instances of an adult plover nesting in two widely separated locales, although adults have moved up to 40 km between nesting sites in Montana (SJD, unpublished data).

Most mountain plovers are thought to breed at age 1, and this is supported by color banding data from Montana and because few unmated plovers are seen on the breeding grounds. The proportion of the population nesting in a given year is unknown, but is assumed to be high because sightings of plovers away from the breeding grounds during the nesting season are rare, and most plovers seen on the breeding grounds are engaged in courtship or nesting activity.

The possible genetic consequences for small populations of mountain plovers have not been addressed. Hybridization is extremely rare in Charadriidae and is unknown in mountain plovers. There is, however, a record of a mountain plover placing eggs in a killdeer (*Charadrius vociferus*) nest (Jojola-Elverum and Giesen 2000), the only indication of inter-specific encounters.

The specific factors limiting population growth in mountain plovers are unknown, although there is widespread agreement (Knopf 1996a, Dinsmore 2000) that the loss of quality nesting habitat is a major factor. However, there is no information to assess whether habitat loss or other factors (e.g., food, predation, competition, etc.) differentially affect populations of plovers.

Life cycle

A generalized life cycle diagram (Gotelli 1998, Caswell 2001) for mountain plovers includes the juvenile and adult life stages (**Figure 9**). However, the only demographic study measured annual survival of juveniles (from hatching to age 1) and adults (any annual rate after age 1). Thus, the plover may instead have three age classes: juveniles, 1 year-olds, and adults >2 years of age. The lack of an estimate of fecundity is a major gap in our knowledge of the plover, and this is further hampered by the unusual mating system of this species. However, some females are known to lay two clutches of three eggs annually.

The meta-population dynamics of populations of plovers within and outside of Region 2 are unknown. Source-sink dynamics are also unknown, although it has been suggested that agricultural landscapes may represent a population sink for this species (Knopf and Rupert 1999a, U.S. Department of the Interior 1999a; see Threats section). For details on distribution,

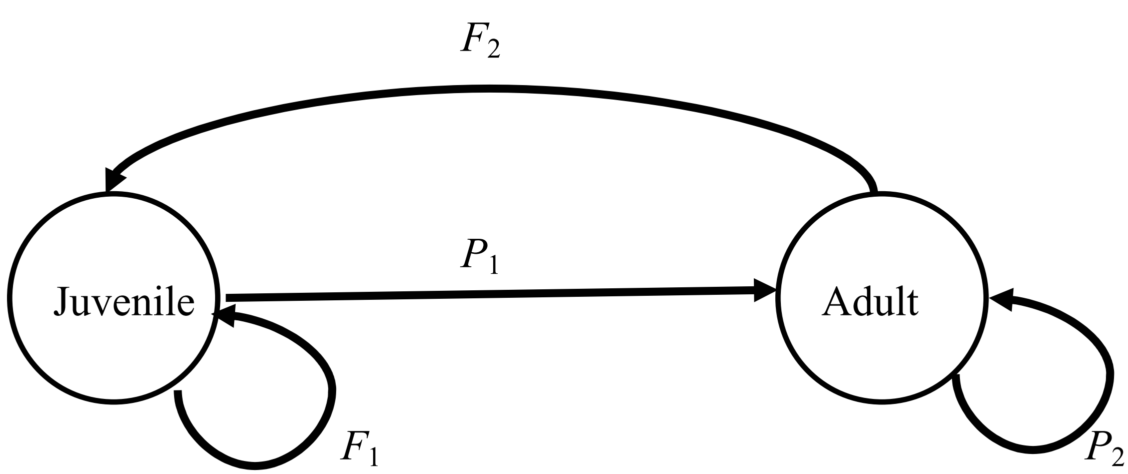

Figure 9. A life cycle diagram for the mountain plover showing the two critical life stages (juvenile and adult). Survival rates are illustrated for the juvenile stage (P_1, the probability that a plover survives from hatching to age 1) and the adult stage (P_2, the probability that a plover of age >1 survives to the next year). Fecundity rates (the number of eggs laid per female) are also shown for the juvenile (F_1) and adult (F_2) stages.

degree of population isolation, and spatial variation in abundance see earlier discussion under "Distribution and Abundance".

Matrix analysis

To provide a cursory indication of basic parameters that influence population growth in the mountain plover, I performed simple sensitivity and elasticity analyses (see Caswell 2001). These were largely exploratory analyses, and given the tenuous nature of several key assumptions (see below) the reader should be cautious when interpreting these results.

I first formulated a simple life cycle graph (see Caswell 2001) for the mountain plover that comprised two stages (census at the fledgling stage and as "adults"). In the following discussion, F_i is a stage-specific estimate of fecundity for stage i ($F_i = P_i m_i$; the per capita number of female offspring of age 0 born to individuals of each age class and that survive to stage i), where m_i is the average number of female offspring per female in stage i in the population, and P_i is a stage-specific estimate of annual survival for stage i. The matrix is illustrated as $\begin{bmatrix} F_1 & F_2 \\ P_1 & P_2 \end{bmatrix}$. I used a mean fledging rate (m_i) of 1.14 female fledglings per female as the basis for calculating fertilities. The calculation of m_i is critical to estimating fecundity and was computed as 2 x 3 x 0.40 x 0.95 x 0.50 = 1.14 (see below for an explanation of this calculation). Because of a lack of data, I did not assume a change in fertility with age, an assumption that is often justified in avian demography (Ricklefs 1973, McDonald and Caswell 1993). The only estimates of survival for this species were 0.35 for juvenile birds and 0.68 for adult survival (Dinsmore et al. 2003). The juvenile survival rate in the matrix model measures survival from hatching to age 1, and it is lower than the estimate of $P_1 = 0.48$ reported by Dinsmore et al. (2003) to account for high losses immediately post-hatch. The resulting numeric values used in the matrix analysis were $F_1 = 0.399$, $F_2 = 0.775$, $P_1 = 0.35$, and $P_2 = 0.68$.

From the resulting life cycle graph (**Figure 9**), I produced a matrix population analysis, with a post-breeding census, for a birth-pulse population with a one-year census interval (McDonald and Caswell 1993, Caswell 2001). The model assumes female demographic dominance, so fertilities are given as female offspring per female; thus, the fledgling number used was half the total annual production of fledglings, assuming a 1:1 sex ratio. Note also that the fertility terms (F_i) in the top row of the matrix include both a term for fledgling production (m_i) and a term for the survival of the mother (P_i) from the census (just *after* the breeding season) to the next birth pulse almost a year later. The estimated population growth rate (λ) was 1.08, based on the estimated vital rates used for the matrix. Although this suggests a growing population, this value derives from approximations for the vital rates, and should not be interpreted as an indication of the general health of the population.

I assumed the following when making these population matrix calculations: 1) all female plovers breed at age 1 and in subsequent years (a few may not breed, but given the short lifespan it is likely that the majority do breed at age 1), 2) each female lays an average of two clutches per year (it is believed that most females lay a clutch for themselves and a clutch for a male, some may lay clutches for >1 male, and some may not nest at all, so a guess at the mean would be approximately two clutches per female per year), 3) average clutch size is three eggs (Knopf 1996a), 4) 40 percent of all nests hatch, which is weighted to account for differences between male- and female-tended nests; Dinsmore et al. 2002), 5) 95 percent of all eggs hatch (an approximate estimate based on personal examination of nest data from Montana during the period 1995 to 2000), and 6) the sex ratio of offspring is equal (this is just a guess since there are no data to evaluate this).

Sensitivity analysis

A useful indication of the state of the population comes from the sensitivity and elasticity analyses. *Sensitivity* is the effect on population growth rate (λ) of an absolute change in the vital rates. Sensitivity analysis provides several kinds of useful information (Caswell 2001: 206-225). First, sensitivities show how important a given vital rate is to population growth rate (λ), which Caswell (2001: 280-298) has shown to be a useful integrative measure of overall fitness. Sensitivities can thus be used to assess the relative importance of survival (P_i) and fertility (F_i) transitions. Second, sensitivities can be used to evaluate the effects of inaccurate estimation of vital rates from field studies. Inaccuracy will usually be due to paucity of data, but could also result from use of inappropriate estimation techniques or other errors of analysis. To improve the accuracy of the models, researchers should concentrate additional effort on transitions with large sensitivities. Third, sensitivities can quantify the effects of environmental perturbations, wherever those can be linked to effects on stage-specific survival or fertility rates. Fourth, managers can concentrate on the most important transitions. For example, they can assess which stages or vital rates are most critical to increasing the population growth (λ) of endangered species.

The sensitivity matrix resulting from this analysis was $\begin{bmatrix} 0.37 & 0.32 \\ 0.72 & 0.63 \end{bmatrix}$. The summed sensitivity of λ to changes in survival (66 percent of total sensitivity accounted for by survival transitions) is higher than that for fertility (34 percent). Juvenile survival seems to be the most important transition. The major conclusion from this sensitivity analysis is that survival rates, especially the juvenile survival rate, are most important to population viability – given the proviso that the changes in vital rates are absolute (as opposed to proportional, as discussed below in the section on elasticity analysis).

Elasticity analysis

Elasticities are useful for resolving the problem of scale that can affect conclusions drawn from the sensitivities. Interpreting sensitivities can be somewhat misleading because survival and reproductive rates are measured on different scales. For example, an absolute change of 0.50 in survival may be a large change (e.g., a change from a survival rate of 0.90 to 0.40). On the other hand, an absolute change of 0.50 in fertility may be a very small proportional alteration (e.g., a change from a clutch of 3,000 eggs to 2,999.5 eggs). Elasticities are the sensitivities of λ to proportional changes in the vital rates and thus partly avoid the problem of differences in units of measurement. The elasticities also have the useful property of summing to 1.0. The difference between sensitivity and elasticity conclusions results from the weighting of the elasticities by the value of the original vital rates. Management conclusions will depend on whether changes in vital rates are likely to be absolute (guided by sensitivities) or proportional (guided by elasticities). By using elasticities, key life history transitions and stages can be further assessed, as well as the relative importance of reproduction (F_i) and survival (P_i) for a given species. It is important to note that elasticity as well as sensitivity analysis assumes that the magnitude of changes, or perturbations, to the vital rates is small.

The matrix of elasticities for the mountain plover resulting from this analysis was $\begin{bmatrix} 0.14 & 0.23 \\ 0.23 & 0.40 \end{bmatrix}$. The rate of population change (λ) was most elastic to changes in adult survival (40 percent). Next most elastic were juvenile survival and adult reproduction (23 percent each). Least important was reproduction by juvenile birds (14 percent of total elasticity).

The sensitivities and elasticities for mountain plover were generally consistent in emphasizing survival transitions, with the elasticities strongly emphasizing adult survival, whereas the sensitivity analysis gave a slight edge to juvenile survival. Thus, survival rates, particularly adult survival rates, are the data elements that warrant careful monitoring in order to refine the matrix demographic analysis.

Community ecology

Relationships between mountain plovers and other members of their community are poorly understood because most previous work focused on this species alone and not on interactions with other species. The following discussion highlights what little is known. To illustrate the community ecology of mountain plovers, see the envirogram (after Andrewartha and Birch 1984) that illustrates known pathways between plovers and the food web (**Figure 10**). Knopf (1996a) summarized known incidences of predation, although the exact composition of the predator guild is unknown. Eggs and chicks are taken by a variety of mammals, raptors, and probably bullsnakes (*Pituophis melanoleucus*) (Dinsmore 2001). Adults have been killed by kit fox (*Vulpes macrotis*) and prairie falcons (*Falco mexicanus*) and have been shot by varmint shooters in Montana (pers. obs.). Range wide differences in predation rates have not been studied, although at least one of the major nest predators, the swift fox, is not found throughout the entire plover breeding range. It is interesting to note that nest predators differ substantially between two major breeding areas: nest losses are primarily to swift fox on the Pawnee National Grassland (Knopf 1996a) and apparently to bullsnakes in Phillips County, Montana (Dinsmore et al. 2002). The swift fox has been extirpated from the latter site, although recent reintroductions in Canada may soon change their status there.

Possible relationships between landscape changes and the resulting changes in predation rates are speculative because no experiments or monitoring efforts have specifically studied this component of their life cycle. The dramatic changes throughout the breeding range of the plover have no doubt influenced the predator community. The introduction of exotics such as the house cat (*Felis catus*), increased occupancy by humans resulting in a proliferation of predators like

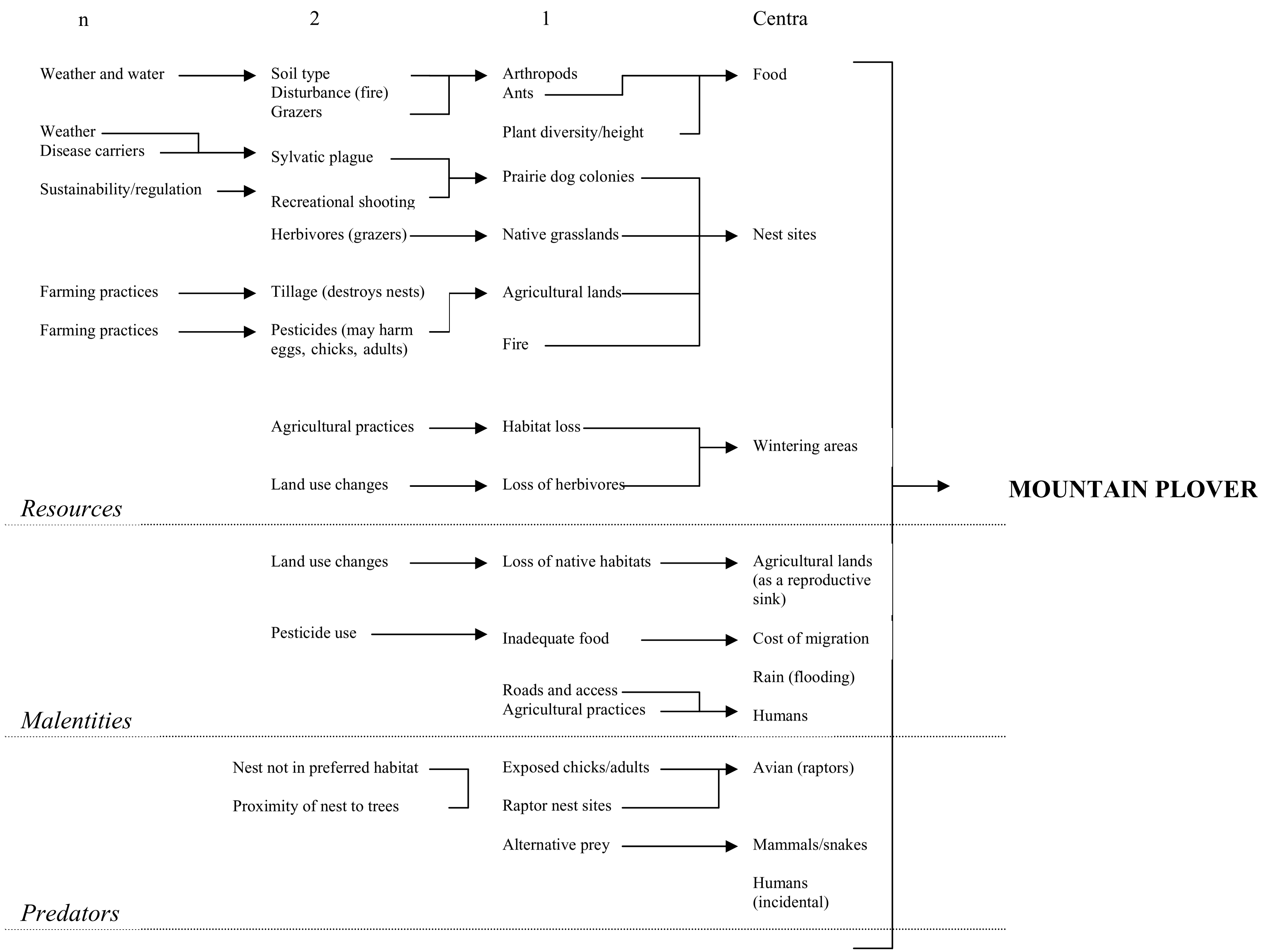

Figure 10. An envirogram for the mountain plover. The envirogram outlines the processes that affect the mountain plover, dividing them into three centra (resources, malentities, and predators). Resources are the items in the environment used by the plover, malentities are items that negatively impact the plover without harming themselves, and a predator is an organism that increases its fitness at the expense of the plover. The horizontal scale identifies pathways with the most distant effects being to the left.

the raccoon (*Procyon lotor*), and plantings of trees that may increase raptor numbers may all affect predation rates on plovers.

There is no information about possible competitors with mountain plovers and how these might be related to habitat use. Plovers regularly initiate aggressive interactions with several species of small mammals and ground-nesting birds, but whether this is a result of competition is unknown. In Montana they often nest near killdeer territories, but no aggressive encounters have been observed. The two species seem to segregate based on microhabitat preferences, with killdeer preferring to nest near water).

Disease and parasites have not been studied in mountain plovers. Upon close inspection, most individuals carry small feather mites, especially on the secondaries and rectrices (pers. obs.); no other information is available. Incidences of symbiosis or mutualistic interactions are also unknown for this species.

Conservation

Threats

Mountain plovers have declined during the last century, mainly as a result of threats occurring on their breeding grounds (Knopf 1994, Dinsmore 2000). The prairie ecosystem occupied by mountain plovers may be the most endangered ecosystem in North America (Samson and Knopf 1994), and the mountain plover is often labeled as one of its main indicator species. Specific threats to the mountain plover within and outside of Region 2 include:

a) **Loss of native habitats.** The major threat facing breeding mountain plovers appears to be the loss of suitable nesting habitat. Native habitat losses in the Great Plains since settlement have been severe, mainly resulting from conversion to agriculture. A minimum of 32 percent of the native grasslands in the Great Plains has been converted to arable lands (Laycock 1987), and large-scale conversion continues to the present (U.S. Department of the Interior 1999a). Knopf (1994) summarized historical changes in the Great Plains landscape including changes in land cover, the loss of primary grazers, and the resulting human encroachment. Losses in the eastern Great Plains, the area east of Region 2, have been most severe. Farther west in the Great Plains, losses are less severe, especially in Wyoming and Montana where >50 percent of the native landscape remains (U.S. Department of the Interior 1999a). Similarly, the loss of native wintering habitat may be affecting the plover. Most plovers are thought to winter in southern California, a region that underwent a remarkable habitat transformation in the last century. Impacts to winter habitat could therefore negatively affect a large proportion of the continental population of plovers, although at least one study suggested that over-winter survival was not significantly impacted (Knopf and Rupert 1995). The loss of native grasslands thus has numerous negative effects on plovers including fewer sites for nesting, possible increased predation rates, possible lower survival, reduced over-winter survival, and changes in community structure that could have far-reaching effects such as a reduction in food resources.

b) **Loss of prairie dogs.** Historical Great Plains grazers, like the bison, are functionally extinct, and the only primary grazer that remains abundant is the prairie dog. Prairie dogs, and especially the black-tailed prairie dog, may have declined by as much as 99 percent to their present day numbers (Summers and Linder 1978, Van Pelt 1999), yet they still remain locally abundant in parts of the Great Plains (see earlier discussion under Habitat). The black-tailed prairie dog was recently petitioned for listing under the U.S. Endangered Species Act, and the warranted but precluded finding prompted immediate and widespread conservation measures (U.S. Department of Interior 1999b, Van Pelt 1999). Prairie dog colonies are selectively used by nesting plovers throughout their range and probably represent the most intact native breeding habitat. Continued losses of prairie dogs, resulting from disease (e.g., sylvatic plague), poisoning, or recreational shooting, should be viewed as a direct threat to the mountain plover range-wide. Unregulated shooting that impacts prairie dog density and colony size may be a serious threat to plovers including the loss of nesting areas, possible reductions in nest, brood, and adult survival, and a reduction in food supply. All of this suggests that activities that increase the distribution of prairie dogs will also increase the distribution and abundance of the mountain plover.

c) **Alteration of current grazing regimes.** Historically, the mountain plover evolved in a landscape that was grazed by a variety of native herbivores including bison, pronghorn antelope (*Antilocapra americana*), and prairie dogs. Concurrent with precipitous declines in these native grazers was an increase in grazing by domestic livestock, primarily cattle and sheep. The change in grazers resulted in significant changes in vegetation at fine and broad scales. Native, unregulated grazers resulted in highly variable grazing impacts both temporally and spatially. As a consequence, vegetation composition and structure also varied temporally and spatially. Domestic grazers managed under typical grazing regimes result in relatively uniform grazing intensity leading to vegetation that is temporally and spatially more uniform. More important, common domestic grazing systems generally result in vegetation patterns with less of the mosaic of bare ground and vegetation structure favored by the plover. Other current practices that reduce site suitability for plovers include contour furrowing to improve soil moisture, fire suppression, and the introduction of exotic grasses that produce non-preferred structure and compete with native grasses preferred by plovers (U.S. Department of the Interior 1999a). These changes have created a landscape where vegetation structure and composition no longer favor nesting plovers, and sites that were once used by plovers may no longer be suitable.

d) **Agricultural lands as a reproductive sink.** Several authors (Knopf 1996a, Knopf and Rupert 1996, Shackford et al. 1999) have suggested that the use of agricultural lands by nesting plovers may pose a threat to the species by acting as a reproductive "sink". In southern areas of their breeding range, plovers actively nest on agricultural lands. It is hypothesized that these lands may attract plovers away from more suitable nesting areas such as native grasslands, and that plovers nesting on agricultural lands may experience reduced nesting success and brood survival because of mechanical working of the field (U.S. Department of the Interior 1999a). In the only published study on agricultural lands, 67 percent of plover nests were lost when the fields were tilled (Shackford et al. 1999). Crop type, planting schedule, and the frequency of mid-season manipulations can all be factors contributing to continental population declines. Therefore, source-sink dynamics may be acting to reduce mountain plover numbers, especially in the southern part of the breeding range (Knopf and Rupert 1996).

e) **Habitat fragmentation.** As indicated earlier, the landscape within the historic breeding range of the plover is now highly fragmented with suitable habitat occurring in patches. The present distribution of plover nesting habitat is a result of several factors such as the reduction and loss of primary grazers, the loss of native grasslands, and changes in grazing practices. Given that nesting plovers exhibit at least some degree of site faithfulness (Dinsmore 2001), further habitat fragmentation may hamper the ability of dispersing plovers to successfully find suitable nesting sites.

f) **Oil and mineral development.** The development of several minerals, oil, and natural gas occur throughout the breeding range of the mountain plover. Potential negative impacts to the plover include habitat loss through development of oil well pads and access roads, the direct loss of nesting habitat through surface mining, and mortality resulting from vehicle collisions (most important for flightless chicks) (U.S. Department of the Interior 1999a).

g) **Small-scale landscape changes.** The impact of local landscape changes such as road construction, timber harvest, blowdowns, and non-motorized recreational activities appear to have little or no negative impact on mountain plovers, although possible impacts resulting from these actions have been poorly studied. Mountain plovers are tolerant of human activities of short duration as exemplified by their willingness to nest on roads (Knopf 1996a) and near areas of human disturbance such as oil and gas development sites (Day 1994). The USFS mountain plover Management Strategy (see Existing

Regulatory Mechanisms, Management Plans, and Conservation Strategies section) addresses this level of threat to the plover.

h) **Agricultural pesticides.** The impacts of agricultural pesticides were once thought to be a threat to mountain plovers (Knopf 1996a). Recent work found low levels of exposure to organophosphates in plovers wintering in California (Iko et al. 2003), although the results did not conclusively establish this as a serious threat and other chemicals may be impacting plovers. Although research of this topic is lacking for plovers, it is worth acknowledging that the plover can come into contact with numerous pesticides used to control insects, and that some of these may have unknown negative consequences for the plover. One example is the use of deltamethrin to control fleas that transmit sylvatic plague in prairie dogs. Active prairie dog burrows are actively treated with deltamethrin with the intent of protecting prairie dogs from plague. However, deltamethrin is a long-lasting (up to eight months) insecticide and kills several important prey items of the plover (e.g., beetles). Deltamethrin probably does not kill plovers directly, but it could have profound negative impacts on some of their principal food items.

Mountain plovers are not known to interact with any exotic animal or plant species within or outside of Region 2. They are no longer hunted, and their use for recreation (e.g., bird-watching) and education (e.g., class field trips) is very limited and probably poses no threat. Scientific use of plovers is also limited and the lengthy permitting process at federal and state levels minimizes excessive disturbance resulting from research activities. Collectively, these uses pose little, if any, threat to the persistence of mountain plovers in Region 2 or elsewhere.

Conservation Status of the Mountain Plover in Region 2

The mountain plover has suffered from a long-term reduction in both numbers and distribution within Region 2, although this is still the center of the species' breeding range. Their present distribution in Region 2 appears stable, although recent and sharp declines are suspected in key nesting areas such as the Pawnee National Grassland (see discussion under Population trend) and may indicate that their geographic distribution is still declining. Breeding Bird Survey data indicate no significant trend, either increasing or decreasing, in plover numbers for the area including Region 2 (Sauer et al. 2001). All major threats to the species (see Threats) are present in Region 2.

Mountain plovers have clearly declined in Region 2, but these declines are not well demonstrated, except on the Pawnee National Grassland, and the causes for these declines are not understood. Declines seem to be correlated with regional changes in habitat (loss of native grasslands, conversion to agriculture, loss of native herbivores, etc.), although there may be other causal factors that are unknown. Almost nothing is known regarding the relative quality of different habitats for plovers and/or their primary prey species. They have specific habitat requirements and appear sensitive to habitat changes resulting from a wide range of sources, including management actions such as changes in grazing regimes that do not favor the shortgrass habitat plovers require. Specific management plans to protect the plover in Region 2 have been enacted by the USFS and BLM, although stronger actions may be necessary to reverse recent population declines. As a result of the information presented in this assessment, I conclude that mountain plovers in Region 2 suffer from multiple threats that jeopardize their long-term persistence, and that some of these threats result directly from current land management practices.

Management of the Mountain Plover in Region 2

This assessment has provided a comprehensive overview of the ecology of the mountain plover and issues regarding their conservation range-wide, but particularly in Region 2. Several key elements emerge for consideration regarding their management in Region 2. However, as detailed in the introduction to this assessment, management decisions should be made on the basis of sound scientific knowledge from carefully designed experiments and secondarily from observational studies. The latter study type dominates the literature on mountain plovers, so defensible information on cause-effect relationships is largely missing. Many of the management actions outlined below have not been studied in an experimental framework, so the recommendations are made on the basis of correlative rather than cause-effect relationships. Many of the recommendations that follow can be incorporated using an adaptive management approach, a process that explicitly incorporates research into management actions, so that important knowledge gaps can be filled.

The only active mountain plover management in Region 2 occurs on the Pawnee National Grassland, where known plover nesting areas are protected during the nesting season (10 April to 10 July). A 200 m buffer around known nests protects them from disturbance, and livestock grazing is used as a tool for managing plover nesting habitat. However, the record of decision states (U.S. Forest Service 1994b:5), "As prairie dogs have not been shown to be significantly detrimental or beneficial to the plover and its nesting habitat on the Pawnee, management will continue as described in the Forest Plan". The plan further calls for maintaining "…between 12 and 30 prairie dog towns on 200 to 1,000 acres as described in the Forest Plan". Studies of plovers in the northern reaches of the breeding range, where prairie dogs are still abundant, have demonstrated a strong association between nesting plovers and prairie dogs, and this association may also include the remainder of the breeding range. Current knowledge suggests that quality breeding habitat for the mountain plover occurs on mid-sized prairie dog colonies (Olson-Edge and Edge 1987). To the extent that management favors maintaining existing prairie dogs and expanding the distribution of colonies, breeding habitat for the plover will be improved.

After carefully considering the science presented in this assessment, three potential elements of management plans for plovers in Region 2 emerge, as follows:

1. **Size of the area.** Information on minimum area requirements for nesting mountain plovers is needed. Graul's (1973a) estimate of a mean adult territory size of 16 ha and Knopf and Rupert's (1996) estimate of mean brood rearing areas averaging 57 ha provide approximate estimates of the area needed by nesting plovers in Region 2. Much larger areas are almost certainly necessary for this species to maximize nesting opportunities and nest and brood survival. In areas occupied by prairie dogs, territory size is determined by colony size, and colonies of intermediate sizes are utilized by plovers (Olsen-Edge and Edge 1987). Plovers are at least partially site-faithful, so responses by plovers to management actions will also be a function of the number of plovers in the immediate area. Management of sites distant from areas occupied by plovers may have little if any response from plovers, except possibly in the long-term through dispersal.

2. **Local habitat features.** Development of conservation plans for habitat should emphasize features utilized by plovers (see Habitat section). On the breeding grounds within Region 2 these include a bare ground component (minimum of 30 percent), short vegetation (<5 cm preferred, although higher vegetation is acceptable in some habitats), relatively flat terrain (slope <5 percent is best, sites with slope >15 percent are probably unsuitable), and some form of disturbance (e.g., frequent use of fire, rotational grazing by bison or cattle, or management for or restoration of prairie dogs).

3. **Restoration.** Restoration of mountain plovers was attempted in 1982 in Kansas through the translocation of chicks (Ptacek and Schwilling 1983). The restoration was not considered successful (Fellows and Gress 1999), although plovers now occupy this region in seemingly greater numbers than prior to the restoration (see summary in Fellows and Gress 1999). Specific reasons for labeling the restoration unsuccessful are unclear, although it appears to be based on the lack of subsequent resightings of any of the banded plovers. Although this single restoration attempt was unsuccessful, it is possible that plovers could be successfully reintroduced to other former nesting areas in the near future. Restoration of plovers might also be accomplished through indirect actions to manipulate habitat (grazing, fire, changes in agricultural practices, introduction of prairie dogs, etc.) and make it more suitable for plovers. If this method of restoration is attempted, it should be noted that other factors (e.g., distance from known plover areas) might diminish the result.

Given the historical declines and current status of the mountain plover in Region 2, there is interest in initiating long-term monitoring of plovers and their principle nesting habitats. Monitoring efforts for mountain plovers in Region 2 will need to incorporate key elements of the information presented in this assessment, as discussed in the following inventory and monitoring categories.

1. **Species inventory.** At present, there are no formal distribution surveys for mountain plovers in Region 2. The limits of mountain

plover breeding distribution within Region 2 are reasonably well known, except possibly in western Colorado and parts of Wyoming. One approach to better delineate their breeding range is to map potential habitat to identify areas where plovers could occur but have not been recorded. Given that their broad distribution is known, detailed surveys are needed to determine geographic variation in abundance. Elements to consider when designing such surveys include the timing of the survey (best during the courtship or post-hatching periods), survey methodology (should probably use point counts incorporating distance sampling), biases resulting from roadside-only surveys, and the possibility of targeting searches in utilized habitats such as prairie dog colonies and heavily grazed sites. Some consideration could be given to wintering grounds surveys, although the spatial extent of the wintering grounds is less well known than that of the breeding grounds, making such surveys that much more difficult.

2. **Habitat inventory.** No broad surveys of the habitats used by mountain plovers are presently conducted in Region 2. However, there are periodic dedicated surveys of prairie dogs (see Van Pelt 1999) and native grasslands and lands used for agriculture (U.S. Department of Agriculture surveys), all of which are key elements of plover nesting habitat. A major weakness of these surveys is the coarse nature of these habitat classifications. These resources should continue to be used, although a better understanding of the specific habitats mountain plovers prefer is needed to design efficient habitat inventories.

3. **Population monitoring.** There are currently no regional population monitoring efforts for mountain plovers in Region 2 or range-wide except for the Breeding Bird Survey (but see discussion of biases under Population Trend), and I am unaware of plans to initiate large scale monitoring in the near future. Monitoring could conceivably occur on either the breeding or wintering grounds. Wintering ground monitoring will be difficult because: 1) the birds are scattered and the proportion of the population wintering in a given area (e.g., the Imperial Valley in California) probably changes temporally, and 2) inferences to plovers nesting in specific areas (e.g., the Pawnee National Grassland) would not be possible. Monitoring plovers on the breeding grounds avoids many of these problems and allows inference to both the continental and population levels with a proper survey design. As part of the U.S. Shorebird Conservation Plan (Brown et al. 2001), Dinsmore (1999) outlined a protocol for monitoring mountain plovers range-wide, using a modified BBS route design. This or a similar survey could be implemented to monitor plovers throughout their breeding range. Key monitoring considerations include:

   a. The geographic scale of the survey will depend on the specific objectives. Range-wide monitoring will be necessary to make inferences regarding trends in continental numbers of mountain plovers. Monitoring at smaller scales is possible, but the definition of a discrete population or area (thus minimizing emigration and immigration) is critical, and sampling will need to be more intensive to generate sufficient numbers of detections to estimate local trends.

   b. Temporally, monitoring needs to occur for a minimum of 8 to 10 years in order to detect long-term trends that are not the result of short-term fluctuations or sampling error.

   c. Monitoring efforts should consider the trade-offs between road-based surveys and other survey types. Roadside surveys are logistically easier, but inferences are tempered by possible road bias. Surveys that randomly sample the landscape, including roadsides, minimize this source of bias and allow stronger inference to the entire continental population of plovers.

   d. The best and most feasible indicator of trends in mountain plovers will probably be the number of breeding adults. Long-term studies of survival are possible, but the low density and generally low detectability of plovers will make it difficult and expensive to obtain meaningful estimates of survival over long time periods and from multiple sites.

e. Surveys need to be timed to sample adult plovers during either the courtship period (generally between mid-April and late May and before most adults are on nests) or the post-hatch period (generally between mid-June and mid-July). These surveys will detect the highest proportion of adults. Surveys conducted in early morning (roughly sunrise to 10 a.m.) will minimize the effects of heat and excessive wind on the detectability of plovers.

f. During monitoring efforts, collect data on counts of plovers rather than simple presence-absence data. Presence-absence data restrict the range of analyses and questions that may be addressed.

4. **Habitat monitoring.** There are currently no regional habitat monitoring efforts for mountain plovers in Region 2. Existing monitoring efforts (e.g., for prairie dogs, native grasslands, and agricultural lands) should continue and could be expanded to include finer resolution to measure factors that are important to the plover. Such expansion might include remote sensing work to identify key habitat features that are important to the plover including bare ground, short vegetation, and perhaps even certain plant communities.

From the information presented earlier in this report (see Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies section), biologists have several tools available to actively, and successfully, manage their lands for mountain plovers. These tools include:

1. **Fire.** Prescribed burns are effective for attracting nesting plovers in eastern Colorado (Dinsmore 2000, F. L. Knopf personal communication 2002). Plovers also use incidental burns, although their frequency is extremely low in Region 2 due to active fire suppression. Unplanned fires in Region 2 burned an average of 525 ha (SD = 1,011) annually between 1970 and 2000, although not all burned areas resulted in suitable plover nesting habitat. On a regional scale, incidental fires are probably not very beneficial to plovers and prescribed natural fires will be necessary to provide large areas of suitable nesting habitat.

2. **Grazing.** Grazing plans that favor habitat features utilized by plovers (e.g., short vegetation, bare ground, etc.) can be readily implemented within their breeding range. Rotational grazing can be used to create a landscape mosaic of preferred plover habitat such that specific sites do not need to be grazed every year. This tool is already used on a limited basis on the Pawnee National Grassland (U.S. Forest Service 1994b).

3. **Seasonal closures of nesting areas.** The USFS mountain plover Management Strategy (U.S. Forest Service 1994a, 1994b) calls for nesting area closures between 10 April and 10 July to protect known plover nesting sites. Such closures may be effective for specific sites, but broad scale habitat management is necessary to ensure that an adequate number of such sites are available regionally.

Information Needs

Although some components of mountain plover biology are well studied, many key elements of their life history are poorly understood. The following discussion identifies important information gaps and suggests priority topics for further study. The distribution of mountain plovers has been mapped in detail, and it is unlikely that major nesting areas remain to be discovered. However, as outlined earlier, information on geographical patterns of abundance is needed. Rigorous attempts to formally estimate abundance, particularly at key nesting sites, will provide a first step in prioritizing conservation strategies and will provide a basis for a sound estimate of the continental number of plovers. A similar information gap exists for detailed demographic information, which exists for only a single breeding area in Montana. Geographic variation in demographic parameters is unknown, and without this information analyses of population persistence will be little better than guesses.

The tools and methods necessary to monitor trends in mountain plovers at varying geographic scales exist and have already been used on a limited basis in Montana and Colorado. But the difficulty in monitoring this species does not result from a lack of methodology. Instead, it results from the enormous effort needed to adequately sample the low density populations.

Cause-effect relationships between plovers and specific habitat management actions are largely unknown. Habitat changes, resulting from natural disturbances or specific management actions, undoubtedly affect mountain plovers in many ways. However, experiments that are carefully designed to measure these responses have not been conducted, nor have many of the observational studies been completed to lay the foundation for good experiments. For example, burns are known to attract nesting plovers, but it is unknown if burns provide improved nesting habitat resulting in greater nesting success, better food resources for adults and chicks, a reduced risk of predation, etc. The specific responses of plovers to fine and broad scale habitat changes are therefore largely unknown and the effects of specific management actions cannot be inferred.

A single attempt to restore breeding mountain plovers to southwestern Kansas through translocation (Ptacek and Schwilling 1983) is the only such attempt for this species. Although this restoration was considered a failure, it is interesting that mountain plovers are now regular breeders in this part of Kansas (Fellows and Gress 1999). Translocation has not been attempted for other species of shorebirds, and based on the very limited information that is available it seems unlikely that it would be successful with mountain plovers. Translocating adult plovers will almost certainly fail. Limited information on site-fidelity suggests that adults will probably quickly return to the area from which they were captured. Releasing flightless chicks or fledged juveniles holds slightly more promise for restoration. However, their low survival (in both the chick stage and the post-fledging period) and their tendency to disperse from the natal area (in this case, the restoration site) will greatly reduce the chances for success. Restoration of plovers through indirect means such as habitat improvements offers more promise, but this will be influenced by the proximity of the restoration site to other sites already occupied by plovers.

Research priorities for mountain plovers are many and they are not restricted to Region 2 because of the scale of some questions. In my opinion, important research priorities include:

1. A defensible estimate of the continental number of mountain plovers.

2. A thorough exploration of habitat preferences and requirements range-wide during the nesting season. This would include studies at multiple scales and would explore biotic and abiotic community interactions. This should also include rigorous experimental studies of habitat relationships, including but not limited to the plover-prairie dog relationship outlined earlier. An understanding of these cause-effect relationships will allow adaptive management actions to be implemented, will improve management at existing sites occupied by plovers, and may provide deeper insight into mechanisms for establishing plovers at presently unoccupied sites.

3. Long-term estimates of demographic parameters (e.g., annual survival) from multiple sites. Particular emphasis should be placed on estimating survival from hatch to age 1 and on estimating recruitment rates at multiple sites.

4. More detailed information on the species' basic ecology, including experimental tests of responses to habitat alterations (e.g., burning or grazing) and the collection of detailed life history information on the mating system, regional and temporal patterns in diet, and more rigorous information on range-wide site fidelity.

5. A better understanding of the species' movement patterns, both within and outside of Region 2, including topics like migration routes, post-breeding movements, and winter site fidelity. More information is also needed on dispersal capabilities, particularly as they pertain to colonization of "new" nesting sites.

6. An understanding of the spatial and temporal variation in mountain plover predator and prey communities, on both the breeding and wintering grounds. Such information will be useful for understanding plover responses at the population level (e.g., long-term population trends) and may provide insight into threats to their persistence.

Research on mountain plovers, within and outside Region 2, continues and seeks to address many of these information needs. On-going work continues with the following studies: breeding biology on the Pawnee National Grassland in Colorado (contact Fritz L. Knopf, fritz_knopf@usgs.gov), breeding biology on private lands in eastern Colorado (contact Victoria J. Dreitz, victoria_dreitz@usgs.gov), breeding biology study in Park County, Colorado and a range-wide stable isotope study to understand continental movement dynamics (contact Michael B. Wunder, mbw@lamar.colostate.edu), a Wyoming state-wide survey to estimate distribution and abundance (contact Reagan Plumb, rplumb@uwyo.edu), population and breeding biology, population trends, and associations with prairie dogs in Montana (contact Stephen J. Dinsmore, sdinsmore@cfr.msstate.edu), and habitat use and numbers wintering in California (contact Fritz L. Knopf, fritz_knopf@usgs.gov).

ADDITIONAL READING

For additional information on mountain plovers, see one of the following references:

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DEFINITIONS

Population. In this assessment, the term “population” is used in the classical sense to describe a group of organisms of the same species occupying a particular space at a particular time (Krebs 1972).

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