Draft Revised Recovery Plan for the Northern Great Plains Piping Plover

(*Charadrius melodus*)

First Revision

Original Recovery Plan Approved in 1988

Summer Plumage

Winter Plumage

Region 6
U.S. Fish and Wildlife Service

in conjunction with

Region 2

Albuquerque, New Mexico

Region 3

Minneapolis, Minnesota

Region 4

Atlanta, Georgia

March 2016

Draft Revised Recovery Plan for the Northern Great Plains Piping Plover (*Charadrius melodus*) March 2016

First Revision
Original Recovery Plan Approved in 1988

Region 6
U.S. Fish and Wildlife Service
Denver, Colorado

Approved: ______________________________
Deputy Regional Director, Region 6, U.S. Fish and Wildlife Service

Date: 2.5.16

Concurred: ______________________________
Regional Director, Region 2, U.S. Fish and Wildlife Service

Date: MAY 8, 2015

Concurred: ______________________________
Regional Director, Region 3, U.S. Fish and Wildlife Service

Date: 5/26/15

Concurred: ______________________________
Regional Director, Region 4, U.S. Fish and Wildlife Service

Date: 6/8/15

DISCLAIMER

Recovery plans delineate such reasonable actions as may be necessary, based upon the best scientific and commercial data available, for the conservation and survival of listed species. Plans are published by the U.S. Fish and Wildlife Service (Service) sometimes prepared with the assistance of recovery teams, contractors, State agencies and others. Recovery plans do not necessarily represent the views, official positions or approval of any individuals or agencies involved in the plan formulation, other than NMFS. They represent the official position of the Service only after they have been signed by the appropriate Regional Directors. Recovery plans are guidance and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any Federal agency obligate or pay funds in any one fiscal year in excess of appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions.

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An electronic copy of this document is available at:
http://www.fws.gov/endangered/species/recovery-plans.html

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ORGANIZATION OF THE PLAN

Piping plovers spend three to five months on the breeding grounds annually (Volume I), and the rest of the year on the wintering (Volume II) or in migration (partially addressed in both Volume I and II). The habitat, management entities, and many of the threats are different on the breeding and wintering grounds. In order to provide recommendations specific to managers in each part of the annual cycle, the recovery plan is presented in two volumes. Volume I covers the breeding portion of the range. Volume II covers the coastal migration and wintering portion of the range. Volume II was originally written as a Comprehensive Conservation Strategy (CCS) to identify threats, actions, and research needs on the wintering grounds. We have made minimal changes to the CCS so that it can serve as an integrated document for recovery planning across the coastal nonbreeding range of all three populations. This approach should allow biologists, land managers, regulators, and others seeking to conserve piping plovers to readily find information specific to their needs.

EXECUTIVE SUMMARY

Current Status: Piping plovers were listed under the provisions of the Endangered Species Act on January 10, 1986. The Northern Great Plains population was listed as threatened[1]. Critical habitat was designated on the Northern Great Plains breeding grounds on September 11, 2002. Critical habitat was designated for all populations of piping plovers on the wintering grounds on July 10, 2001, and redesignated in 2008 and 2009. The breeding population of the Northern Great Plains piping plover extends from Nebraska north along the Missouri River through South Dakota, North Dakota, and eastern Montana, and on alkaline (salty) lakes along the Missouri River Coteau (a large plateau extending north and east of the Missouri River) in North Dakota, Montana, and extending into Canada. The majority of piping plovers from Prairie Canada winter along the south Texas coast, while breeding piping plovers from the U.S. are more widely distributed along the Gulf Coast from Florida to Texas.

Habitat Requirements and Limiting Factors: In the Northern Great Plains, piping plovers breed and raise young on sparsely vegetated sandbars and reservoir shorelines on river systems as well as on the shorelines of alkaline lakes. Changes in the quality and quantity of riverine habitat due primarily to damming and water withdrawals are a primary threat to the species. On the wintering grounds, piping plovers forage and roost along barrier and mainland beaches, sand, mud, and algal flats, washover passes, salt marshes, and coastal lagoons. Habitat destruction and degradation are pervasive and have reduced suitable habitat. Human disturbance, predation, and invasive plants further reduce breeding and wintering habitat quality and affect survival.

Recovery Goal: To remove the Northern Great Plains population of piping plovers from the list of federally Threatened and Endangered Species.

Recovery Objective: To restore and maintain a viable population of piping plovers (less than 5 percent likelihood of extinction in the next 50 years) in the Northern Great Plains by 2035.

Recovery Strategy: To restore ecosystem function on both the breeding and wintering grounds so that the population can persist into the foreseeable future without extensive human intervention. Because some human activities are likely to continue to impact piping plover habitat, this task will likely involve developing and maintaining public outreach and education and partnerships for long-term protection and management.

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[1] We have always managed the Northern Great Plains piping plover population as a separate population and intend to eventually delist this population as a stand-alone Distinct Population Segment when the data support such an action. Our 2009 5-year review considered this issue and concluded that this population satisfies the criteria of a Distinct Population Segment and can be delisted separately from the remaining piping plover populations (USFWS 2009).

Recovery Criteria:

Criterion 1: Using the most current estimates of region-specific breeding population and population growth (λ), the NGP plover population model indicates that the upper 95 percent confidence limit on the probability of a regional population going extinct within the next 50 years is < 0.05. This criterion is satisfied for all four regions (description of the areas is under number '2' below). In addition, the following are met:

1. for every region, population growth is stable or increasing (≥ 1.0) over a 10-year average, and is projected to remain steady or increasing over the next 50 years, and
2. the population will be distributed so that at least 15 percent of the population is in each of the following regions:
    a. Southern Rivers (Missouri River system from Fort Randall Dam, South Dakota to Ponca, Nebraska, the Niobrara River, the Loup River system and the Platte River system)
    b. Northern Rivers (Missouri River system from Fort Peck Lake, Montana to Pierre, South Dakota)
    c. U.S. Alkaline Lakes
    d. Prairie Canada (see discussion on pages 70-71)

Purpose: 1) To demonstrate that the breeding population is viable and projected to remain viable into the foreseeable future; and 2) to ensure that the breeding population is distributed across the range so that a regional catastrophic event does not negatively impact the entire population.

Criterion 2: A minimum amount of suitable nesting and foraging habitat is available on a regional basis, as described below.

a. 1,630 ha (4,030 ac) in Southern Rivers (Missouri River system from Fort Randall Dam, South Dakota to Ponca, Nebraska, the Niobrara River, the Loup River system and the Platte River system)
b. 1,320 ha (3,270 ac) in Northern Rivers (Missouri River system on Fort Peck Lake, Montana to Pierre, South Dakota)
c. 1,460 ha (3,600 ac) in the U.S. Alkaline Lakes
d. 1,460 ha (3,610 ac) in Prairie Canada (Provided for information only. We defer to the Prairie Canada Recovery Plan. See discussion about Canadian recovery criteria below.)

Habitat is cyclical on the Northern Great Plains, so the habitat should be available, on average, a minimum of three-out-of-four years. For example, the criteria would be met if there were habitat available for a six year period in a region, followed by two years of high water when most of the habitat was flooded. This criterion should be met for a minimum of 12 years prior to initiating delisting.

Purpose: To ensure that there is sufficient habitat broadly distributed on the breeding grounds to support a stable population.

Criterion 3: Sufficient habitat is available on the coastal migration and wintering grounds in quantity and quality to support conservation of the species at recovery levels as defined by Criterion 1. This will include designated Critical Habitat, and additional habitat that was not designated but is regularly used by wintering piping plovers. Piping plovers should be spatially distributed in the following locations.

a. Western Gulf Coast - from the Galveston Bay area, west-southwest along the coast of Texas and Mexico
b. Central Gulf Coast - east-northeast of Galveston Bay through Jefferson County in NW Florida
c. Eastern Gulf Coast - Florida's west coast-Taylor County, Florida south to Monroe County
d. Atlantic Coast Florida's east coast, including the Florida Keys up through northeastern North Carolina, Caribbean Islands, and the Bahamas Islands

Purpose: To ensure that there is sufficient habitat to support the population at recovery levels widely distributed on the coastal migration and wintering grounds.

Criterion 4: Ensure commitments are in place and functioning as anticipated to provide long-term funding, protection, and conservation management activities in essential breeding and wintering grounds.

a. Southern Rivers (Missouri River system from Fort Randall Dam, South Dakota to Ponca, Nebraska, the Niobrara River, the Loup River system and the Platte River system)
b. Northern Rivers (Missouri River system from Fort Peck Lake, Montana to Pierre, South Dakota)
c. U.S. Alkaline Lakes
d. U.S. Wintering Grounds

Purpose: To make sure that management commitments necessary for piping plovers' continued persistence are in place and functioning, and will continue to operate after the species is recovered.

Actions Needed:

Breeding (B)

1B Habitat Protection, Management, Restoration, and Creation
2B Public Outreach to Minimize Human Disturbance and Promote Favorable Land Management
3B Regulatory Compliance and Certainty
4B Population Trends and Reproductive Monitoring
5B Climate Change Planning
6B Plan Evaluation and Revision

Wintering (W)

1W Maintain natural coastal processes that perpetuate wintering and coastal migration habitat.
2W Protect wintering and migrating piping plovers and their habitat from human disturbance.
3W Monitor nonbreeding plovers and their habitat.
4W Protect nonbreeding plovers and their habitats from contamination and degradation from oil or other chemical contaminants.
5W Assess predation as a potential limiting factor for piping plovers on wintering and migration sites and take action to address predation as needed.
6W Improve application of regulatory tools.
7W Develop mechanisms to provide long-term protection of nonbreeding plovers and their habitat.
8W Conduct scientific investigations to refine knowledge and inform conservation of migrating and wintering piping plovers.
9W Coordinate, review, and refine recovery efforts.

Estimated cost of recovery for FY 2016-2035:

Breeding (Volume I):	$603,420,000
Wintering (Volume II):	$193,190,000
Total:	**$796,610,000**

Date of Recovery:

Contingent on various factors and vigorous implementation of recovery actions, full recovery of this species could occur in 2035.

VOLUME I:

DRAFT BREEDING RECOVERY PLAN FOR THE NORTHERN GREAT PLAINS PIPING PLOVER (*Charadrius melodus*)

March 2016

Region 6
U.S. Fish and Wildlife Service
Denver, Colorado

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PART I. INTRODUCTION

The piping plover (*Charadrius melodus*) was listed on January 10, 1986, under provisions of the U.S. Endangered Species Act (ESA) of 1973, as amended (USFWS 1985). Piping plovers breed in three geographic regions of North America: beaches of the Atlantic Coast from South Carolina to Newfoundland, shorelines of the Great Lakes, and along alkaline wetlands and major rivers and reservoirs of the NGP (Figure 1).

Populations on all three portions of the range have increased since listing. The Atlantic Coast population has increased an estimated 234 percent, from approximately 790 pairs in 1986 to 1,762 in 2011 (USFWS 2009a, USFWS 2012a). Likewise, the Great Lakes population has increased from an estimated 12 pairs in 1984 to 58 nesting pairs in 2012, most of which nested in Michigan (USFWS 2009a, USFWS 2012b). The NGP population is the largest, with an estimated 2,953 individuals (note, pairs are not tracked in the NGP as they are in the other two populations) in 1991 (1,981 in the U.S. excluding Canada) and an estimated 4,662 individuals in 2006 (2,959 in the U.S. excluding Canada) (Ferland and Haig 2002, Elliott-Smith *et al.* 2009).

The three breeding populations are recognized and treated separately in the Final Rule listing the piping plover across its range: the Atlantic and NGP populations are classified as threatened and the Great Lakes population as endangered (USFWS 1985). The two subspecies (Atlantic *C. melodus melodus* and Interior *C. melodus circumcinctus*) are listed separately as *Endangered* under the Species at Risk Act in Canada, as of 2003 (COSEWIC 2003).

In the United States, NGP piping plovers breed along rivers and reservoirs in Nebraska, South Dakota, North Dakota and Montana (USFWS 2009a). Also, they nest on alkaline (naturally salty) lakes in North Dakota, and Montana, and on sand and gravel mines in Nebraska. Small numbers (33 birds reported in the 2006 International Census) breed in Colorado, Iowa, Kansas and Minnesota (Elliott-Smith *et al.* 2009). Critical habitat was designated on September 11, 2002 for the U.S. NGP population (USFWS 2002). In Nebraska, the critical habitat designation was remanded (Nebraska Habitat Conservation Coalition v. USFWS 4:03 CV 3059) because of a determination that the economic analysis was incomplete. The Canadian breeding range includes alkaline and freshwater lakes and reservoirs in Alberta, Saskatchewan, Manitoba, and Ontario (Environment Canada 2006). Critical habitat has been designated in Canada (Government of Canada 2007).

Figure 1. Piping plover range map
Credit: Birds of North America Online http://bna.birds.cornell.edu/bna maintained by the Cornell Lab of Ornithology

A. Previous Recovery Plans

In 1986, recovery teams were appointed to develop recovery plans for the Atlantic Coast and the combined Great Lakes and NGP breeding populations. These teams worked with the two Canadian recovery teams to produce recovery plans for the Atlantic Coast (USFWS 1988a), the Great Lakes and NGP populations (USFWS 1988b), and the Canadian portion of the population (Canadian Wildlife Service 1993). In 1994, the Great Lakes/NGP team released a draft revised recovery plan for public comment. Subsequently, the Service decided the two inland populations would benefit from separate recovery plans; however, the 1994 draft was never made final. The Great Lakes recovery plan was revised in 2003 (USFWS 2003a). This recovery plan for the NGP population reviews progress towards recovery and outlines a strategy to achieve full recovery for the NGP portion of the species' range.

Table 1: Recovery Priorities Table

Degree of Threat	Recovery Potential	Taxonomy	Priority	Conflict
High	**High**	Monotypic Genus	1	1C
		Species	**2**	**2C**
		Subspecies/DPS	3	3C
	Low	Monotypic Genus	4	4C
		Species	5	5C
		Subspecies/DPS	6	6C
Moderate	High	Monotypic Genus	7	7C
		Species	8	8C
		Subspecies/DPS	9	9C
	Low	Monotypic Genus	10	10C
		Species	11	11C
		Subspecies/DPS	12	12C
Low	High	Monotypic Genus	13	13C
		Species	14	14C
		Subspecies/DPS	15	15C
	Low	Monotypic Genus	16	16C
		Species	17	17C
		Subspecies/DPS	18	18C
The above ranking system for determining Recovery Priority Numbers was established in 1983 (USFWS 1983a as corrected in USWFS 1983b).				

Species' Recovery Priority Number: 2C. This ranking refers to an entity listed at the species level with a high degree of threat and high recovery potential. Priority ranking numbers range from 1-18 with numbers 1-6 indicating a high degree of threat, 7-12 moderate, and 13-18 a low degree of threat. Within each category, the smaller three numbers indicate the recovery potential, so 1-3, 7-9, and 13-15 indicate a high recovery potential within the identified threat level (48 CFR 43098). The "C" denotes taxa that are in conflict with construction, other development projects, or other forms of economic activity. See the breakdown of Recovery Priority Numbers in Table 1.

B. Ecosystem Implications of Piping Plover Protection

Piping plovers breed on bare sandy or gravelly beaches, sandbars, or islands in several different types of habitat across the broad landscape of the NGP, but all of these habitat types are under threat from human-related causes. Many large rivers have been altered by dams, water diversions, channelization, construction of river infrastructure, hydropeaking (a water management regime whereby dams are run to maximize electricity profitability, generally with higher releases in the afternoons and lower releases for the rest of the day), and changes in the annual hydrograph (the annual water flow). These changes have resulted in a reduction or elimination of riverine habitats, including sandbars historically used for nesting, and in the creation of highly dynamic shoreline habitat on reservoirs which may function as an ecological trap for plovers (Anteau *et al.* 2012a; Anteau *et al*. 2014a).

An ecological trap occurs when individuals select habitat based on cues that no longer signal good quality habitat due to human-caused changes in the environment (Schlaepfer *et al.* 2002). The loss of riverine habitats has also resulted in declines in the native fish community and macroinvertebrates, all of which were adapted to systems with high sediment levels and variable flow that usually peaked in the spring and declined throughout the summer, exposing more sandbars and foraging area over the course of the breeding season (Funk and Robinson 1974; Williams and Wolman 1984; Hesse and Sheets 1993; Moog 1993). Invertebrate abundance is higher on protected shoreline, such as inter-sandbar channels, and plovers preferentially forage in those areas (Le Fer *et al.* 2008). With increased flows however, this habitat is often inundated, reducing the forage availability (Catlin *et al*. 2013).

Higher flows are correlated with longer time to fledging and reduced chick survival, presumably because foraging habitat is inundated, leading to a longer flight period when chicks are at greater risk of predation (Catlin 2013).   Reduction in the intensity, duration, and magnitude of high flows has also resulted in reduction sandbar size and elevation relative to base flows. Restoring all or portions of natural river function will benefit additional species that have been impacted by the changes to rivers' hydrographs and loss of floodplain connectivity, resulting in a loss of sediment and nutrient input into the system (Guillory 1979; Johnson 1992).

The alkaline lakes in the northern portion of the piping plovers breeding range support an assortment of shorebird species, including spotted sandpiper (*Actitis macularius*), American avocet (*Recurvirostra americana*), Wilson's phalarope (*Phalaropus tricolor*), and willet (*Tringa semipalmata*), among many others. Protecting the alkaline lakes habitat also benefits these species. Inter-annual fluctuation of water levels creates invertebrate-rich foraging habitat for these and other species. In addition, water-level fluctuations, in response to variable climate, ultimately maintain nesting habitat for piping plovers and other shorebird species on alkaline lakes (Anteau 2012). Consolidation drainage, a process in which smaller temporary and seasonal wetlands are drained into larger wetlands for the purpose of increasing agricultural land base, is believed to alter water-level fluctuations in alkaline lakes, making them more stable and thereby affecting the availability of food resources and suitable nesting habitat (Anteau 2012).

Additionally, many of the alkaline lakes are surrounded by grassland habitat because blowing salt makes the nearby land unsuitable for crops. However, most native prairie habitat in the Northern Great Plains has been converted to other uses, primarily agriculture. Today, only about 30 percent of the prairie habitat in the U.S. Great Plains and Canada remains from pre-colonial times (Samson *et al.* 2004). Remaining prairie continues to be threatened, with an estimated conversion rate faster than that of the Amazonian rainforests (Stephens *et al.* 2008). Grassland bird species show a steep, widespread decline which is greater than any other North American guild (Samson and Knopf 1994). Protecting the alkaline lakes and their surrounding native habitat will benefit piping plovers and other species that also rely on those ecosystems.

C. Description and Taxonomy

The piping plover is a small [about 16.5 to 17.5 cm (6.5 to 7 inches long); 46 to 64 grams (1.5 to 2 ounces)] migratory shorebird with a short, stout bill, pale underparts and orange legs. During the breeding season, it also has a black band across the forehead, a single black neckband, and the bill is orange with a black tip. The piping plover was named for its melodic high-pitched call from which the scientific name is derived (USFWS 1988b). During the winter, the legs pale, the bill turns black, and the dark bands disappear. Chicks are speckled gray, buff, brown, and white down. Juveniles resemble adults in winter. Juveniles acquire adult plumage the spring after they fledge (Prater *et al.* 1977).

Although the final listing rule (50 FR 50726) did not utilize subspecies, its preamble acknowledged the continuing recognition of two subspecies, *Charadrius melodus melodus* (Atlantic Coast of North America) and *Charadrius melodus circumcinctus* (Northern Great Plains of North America) in the American Ornithologists' Union's most recent treatment of subspecies (AOU 1957). Genetic-based investigation by Miller *et al.* (2010) confirmed separate Atlantic and interior piping plover subspecies, with the birds from the Great Lakes region allied with the NGP subspecies as *C. m. circumcinctus*. This genetic evidence is consistent with demonstrated geographic separation, (i.e., results from studies of banded piping plovers on their breeding grounds) and ecological differences, summarized in the 2009 5-Year Review (USFWS 2009). Evaluation documented in USFWS (2009) also supports recognition of two distinct population segments, NGP and Great Lakes, within *C. m. circumcinctus*. Marked separation of breeding ranges, differences in concentration across their wintering ranges, and ecological differences in breeding habitat distinguish these two populations. Loss of either population would result in a significant gap in the range, and the Great Lakes population also persists in an ecological setting that is unique for *C. m. circumcinctus*.

Notwithstanding two documented interchanges among breeding populations[1] since completion of the 2009 5-Year Review, the extremely low rate[2] remains consistent with marked separation of the three populations. Although we cannot discount the possibility of other rare interchanges among populations, banding information, behavioral differences, and ecological evidence continue to demonstrate that the three populations function independently. The wintering ranges of all three populations overlap (Gratto-Trevor *et al.* 2009), but there are marked differences in the proportions of each population using different wintering areas.

Because of the extreme rarity of interchange among the three populations, and the differences in threats and required management, it is appropriate to develop separate recovery plans providing recovery objectives, criteria, and actions specific to each population. Recovery plans have already been developed for the Atlantic Coast population and the Great Lakes population (USFWS 1996, USFWS 2003a).

D. Life History and Ecology

1. Breeding Chronology and Behavior

Piping plovers begin to arrive on the breeding grounds in the first half of April, with courtship, followed by nesting, beginning in mid-to-late April (Catlin and Fraser 2006a; Catlin and Fraser 2007; Felio *et al.* 2009; Felio *et al.* 2010a; Felio *et al.* 2010b; Shaffer *et al.* 2013). Arrival is later in the northern areas (Gratto-Trevor 2012, pers. comm.). First-year adults arrive approximately one month later than older adults (Catlin 2009). The male creates a shallow depression on the ground which both adults line with small pebbles. Both adults share incubation duties (Wilcox 1959, Cairns 1982) which last 25 to 28 days (Elliott-Smith and Haig 2004). Incubation time is reduced in nests laid later in the season and increased when there are more eggs in a clutch (Elliott-Smith and Haig 2004, Catlin 2009).

Hatching begins in late May to early June, generally peaking in June and early July (Catlin 2009). The young leave the nest within hours of hatch and begin to forage almost immediately (Wilcox 1959, Haig 1992). Chicks may be brooded for up to 21 days post-hatch, although the female sometimes deserts the brood after 5 to 10 days (Haig and Oring 1988; Haig 1992; Maxson 2000). Chicks fledge 25 to 35 days after hatching, and are capable of sustained flight soon after fledging (Knetter *et al.* 2001; Catlin *et al.* 2013). Piping plovers readily renest if earlier nests fail (Whyte 1985; Haig 1987). They generally only raise one brood a season,

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[1] A bird fledged on the Great Lakes bred on the Atlantic Coast in 2011 (Hillman 2012), and a bird that originated in Manitoba has bred for several years on the Great Lakes (Van Zoeren *in litt.* 2015).
[2] More than 10,000 piping plovers were banded between 1982 and 2013 (Catlin *in litt.* 2015, Cavalieri *in litt*. 2015, Gratto-Trevor *in litt*. 2015, Roche *in litt.* 2015).

although they have been documented to raise two broods on rare occasions (Bottitta *et al.* 1997). Piping plovers begin to leave the breeding grounds as early as mid-July, with adults leaving first and juveniles last (Elliott-Smith and Haig 2004).

2. Foraging and Diet

Piping plovers forage by gleaning invertebrates from the substrate or running and pecking on the substrate with short runs between pecks (Elliott-Smith and Haig 2004). The species' status as a federal threatened or endangered species has precluded collection for stomach content analysis, but forage has been described as various macroinvertebrates, with fecal evidence suggesting that the birds select prey at roughly the same rate as its availability (Shaffer and Laporte 1994), although a study of fecal material on the Northern Great Plains suggests that birds selected for less abundant Coleoptera over Diptera (Le Fer 2006). The reasons for this preference were not clear, but may have been due to handling time or energetic and nutritional factors (Le Fer 2006).

The prey base varies among locations across the Northern Great Plains. A study comparing prey base on the alkaline lakes, a reservoir (Lake Sakakawea, North Dakota) with sandbars below Garrison Dam, North Dakota (a cold water release dam), and Gavins Point Dam, South Dakota (a warm water release dam) determined that the prey biomass was lowest below the cold water release dam (Le Fer 2006). Protected shoreline (inter-sandbar channels, inlets and backwater areas) had more invertebrate biomass than exposed shoreline (Le Fer *et al.* 2008). While chicks may gain weight more slowly in areas with lower prey base, it is not clear if this correlates with decreased survival, in part because sample sizes in the studies to date have been small, and predation has had a much larger effect on chick survival (Le Fer *et al.* 2008; Catlin 2009). Predation may be linked with slower chick growth in that chicks that grow more slowly may reach fledging later and thus be vulnerable to predation longer than their faster growing counterparts (Catlin *et al.* 2013).

Prey may be limiting in some cases on engineered sandbars mechanically created on the Missouri River to provide breeding habitat for plovers and least terns (*Sternula antillarum athalassos*) (Catlin 2009). With a small amount of habitat available, plovers have nested in high densities (approaching four pairs per hectare (2.5 ac) on constructed bars (Catlin *et al. in review*). If water levels rise over the course of the summer, less foraging habitat is available, and chicks must compete for limited forage. Under these circumstances, the engineered bars may actually be a population sink, if they attract a large number of birds which do not successfully raise chicks (Catlin 2009). Note that while piping plovers are capable of moving large distances to find nesting habitat, most birds nest relatively near to their previous year's nest (Friedrich *et al.* 2015). Presumably moving away from a known area has reproductive and survival implications.

Plovers on the alkaline lakes fledge at a younger age than those on the Missouri River system (Murphy *et al.* 1999; Catlin 2009). This has been postulated to be a result of more food resources available on the alkaline lakes than on the Missouri River (Le Fer 2006). There is limited evidence that food resources on the alkaline lakes may be produced on the nearby prairie (Nordstrom 1990). If so, changes in surrounding land use may change the available prey on alkaline lakes.

3. Migration

Piping plover migration is not well-defined. Piping Plovers appear to be low-density migrants throughout the midcontinent, often observed singly or in small groups. They appear to use sites opportunistically and therefore do not have regularly-used stopover sites in the central portion of the country, making management for piping plovers during migration difficult (Pompei and Cuthbert undated). One color-banded juvenile was reported to migrate more than 1,200 miles (2,000 km) from North Dakota to the Texas coast in less than five days, suggesting that migration may occur over short periods (Knetter et al 2001). Because there are few sightings of plovers in migration, it is difficult to parse out survival during migration versus during the breeding or winter seasons (LeDee 2008), but overwinter survival appears to be high (Drake *et al.* 2001; Cohen *et al.* 2008). Mortality may be higher during the northerly migration than the southerly, due to spring weather conditions or habitat-related effects on the wintering grounds (LeDee 2008). However, low sample sizes preclude firm determinations.

4. Population Trends, Breeding Distribution, and Habitat Requirements

Overall NGP Population Trends

The Northern Great Plains population is geographically widespread, with many birds in unpopulated areas, especially in the United States (U.S.) and Canadian alkaline lakes region. Determining the number of birds or even identifying a clear trend in the population is challenging. The International Piping Plover Census was designed, in part, to address this problem by implementing a range-wide survey every five years, starting in 1991. During a two-week window, monitors attempt to survey every area with known or potential piping plover breeding habitat. The relatively short window is designed to minimize double counting if birds move from one area to another.

Although participation in the International Piping Plover Census has been excellent in the Northern Great Plains (Elliot-Smith *et al.* 2009) the large area to be surveyed and sparse human population in the Northern Great Plains make annual surveys of the entire area impractical. While monitors attempt to survey all potential habitat, regardless of land ownership, access is not granted to survey on some private land. Many areas are only surveyed during the Census years.

Figure 2 shows the approximate number of adult plovers in the Northern Great Plains (U.S. and Canada) recorded by the five International Censuses.

The wide swings in bird numbers appear closely tied to the amount of habitat available for nesting. The amount of available habitat, in turn, is largely caused by multi-year wet and dry cycles in the Northern Great Plains. The International Census may not be sufficiently robust in statistical design to inform our understanding of the population's dynamics. For example, the drop in 2011 likely does not represent such a severe decline in bird numbers, but rather primarily an inability to locate birds scattered across the landscape in an extremely wet year when nearly all habitat traditionally used for nesting was flooded. Additionally, the five-year time interval between census efforts may be too long to allow managers to get a clear picture of population trends and allow them to respond accordingly.

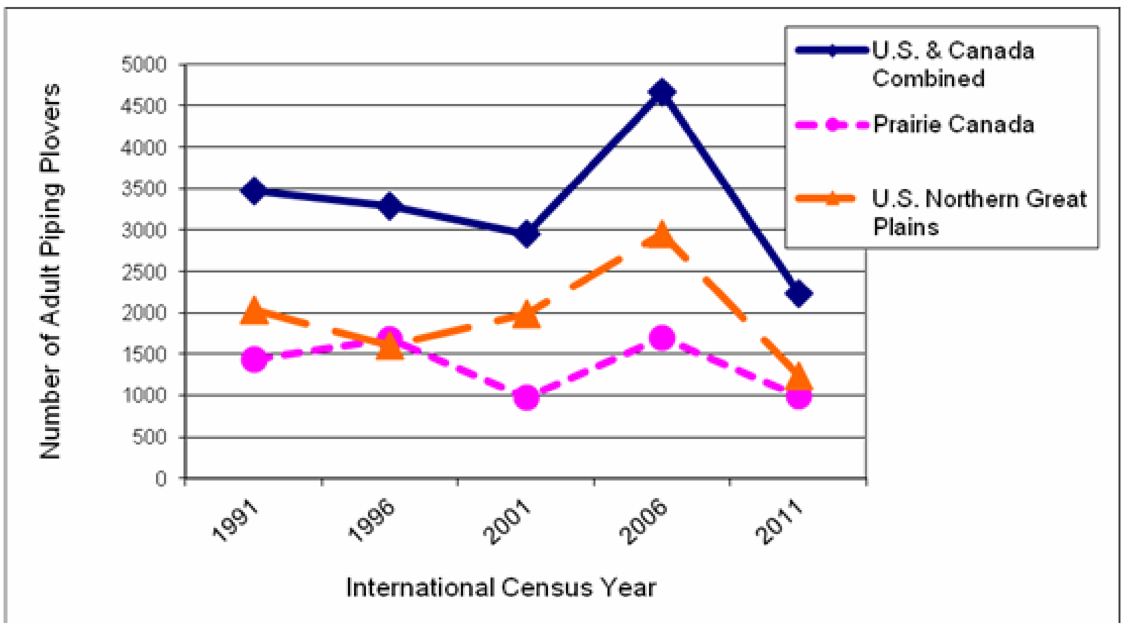

Figure 2. The number of adults reported for the U.S. and Canada Northern Great Plains during the International Censuses. Unpublished data

The U.S. Army Corps of Engineers (USACE) has conducted an annual adult census of piping plovers on the Missouri River since the mid-1990s. Data from this census feed directly into the International Census every 5 years. A recent review to evaluate the accuracy of the Missouri River census results found that the detection rates were low and substantially underestimated adult numbers (Shaffer *et al.* 2013). The study included two riverine segments (Garrison and Gavins Point reaches) and one reservoir (Lake Sakakawea). On the Gavins Point reach, where the birds were concentrated on engineered sandbars, surveyors underestimated plovers by about 25 percent, but in the other areas, adult estimates were 50 to 60 percent below actual values (Shaffer *et al.* 2013).

In 2006 and again in 2011, the International Census included a detectability survey, in which a number of pre-selected sites were visited twice during the two-week window to get an estimate of variation in numbers observed when the number of birds actually using the site presumably remained fairly constant. As of this writing (August 2014), the results are not yet available for 2011, but in 2006, detectability ranged between 39 percent to 78 percent among habitat types in the Northern Great Plains (Elliott-Smith *et al.* 2009). However, Shaffer *et al.* (2013) found that the number of adults in an area could vary substantially from week to week. Therefore, it is not clear whether two counts performed several days apart are appropriate to test detectability, since the number of birds present may have actually changed.

In 2008, a model was completed to examine the potential impact of the reproductive success of plovers associated with the Missouri River system (McGowan 2008). The model was developed as an interactive tool, allowing users to input different parameters (e.g., mortality, nest success, adult and juvenile survival, initial population size) to evaluate the modeled performance of the Great Plains' piping plover population. A number of estimates have been developed for survival (Prindiville Gaines and Ryan 1988; Root *et al.* 1992; Melvin and Gibbs 1996; Larson *et al.* 2000; Wemmer *et al.* 2001; Cohen and Gratto-Trevor 2011; Catlin *et al. In review*), ranging from 0.664 to 0.82 for adult survival (Root *et al.*1992; Catlin 2009; Catlin *In review*) to 0.24 to 0.57 for juvenile survival (Melvin and Gibbs 1996; Wemmer *et al.* 2001; Cohen and Gratto-Trevor 2011).

Because the numbers reported in the 2006 International Piping Plover Census indicated a dramatic increase compared to 2001, we ran the McGowan (2008) model using the higher-end adult and juvenile survival estimates from the literature and no mortality due to the operations on the Missouri River. We reasoned that, although average survival is probably between the lower and higher-end estimates, by using the higher-end numbers we could assess whether the very high numbers reported in the 2006 International Piping Plover Census seemed like a plausible increase in population due only to an increase in reproduction (rather than an increase in detection). With the high-end survival estimates, the model shows only a 13 percent increase over the five-year period on average. The upper bound using these high-end survival estimates of one standard deviation above average is 51 percent, 7 percent below the increase found during the 2006 Census. Earlier, Cohen and Gratto-Trevor (2011), using data from Saskatchewan, modeled a 40 percent increase in population from 2001 to 2006, while the measured increase from the surveys was 74 percent.

This suggests that despite the likelihood of some population increase between 2001 and 2006, it is unlikely that the population has actually grown to the extent indicated by the International Piping Plover Census (even with good habitat conditions in the intervening five years). Rather, a number of other factors may explain the apparent increase. The breeding population may have been under-counted in 2001 and/or over-counted in 2006. Plovers can easily be missed because of their cryptic coloration and secretive behavior, especially when surveying from a distance; conversely, the birds are also easy to over-count, especially when walking along a shoreline with a number of territorial pairs. The birds will often follow an observer for some distance, making it difficult to determine which individuals have already been counted. Additionally, the tight survey window and large survey area result in participation by less experienced plover surveyors. These problems are compounded when the count is done during a single visit to the area, making it difficult to ascertain how many plovers have been using the area that year or how they are distributed along the shoreline.

Population Dispersal

It is unknown whether plovers move to previously unused areas (rather than not breed) if habitat is not available in their previous nesting area. Based on International Piping Plover Census results, it has been hypothesized that birds on the Missouri River System move to the alkaline lakes to breed if river conditions are poor, and vice versa (Plissner and Haig 1996). However, despite extensive searching for banded plovers during the 2011 piping plover international census when there was very little habitat on the Missouri River, relatively few Missouri River birds were observed nesting on the alkaline lakes (Brennan 2014, pers. comm.). Birds which had previously nested on the Missouri River may have moved to sites which were not monitored, but no large scale movement was observed, despite efforts to find it. Similarly, only three of the many marked birds flooded out of Lake Diefenbaker, SK, were found nesting later the same summer at Chaplin Lake, SK (Gratto-Trevor 2014, pers. comm.). Altogether, even with considerable variability in habitat availability during the course of the study in Prairie Canada, there was little dispersal of adults (Roche *et al.* 2012) or young (Gratto-Trevor 2014, pers. comm.) from their original banding area. A study is currently underway to evaluate movement between Northern Rivers, U.S. alkali lakes, and possibly Canada (USGS 2014).

The available data underscores the importance of maintaining available nesting habitat throughout the breeding range. Most individuals remain in the same general area where they were fledged (Friedrich *et al.* 2015). If the species' range were to shrink to just one region within the NGP, a single event in that area could cause catastrophic loss to the population.

Habitat Acreage Requirements

There are few studies evaluating how much habitat is necessary for a plover pair to successfully raise a brood of chicks. From the information currently available, habitat should be available to support a density of no greater than 1.5–2 pairs/ha (0.58- 0.61pairs /ac) on occupied sandbars during each breeding season over the long term. So for each pair, 0.5-0.67 ha (1.2-1.7 ac) would be needed. The amount of habitat necessary may be tied to habitat quality (Mayer 1991; Le Fer *et al.* 2008). It has been hypothesized that when habitat quality is good, it supports a higher density of successfully nesting shorebirds than when it is poor (Kruse *et al.* 2002; Colwell 2010).

See Appendix 1B for a more in-depth discussion of the available information about acreage needed for successful breeding.

Habitat Improvement Options

There are a number of habitat modifications that may improve and maintain the habitat quality and reproductive success on the alkaline lakes as identified in the Actions section of this document including; exotic species removal, removing trees and other structures that attract predators, returning surrounding areas to grassland, minimizing human disturbance, ensuring the fresh water inputs and hydrology of the basins do not change (see Anteau 2012), and ensuring that alkaline lakes are not contaminated. For example, drainage and consolidation of smaller wetlands into larger wetlands increases fullness and decreases the dynamics of the larger wetlands. Wetlands historically used by plovers and that had been heavily impacted by consolidation drainage were fuller and used less by plovers than wetlands in intact landscapes (M. J. Anteau and L. A. McCauley, unpublished data). While addressing these issues will improve the quality of alkaline lakes habitat, the amount of habitat available on the alkaline lakes is driven by wet and dry cycles, and there are few additional actions that can change the amount of habitat available in a given year in the entire alkaline lakes region. Although piping plovers have been documented to live as long as 11 years, we estimate that with a 78 to 80 percent adult survival rate, the average lifespan is approximately 5-6 years, so most individuals will survive to breed in the next year if there is limited available habitat one year (Wilcox 1959; Cohen and Gratto-Trevor 2011; Catlin *et al.* *In review*).

By contrast, on the riverine systems, managers can take a number of steps to provide sufficient habitat for plover reproduction. Habitat can be created mechanically (i.e., dredging) or maintained through vegetation removal. These short-term efforts may bridge longer term efforts to support piping plovers at a stable to increasing population level. Because these methods are expensive and short-lived however, the emphasis should be placed on long-term solutions on river systems when possible. This includes implementing management to maintain the form and function of riverine ecology, including flows and sediment transport, to create and maintain habitat.

5. Population Viability

We used a model developed by McGowan *et al.* in conjunction with this recovery plan (2014; Appendix 2B) to evaluate current population viability. The model evaluated population viability in four management units/sub-populations; 1) Southern Rivers (Missouri River system from Fort Randall Dam, South Dakota to Ponca, Nebraska, the Niobrara River, the Loup River system and the Platte River system); 2) Northern Rivers (Missouri River system on Fort Peck Lake, Montana to Pierre, South Dakota); 3) U.S. Alkali Lakes; and 4) Prairie Canada (Figure 3). Overall extinction risk was found to be lower in this model compared with previous modeling efforts (McGowan *et al.* 2014). Even so, the estimated population extinction probability is greater than

5 percent in 3 of the 4 regions in the metapopulation. Due to the habitat work done in Southern Rivers, the extinction probability in that region was below 5 percent.

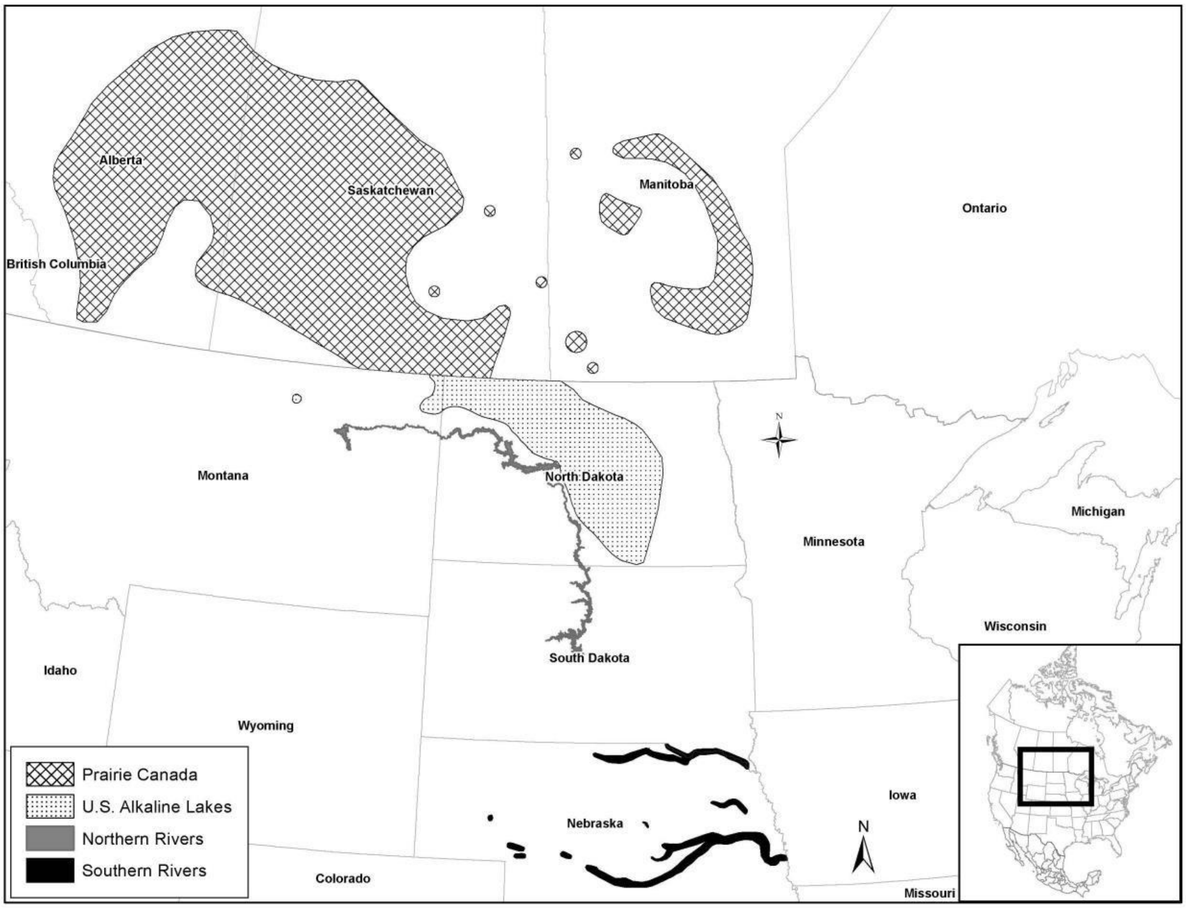

Figure 3. Four recovery regions for the Northern Great Plains piping plover population

E. REASONS FOR LISTING AND EXISTING THREATS (FIVE-FACTOR ANALYSIS)

Under Section 4 of the ESA (16 U.S.C. 1533), the USFWS is directed to examine five factors to determine if a species is warranted for listing as threatened or endangered:

(A) The present or threatened destruction, modification, or curtailment of its habitat or range;
(B) Overutilization for commercial, recreational, scientific, or educational purposes;
(C) Disease or predation;
(D) The inadequacy of existing regulatory mechanisms; or
(E) Other natural or manmade factors affecting its continued existence.

Here we examine the five factors and their on-going impacts on the piping plover.

Because the piping plover is broadly distributed across different types of landscapes, major threats in one part of the range may be minimal or non-existent in another. For example, river management can affect the abundance and distribution of nesting habitat but does not affect the alkali lakes habitat. In order to help the reader determine the relative importance of each threat, we ranked them as low, medium, or high by region. We evaluated the overall impact of each of the five-factors to provide an overall threat ranking. The results are shown in Table 2.

Table 2: Piping plover breeding grounds threats matrix. The threats are ranked according to their overall potential impact on the population based on the best available information and the Recovery Team's professional judgment. The Recovery Team considered the scope, severity, and intensity of each threat on the regional populations as well as on the population as a whole.

	Threat Level					
	Low	**Medium**	**High**	**Not Applicable**	**Unknown**	**Overall Threat Level**
Factor A: present or threatened destruction, modification, or curtailment of its habitat or range						***High***
Reservoirs, channelization of rivers, and modification of river flows	Prairie Canada[1]		Northern Rivers Southern Rivers	U.S. Alkali Lakes		
Commercial and industrial development	Southern Rivers Northern Rivers	U.S. Alkali Lakes		Prairie Canada		
Oil and gas development	Prairie Canada		U.S. Alkali Lakes Northern Rivers	Southern Rivers		
Agricultural development	Prairie Canada	Northern Rivers U.S. Alkali Lakes	Southern Rivers			
Neonicotinoids	Prairie Canada Northern Rivers	U.S. Alkali Lakes	Southern Rivers			
Wind power		Prairie Canada			U.S. Alkali Lakes Northern Rivers Southern Rivers	
Invasive species and vegetation growth		Prairie Canada	U.S. Alkali Lakes Northern Rivers Southern Rivers			
Density leading to intraspecific aggression	Prairie Canada U.S. Alkali Lakes	Northern Rivers	Southern Rivers			
Factor B: Overutilization for commercial, recreational, scientific, or educational purposes:						***Low***
Human Disturbance	Prairie Canada U.S. Alkali Lakes	Northern Rivers Southern Rivers				
Factor C: Disease or predation						***Moderate***
Disease	Prairie Canada U.S. Alkali Lakes Northern Rivers Southern Rivers					
Predation		Prairie Canada	Southern Rivers			

	Threat Level					
	Low	**Medium**	**High**	**Not Applicable**	**Unknown**	**Overall Threat Level**
		U.S. Alkali Lakes Northern Rivers				
Factor D: Inadequacy of existing regulatory mechanisms:						***Moderate***
Missouri River management			Northern Rivers Southern Rivers	Prairie Canada U.S. Alkali Lakes		
Oil and gas	Southern Rivers Prairie Canada		U.S. Alkali Lakes Northern Rivers			
Wind power		Prairie Canada[2]			U.S. Alkali Lakes Northern Rivers Southern Rivers	
Factor E: Other natural or manmade factors affecting the species' continued existence						***Moderate***
Power lines					Prairie Canada U.S. Alkali Lakes Northern Rivers Southern Rivers	
Climate change					Prairie Canada U.S. Alkali Lakes Northern Rivers Southern Rivers	

[1] These threats are high regionally, but have a low threat in other parts of the range. For example, reservoir management is very important for plovers on Lake Diefenbaker. Similarly, human disturbance is a major threat to piping plovers in much of Manitoba and Alberta, and in certain locations in Saskatchewan (e.g. lake Diefenbaker), but not a threat in many parts of the range.

[2] While we do not have information regarding piping plover risk of a wind turbine strike, planned projects between major piping plover sites may impact plovers moving between them.

1. **Factor A. Present or threatened destruction, modification or curtailment of habitat or range:**

Reservoirs, channelization of rivers, and modification of river flows

The 1988 recovery plan identifies reservoirs, channelization of rivers, and modification of river flows as a major threat due to the resulting reduction in sandbar riverine habitat, the flooding of remaining breeding habitat during the nesting season, and vegetation growth on sandbars that are rarely scoured by high flows. All of these are continuing threats.

Prior to settlement by Europeans, river systems in the Northern Great Plains generally had large increases in discharge in the spring as water melted off of the prairie and then the mountains. These spring rises carried sediment that created sandbars. The water levels would then drop throughout the summer, exposing more acres of sandbar as the season progressed (USFWS 2003b). After European settlement, river management emphasized predictable flows suitable for navigation, and to minimize seasonal flooding. River channels were straightened and channelized, and a number of dams were constructed. These dams greatly impacted sediment inflow into the system, reducing the amount of sand available for sandbar creation (National Research Council 2002).

Damming and water withdrawals have also altered the Northern Great Plains river systems since European settlement. On the Missouri River, flows formerly declined over the summer as tributary flows decreased. Today, these flows generally increase during the breeding season to provide for downstream human needs (USFWS 2003b). This means that less sandbar habitat is available over the course of the summer, rather than more, as would have been the case prior to dam construction. Alterations in the central Platte River flows due to changes in timing and volume of water have resulted in decreased channel widths and less sandbar habitat (National Research Council 2004).

Reservoir water levels follow regional climate cycles, experiencing drawdowns during dry periods and reaching full pool during wet years. Large areas of habitat may become available for nesting Piping Plovers during long-term drawdowns. Habitat availability is dependent on reservoir cycles, as beach areas around reservoirs with stable water levels become encroached by vegetation. Reservoirs where the exposed-inundated shoreline dynamic occurs and where Piping Plovers breed include Lake Oahe and Lake Sakakawea on the Missouri River and Lake McConaughy on the North Platte River (USFWS 2009a). From 1993 to 2012, reservoirs accounted for 44 percent of plovers recorded on the Missouri River (USACE 2014). Because detection rate of plovers on Lake Sakakawea has been shown to be lower than on riverine portions of the Missouri River (Shaffer *et al.* 2013), the actual percentage was probably higher and may have exceeded 50 percent. Elliott-Smith *et al.* (2009) reported that 29 percent of Northern Great Plains plovers during summer 2006 were on reservoirs. Water-level rises on reservoirs are common during summer when plovers are nesting. Nest inundation is the greatest threat to plover nest success on Lake Sakakawea and probably other reservoirs (Anteau *et al.* 2012). Those authors found that observed and model-predicted annual nest success estimates for plovers on Lake Sakakawea from 1985 – 2012 were markedly lower than those observed at other breeding areas. They concluded that heavy use of Lake Sakakawea by plovers represents a potential threat to population persistence because of potential negative impacts to recruitment (Anteau *et al.* 2012).

The USACE created sandbar habitat mechanically on the Missouri River from 2004 through 2011 and has attempted to identify an effective method of removing vegetation from existing sandbars. However, more sandbar habitat is being lost on the riverine stretches of the Missouri River annually than created, except in extremely rare years with exceptionally high water when flows are high enough to reposition sediment and to create sandbars, (USACE 2011; USACE 2013). The abundance of nesting habitat on the reservoirs generally declines as the reservoirs fill, and there is a corresponding increase in releases through the dams which inundates sandbar habitat downstream in the riverine reaches. Thus, there is generally an inverse relationship between the amount of water in the Missouri River system and the abundance of nesting habitat for piping plovers (USACE and USFWS 2010).

Managers in Nebraska have also manipulated habitat intended to benefit piping plovers. The USFWS Partners for Fish and Wildlife Program has worked on the central Platte River in Nebraska to remove vegetation from islands, reshape existing islands, and create mid-channel islands using dredges to deposit material since 2007 (Dinan 2009, pers. comm.). There are instances of piping plovers successfully raising young on these areas. However, few nests (<10) have been detected on the central Platte River in recent years.

The Platte River Recovery Implementation Program, a partnership between Colorado, Wyoming, Nebraska and the Department of Interior as well as conservation organizations and water users, was developed to improve the management of the Platte River (Platte River Recovery Implementation Program 2014). The Platte River Recovery Implementation Program's goal is to provide habitat for federally-listed species that rely on the Platte River system, while also supporting other water uses (Platte River Recovery Implementation Program 2014).

The lack of sufficient habitat due to modification of river flows continues to negatively impact the piping plover. Depending on the year, up to 45 percent of the birds in the U.S. Northern Great Plains may nest on river systems (Haig and Plissner 1992; Plissner and Haig 1996; Ferland and Haig 2002; Elliott-Smith *et al.* 2009; USFWS 2009a; USFWS 2009b; USACE and USFWS

2010; Brennan *et al.* 2011; Nelson 2011; USACE and USFWS 2011; Brown *et al.* 2012; USACE 2012; USACE and USFWS 2012; Brennan 2013; Peyton and Wilson 2013). The lack of sufficient habitat is likely interrelated with other threats to piping plovers, including intraspecific aggression (aggressive interactions between piping plovers, especially adults to non-related chicks) and predation.

Commercial aggregate (sand and gravel mining)

Commercial aggregate, or sand and gravel mining was identified as a threat in the 1988 recovery plan. However, proactive management at commercial aggregate mines and other human-created habitats can help avoid adversely affecting plovers and may increase reproductive success. Human-created off-river habitats are disturbance-mediated and require management once the disturbance, usually industrial operations, ceases. Because of the need for perpetual management to maintain suitability, human-created off-river habitats do not serve as solutions for long-term recovery. However, with proactive management to maintain habitat, piping plovers have been documented to successfully breed in off-river habitat, and with careful management, we no longer describe sand and gravel mining as a threat.

Surface aggregate mining is ongoing in Nebraska in the lower and central Platte River systems, including the Loup and Elkhorn Rivers. Dredging operations create piping plover habitat by depositing waste sand around central lakes; plovers nest on these spoil piles. Often, when aggregate production is finished, real estate developers convert the sites into housing developments (Baasch 2012a, pers. comm.; Brown 2012, pers. comm.). In other cases, the lake is filled in and the topsoil replaced, returning the area to agricultural crop production. Some lakes have been constructed for housing developments without first mining the area (Jorgensen 2012, pers. comm.). Human disturbance, including dogs and feral cats, can interfere with piping plover nesting if left unmanaged (Brown 2012, pers. comm.). In some cases, human-created off- river habitats have been designed specifically to promote piping plover and least tern nesting, and extensive vegetation removal has taken place to provide and maintain nesting habitat for least terns and piping plovers (Baasch 2012b, pers. comm.).

The Nebraska-based Tern and Plover Conservation Partnership, the Nebraska Game and Parks Commission, and the USFWS cooperate with and provide technical support to entities that own or use human-created off-river habitats to avoid or minimize adverse effects to plovers, improve reproductive success, and increase recruitment of birds into the breeding population. Specifically, the Tern and Plover Conservation Partnership works with industrial operations, real estate developers, utility companies, dredge operators and others to develop management plans that provide the ability for aggregate mining or construction operations to continue during the nesting season while identifying protected areas where piping plovers can breed. The Tern and Plover Conservation Partnership accomplishes their objectives by discouraging nesting in certain areas using various techniques including 1) placing mylar grids (mylar tape streamers are placed in a grid so that their flapping motion and reflective light will deter nesting in the area) in places where plovers might nest, 2) planting an annual grass cover, 3) overtopping the sand with topsoil or large diameter gravel, or 4) frequently raking the sand (Brown *et al*. 2012).

The Tern and Plover Conservation Partnership then monitors nesting activities throughout the summer and attempts to improve reproductive success by 1) fencing nesting areas to keep out potential predators and humans, 2) placing signs and psychological fencing (twine stretched between signs) to discourage people from entering nesting areas, and 3) placing predator exclosures (cages which keep large predators out while allowing attending adults free access to and from the nest) on nests where possible. With this program in place, the number of both adult plovers nesting and juveniles fledged has varied by site and by year. These actions do seem to increase reproductive success, although the amount of habitat available likely still drives the adult numbers and fledgling success (Figure 4).

Although off-river human-created habitats can provide suitable breeding habitat, the threat remains because of a need for intensive ongoing management. Off-river human-created habitats are used by birds in conjunction with sandbar nesting habitat available in nearby rivers. In recent years, because of lack of sandbar habitat in the nearby Platte River due to anthropogenic changes in river hydrology, off-river human-created habitats have been more regularly used for breeding (National Research Council 2004). The amount of human created off-river habitat is dependent on human activities. If human actions cease or change, for example aggregate mining operations change their extraction practices, these habitats could be reduced or eliminated altogether. Thus, relying on off-river human-created habitats as a means of achieving long-term recovery may not meet the conservation needs of the species. Options under different river management scenarious should be explored to provide sustainable riverine (sandbar) habitat over the long-term.

Sandbars have also been created on the central Platte River in Nebraska and vegetation removal has occurred on the lower Platte River in Nebraska, although high flows and/or habitat management are necessary following these actions to keep this habitat available as nesting habitat for piping plovers.

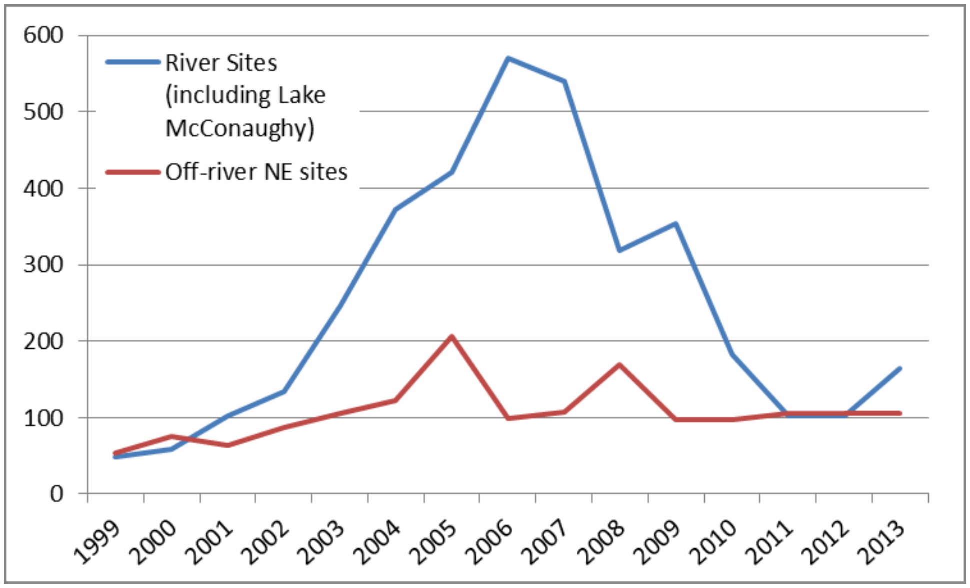

Figure 4. The number of adult plovers counted on riverine habitat (including Lake McConaughy) and on off-river manmade areas in Nebraska from 1999-2013
Note that these numbers represent attempts to count all birds present. We recognize that this is not a "census" since an unknown number of individuals were likely missed. However, the general trend data likely represents the population trajectory over the time shown.
Source: C. Aron, USFWS, *in litt.* 2014

With active management, commercial aggregate mining can be performed so that it has a minimal risk to the species. Ongoing work by the industry, state, and non-profit has shown that the bare habitat created in the mining process can actually provide habitat to nesting plovers. Therefore, we would characterize the threat of commercial aggregate mining as low.

Oil and gas development

The 1988 recovery plan notes that oil spills in the wintering range may be a threat, but it does not address the potential impacts of oil and gas development on the breeding grounds. Oil development on the breeding grounds has increased dramatically since the 1988 Recovery Plan was completed and remains a threat today.

In North Dakota and Montana, oil production near plover nesting habitat has increased substantially since 1988 due to exploitation of the Bakken oil shale formation, and many oil wells are now near known plover nesting areas. As shown in Figure 5, at least in North Dakota and Montana, this activity is concentrated in the alkaline lakes area, where approximately 20 to 30 percent of the NGP plovers nest (Haig and Plissner 1992; Plissner and Haig 1996; Ferland and Haig 2002; Elliott-Smith *et al.* 2009; Unpublished data from 2011 International Census). In North Dakota alone, there were 6,347 wells producing oil and gas in January of 2012, more than 1,000 more than just the previous year (5,067 producing wells), and nearly double the number of producing wells from five years earlier (3,449 producing wells in January 2007) (North Dakota Industrial Commission 2012). The impacts from oil development are largely unknown but potentially substantial.

The USFWS is not necessarily informed about oil activity unless a federal permit is required. USFWS personnel work with oil producers to avoid and minimize impacts to plovers. However, many wells are put in without any input or consideration regarding potential impacts on plovers. For instance, at White Lake in North Dakota, a number of wells have been constructed around the lake, including at least one on critical habitat (USFWS unpublished data). Biologists from state game and fish agencies are also working to reduce impacts from oil and gas development, but they are also rarely involved unless the state manages the land where development is proposed to occur.

Prior to production, seismic surveys are performed over an extensive area to determine the likely location of oil reserves. This requires large equipment that can leave permanent tracks in plover nesting areas, even under frozen conditions in winter. Plover chicks can have difficulty getting out of vehicle tracks, which may contribute to mortality (Eddings 1991; Howard *et al.* 1993).

If the seismic surveys suggest that there may be oil present, companies will construct oil pads and drill for oil. The pads are generally three to five acres and are located at least every 320 or 640 acres (half section to full section). The pads require new road construction as well as new powerlines for the additional load to run the pumps and other equipment. The extensive road construction and re-grading of county roads because of the truck traffic has increased the demand for local gravel mining extensively. Some of these gravel mines are in close proximity to nesting basins, and may cause noise disturbance to nesting plovers Brennan 2012, pers. comm.).

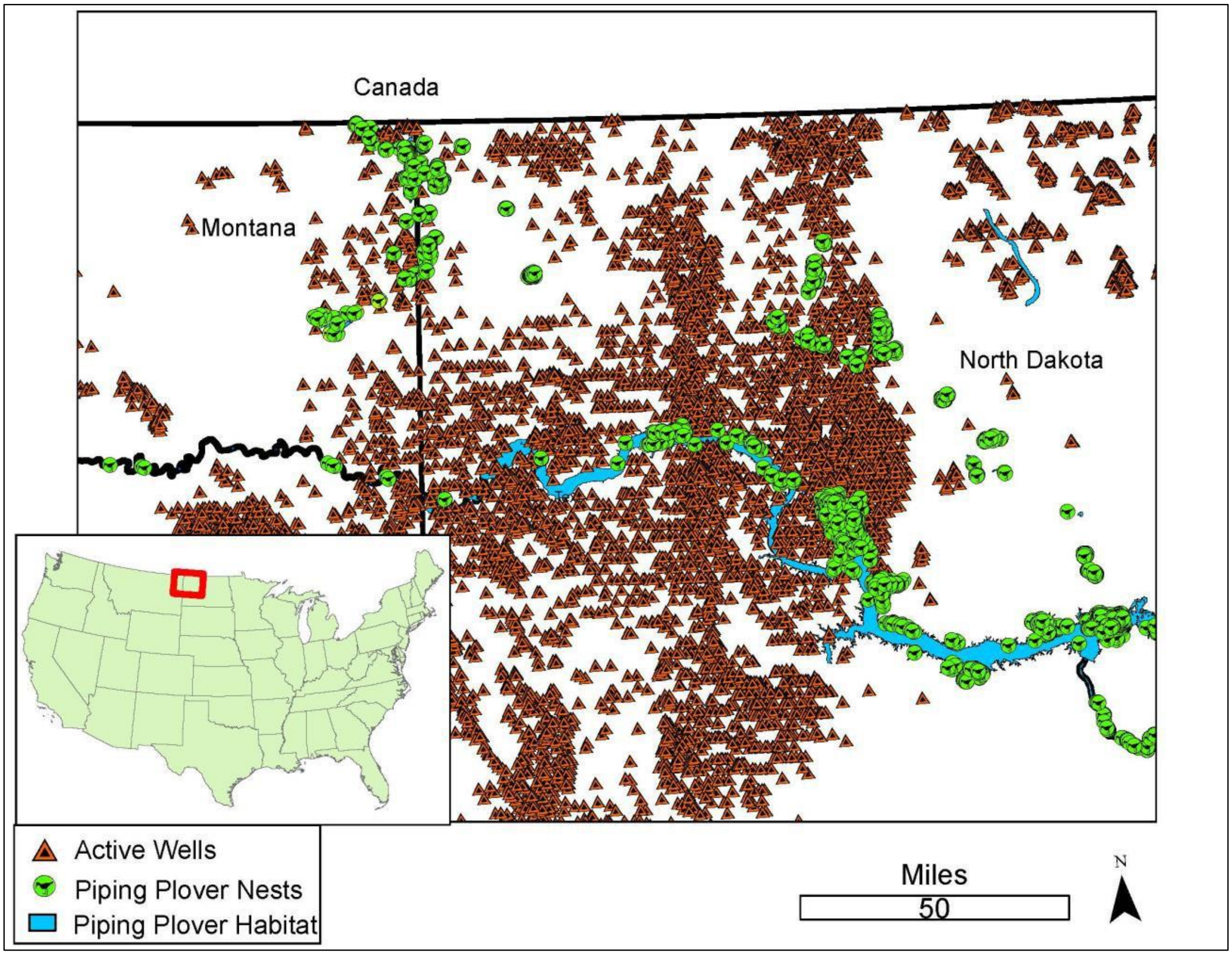

Figure 5**.** Piping plover nests and active oil and gas wells in North Dakota and Montana
Source: DNRC Montana Board of Oil and Gas 2011, North Dakota Oil and Gas Commission 2011, USACE 2012, USFWS 2012

The extensive road system built to access oil wells may cause direct mortality of adult plovers. Plovers were documented to be hit by cars on a road between Lake Audubon and Lake Sakakawea (a Missouri River reservoir) in North Dakota (USFWS 2004; M. Shriner, Western Area Power Administration, *in litt.* 2007; Anteau in litt. 2014). Plover mortality has also been documented from powerline strikes (M. Shriner *in litt.* 2007). Most roads and powerlines are not surveyed for dead birds, so the extent of impact of these features on plovers is not known.

Many oil wells are being placed near plover nesting areas as shown in Figure 5. Drilling activity produces continuous industrial sound that may be disruptive to nesting plovers when near nesting and rearing areas and occurring during the nesting season. The ongoing activity associated with a well in production may continue to cause birds to avoid nesting areas, depending on the proximity of the well to the potential habitat (Thomsen 2006). Additionally, a spill may permanently impact nesting habitat on the alkaline lakes or Missouri River. For example, while it did not impact piping plover habitat, a pipeline break on the Yellowstone River in 2011 resulted in 63,000 gallon oil spill (State of Montana and U.S. Department of the Interior 2013). With the large amount of oil development within the breeding range, there is a high potential of a spill impacting piping plovers and their habitat.

The reserve pits used for the waste material from the bore hole are often not covered with netting to prevent birds from accessing the pit. The USFWS recommends that companies net all pits and federal law enforcement in North Dakota has documented and fined a number of companies for killing migratory birds in these pits. To our knowledge, no plovers have been found in oil pits, but un-netted pits near plover habitat may cause plover mortality. Contamination from the reserve pits, either while the well is active or over time after the extraction is complete, may permanently impact piping plover habitat. Due to a 2012 court decision in North Dakota, it is not clear whether the USFWS can prosecute oil companies that do not take steps to ensure that reserve pits do not kill birds in North Dakota (United States of America v. Brigham Oil and Gas *et al.* 2012).

Another by-product of the drilling process is a brine solution with additional chemicals, some of them toxic. Each well generates approximately two-million gallons of produced water (water with brine and other chemicals) in the drilling process which is injected into a deep water well (North Dakota Department of Mineral Resources 2011). A release of this materialhas the potential to impact plover nesting habitat, either directly, or through contaminated ground or surface water. There is growing concern that many spills associated with oil and gas development that are either not reported or volumes are underestimated (Sontag and Gebeloff 2014).

Although the impacts of oil and gas production on piping plovers in the breeding areas are unknown, large-scale development and the spatial co-occurrence of development within important breeding areas raises concerns. The Bakken Formation in North Dakota, Montana, and Saskatchewan underlies major piping plover nesting areas on the alkaline lakes and Missouri River system (USGS 2008). The oil and gas activity may be placed near piping plover nesting beaches, impacting reproduction directly. Oil or by-product spills may also impact nesting piping plover habitat. Because piping plovers generally nest at the lowest point of the watershed, any spills would likely migrate to the nesting areas.

Agricultural Development

Alkaline wetlands of the prairie pothole region lie within an agricultural landscape and are subject to siltation, pre-mature filling and other impacts (Gleason and Euliss 1998). Wetlands in agricultural fields receive more sediment from upland areas than wetlands in grassland landscapes. Cultivation of the wetland catchment areas, where surface water runs off to the wetland basin, has greatly altered the dynamics of surface runoff and hydrologic inputs to groundwater. Excessive sediment input can potentially alter the aquatic food web and other basic wetland functions. Retaining grasslands or restoring grassland buffers around plover nesting basins may reduce siltation and other contaminant impacts.

Neonicotinoids

Neonicotinoids are a class of insecticide used as a seed coating for a variety of crops, including rapeseed, sunflowers, corn, wheat, barley, oats, field peas, beets and potatoes (Health Canada 2009; Goulson 2013; Main *et al.* 2014). While the insecticide is often applied to the seed prior to planting, the chemical is systemic throughout the plant, making it very popular with farmers because no further treatment is necessary for several months (Goulson 2013). Since their introduction in 1991, neonicotinoid use has been increasing dramatically (Goulson 2013; Hopwood *et al.* 2014). Neonicotinnoid-treated canola (rapeseed) seeds were used on nearly all of the 8.5 million ha of canola (rapeseed) planted in the Prairie Pothole Region of Canada (Main *et al.* 2014).

Neonicotinoids are water soluble and persistent, with a half-life in the soil ranging from 200 to more than 1,000 days (Goulson 2013). They tend to concentrate in wetlands or other water bodies (Goulson 2013). Because neonicotinoids work by binding permanently to specific receptors, they are toxic at any level in bees and presumably other insects given a long enough exposure time (Mason *et al.* 2013). Thus, they may affect the density and diversity of insects in affected wetlands. Killdeer abundance was negatively correlated with the amount of land in an area treated with neonicotinoids (Mineau *et al.* 2005). The relationship was only correlational, but suggests neonicotinoids may impact bird species in areas of use, and further study is indicated. We are not aware of any studies that evaluated the risk of secondary poisoning (i.e., impact to plovers from eating contaminated insects). Although unknown, given the widespread use of neonicotinoids and the tendency to accumulate in wetlands, persistence in the soil, and potential adverse effects on the quantity and composition of the insect community, neonicotinoids may have a negative effect on the piping plover population, particularly breeding areas in alkaline lakes.

Wind power

Wind energy generation in the Northern Great Plains has increased in recent years (American Wind Energy Association 2012). North Dakota has been identified as having the greatest wind energy potential in the U.S., and Montana having the fifth highest potential (American Wind Energy Association 2009). Wind energy development is closely tied to federal tax incentives, with development anticipated to increase in years when incentives are available and dropping sharply in years when incentives are not available (American Wind Energy Association

Undated). The potential impacts of wind farms on piping plovers are unknown. Possible impacts include direct collision with turbines or with the associated power lines, and avoidance in previously used areas where turbines have been constructed. We do not know altitude or routes used by plovers either during the breeding season or in migration, so the potential impacts of wind farms are unknown at this time.

Invasive species and vegetation growth

While the 1988 recovery plan identified loss of habitat as a threat to piping plovers, it did not specifically identify loss of habitat due to invasive species. Piping plover habitat is by nature ephemeral, with fluctuating water levels periodically clearing vegetation, which then grows back over time during dry periods. However, invasive exotics, particularly salt tolerant species, salt cedar and phragmites (common reeds), which are tolerant of flooding, are a growing concern in plover nesting habitat (Root and Ryan 2004; USACE 2010; Nelson 2011). On the Missouri River reservoirs, changing water conditions provide optimum conditions for noxious weeds to become established, with up to 200,000 acres of potential habitat exposed on Lake Oahe alone in dry conditions (USACE 2010). Salt cedar (*Tamarix* spp.), leafy spurge (*Euphorbia esula*), Canada thistle (*Cirsium arvense*), and absinth wormwood (*Artemisia absinthium*) have been identified as noxious weeds on Missouri River reservoir shorelines (USACE 2010). Other invasive species, such as kochia (*Kochia scoparia*) and clover (*Trifolium* spp.) have also been reported to rapidly take over plover habitat, precluding nesting (USACE 2010).

Cottonwoods (*Populus* spp.) and willows (*Salix* spp.), are generally the first species to colonize bare sandbars (Scott *et al.* 1997). While these species are native, they are problematic, because flows are rarely sufficient to scour them from riverine sandbars (Johnson 1994).

Vegetation encroachment is a major factor limiting the amount of suitable nesting habitat. Some small-scale projects have successfully removed vegetation using a combination of chemicals, fire, and/or mechanically removing vegetation (Dinan 2009; pers. comm., Nelson 2011). However, the success of clearing vegetation to restore or enhance piping plover habitat is not yet clear (USACE 2011). Invasive exotics may be even more difficult to remove than native species, so this problem is likely to increase over time.

A study of alkaline shoreline habitat over a 60-year period from 1938-1997 found that average beach width had narrowed during that period because of vegetation growth, leading to less available habitat for plovers (Root and Ryan 2004). The authors speculate that construction of reservoirs and water withdrawals for irrigation may be changing the hydrology of the alkali lakes region, affecting habitat availability. Consolidation drainage in which large wetland basins receive inflows from surrounding basins that have been drained has also altered the hydrology of alkali lakes, making them more stable and reducing amounts of nesting and foraging habitat

(Anteau 2012).

Density leading to intraspecific aggression

Although loss of habitat was identified in the 1988 recovery plan as one of the primary causes of the piping plover's decline, the specific impacts of limited available habitat were not explored. Negative behavioral effects may occur when nesting densities are high and adults attack non-related young (Catlin 2009). In the Northern Great Plains, this agonistic behavior is likely related to limited available habitat, as birds are forced to nest in dense concentrations and compete for resources (D. Catlin 2009; Catlin *et al. In review*). Four of five chick carcasses recovered on the Gavins Point river segment of the Missouri River in 2006, showed signs of trauma which may have been caused by intraspecific aggression (Catlin and Fraser 2007). Attacks by adults on non-related chicks have been observed in other shorebirds in years when food was limiting (Ashbrook *et al.* 2008). On the other hand, Murphy *et al.* (2001) documented no relationship between pair spacing and the number of fledglings produced at Appam Lake, an alkaline lake in North Dakota, although this lake was probably not as densely occupied by plovers as engineered sandbars on the Missouri River, and food was unlikely to have been limiting.

Intraspecific aggression seems to be a symptom of birds nesting so densely as to result in competition for resources. Limited nesting habitat due to a number of factors is a major threat to the species, likely affecting reproductive success and thus future recruitment into the population.

2. Factor B. Overutilization for commercial, recreational, scientific, or educational purposes:

Early 20th century accounts report that shorebird hunting caused the first known major decline of the species (USFWS 1988b). At the time of the 1988 plan, this factor was not thought to be a meaningful ongoing impact to the species in the Northern Great Plains. The USFWS is not aware of any significant new information regarding this threat.

The 1988 recovery plan suggests the species could be sensitive to impacts associated with scientific research and educational impacts. The original listing (USFWS 1985) does not identify scientific or educational impacts as applicable to the piping plover at that time. Since listing, these impacts have been carefully monitored and managed through the permitting process. The impacts of scientific research on piping plovers should be continued to be monitored closely.

Human disturbance

Human disturbance was identified as a threat in the 1988 plan and continues to be a threat today. In areas with high human disturbance, plovers spend less time foraging and brooding, and more time in alert behaviors (Cairns 1982; Flemming *et al.* 1988; Burger 1994; Gratto-Trevor and Abbott 2011). Evidence suggests that chicks that grow more slowly fledge later, and unfledged chicks are at a greater risk of predation (Catlin *et al*. In review), so human disturbance may decrease fledging rate. Piping plovers may avoid areas with high human activity, instead using less optimal habitat (Cohen *et al.* 2008).

Human disturbance is a particular problem in popular river or reservoir reaches where 20 percent to 80 percent of the Northern Great Plains plovers in the U.S. nest, depending on the year (Haig and Plissner 1992; Plissner and Haig 1996; Ferland and Haig 2002; USACE 2006; Elliott-Smith *et al.* 2009; Nelson 2011; Brown *et al.* 2012; USACE 2012; Peyton and Wilson 2013). The sandbar habitat that plovers require for breeding is also highly attractive for human recreation, including sandbars on the Missouri River, and reservoirs in Nebraska and Colorado (USFWS 2003b; Nelson 2012).

The USACE in Colorado and on the Missouri River, as well as at several locations in Nebraska, erects signs and fencing in order to raise public awareness about the importance of avoiding plover nesting areas (USACE and USFWS 2011, Brown *et al.* 2012, Central Nebraska Public Power and Irrigation District 2012, Nelson 2012, USACE and USFWS 2012,). The success of these measures can be difficult to ascertain, because the areas are not continuously monitored and reproduction may be impeded indirectly if adults do not tend to nests or chicks sufficiently because of disturbance.

Off-road vehicle use is not permitted on lands managed by the USACE. Despite these protections, reproductive failures have been attributed to human disturbance and off-road vehicle use is common, especially along rivers and reservoirs throughout the range (pers. obs., USACE and USFWS 2011).

As the waterfront areas in Nebraska, along the Missouri River, and on the shorelines of alkaline lakes become more developed, human disturbance is likely to become more prevalent. South Dakota wildlife conservation officers patrol Missouri River locations in South Dakota where humans are likely to recreate on sandbars and beaches used by plovers. U.S. Fish and Wildlife Service law enforcement agents also patrol throughout the U.S. range, especially during busy holiday weekends, but the large area to cover and the few law enforcement personnel mean that enforcement may not always meet public contact needs.

Overall, human disturbance is a large and growing threat to breeding piping plovers. As more people recreate on the river systems, they are more likely to use nesting areas, with the potential to directly or indirectly reduce breeding success.

3. **Factor C. Disease or predation:**

Disease

The 1988 recovery plan stated that disease was not known to affect piping plover recovery. However, the recovery plan indicated that botulism (USFWS 1988b) had not been carefully investigated and could prove detrimental in the future. Several of the alkaline lakes that support plovers have had historical outbreaks of botulism (National Wildlife Health Research Center *in litt.* 1994). Although botulism may be limited to a specific lake, it could cause a large local die-off.

Since 1988, West Nile Virus has emerged as a concern for avian wildlife species. Despite the fact that piping plover carcasses are rarely found and those that are found are generally not in good enough condition for the cause of death to be determined, a few piping plovers carcasses have tested positive for West Nile Virus (Sherfy *et al.* 2007). Presumably, other piping plovers succumbed to this disease that were not found or for which the cause of death could not be positively identified.

Managers should continue to be aware of the potential impacts of disease on piping plovers. However, at this time we do not have information to indicate that disease is a major threat facing the species.

Predation

The 1988 recovery plan mentions predation as a potential contributing factor to the species' decline in much of the Northern Great Plains. At that time, managers did not appear to think that predation was an important threat to the species. Since 1988, there has been considerable research on the potential impact that predation may be having on piping plovers on the breeding grounds (e.g., Strauss 1990; Kruse 1993; Ivan and Murphy 2005; Catlin *et al.* 2011). Predation occurs naturally, although researchers have suggested that high rates of predation are symptomatic of limited or poor quality habitat which forces the birds to nest too densely (Mayer 1991; Kruse *et al.* 2002). Predation does not appear to be a serious threat to plover nest success on at least one large Missouri River reservoir (Anteau *et al.* 2012).

Most areas in the U.S. and many places in prairie Canada apply nest exclosures to some or most of the plover nests to reduce the impact of nest predation (Prescott and Engley 2008; USFWS 2009b; Gratto-Trevor and Abbott 2011; Brown *et al.* 2012; Heyens *et al.* 2012; USACE and USFWS 2012; White 2012). Nest exclosures have been shown to improve plover nest success but may increase risks to adults since predators can key in on cages and kill the adults as they flush out of the cage (Murphy *et al.* 2003). Additionally, increased nest success may not lead to increased fledging success, since predators may be attracted to areas with a high density of chicks (Neuman *et al.* 2004).

Research suggests that while nest predators tend to be mammalian, chick predators are often avian (Ivan and Murphy 2005). Control efforts to remove avian predators that are thought to prey on chicks were initiated on the Missouri River in 2007 and on the U.S. alkaline lakes in 2008.

California (*Larus californicus*) and Ring-billed gulls (*Larus delawarensis*) have increased by more than 1.5 percent annually throughout most of the piping plover's breeding range from 1966-2011(Sauer *et al.* 2012). Gulls have been documented nesting on islands which had previously supported nesting piping plovers (Beyersbergen et al 2004). The islands that now have gull nesting originated from a variety of causes. Some of these islands are natural. Some are high points that became islands when Lake Audubon was created. In Lake Audubon, some islands have been protected from erosion to benefit nesting waterfowl and plovers by placing rip-rap around them. Still other islands were created in Lake Audubon specifically for piping plover or duck nesting (Frerichs 2014). The alkali lakes region has performed gull control at selected sites where gulls have taken over islands previously used by nesting plovers since 2008 (Brennan 2008). Anecdotally, gull control has been effective, with plovers successfully nesting in areas where gull colonies had formerly been (Mueller 2010).

A preliminary analysis suggests that removal of five great horned owls (*Bubo virginianus*) along the 59-mile Gavins Point River reach in 2008 significantly improved the survival probability of chicks on those sandbars after owls were removed (Catlin *et al.* 2011). While the increase was statistically significant, the number of additional chicks fledged was marginal for a relatively large amount of effort (Catlin *et al.* 2011; USACE and USFWS 2011). Predation control efforts are not always successful at increasing productivity to a level that would stabilize the population (USACE and USFWS 2012).

In some areas, predation appears to be a major impediment to reproductive success, and it possibly removes adults from the population. High predation levels are likely linked with a lack of sufficient high-quality habitat (Kruse *et al.* 2002; Murphy *et al.* 2003). Targeted predator control may be necessary in the short term, but long-term efforts should focus on the key underlying factor of providing sufficient nesting habitat.

Overall, predation appears to be a major factor impacting the Northern Great Plains population. Many cooperators perform predation control activities (caging nests, removing predators, removing trees from prairies) to improve piping plover productivity. Projects that provide more habitat for plovers indirectly reduce the predation threat since nesting plovers are more spread out and thus more difficult to target.

4. Factor D. Inadequacy of existing regulatory mechanisms:

Because of the piping plover's federal threatened status, the species is considered in environmental reviews prior to federal actions (e.g., issuing a permit) that may impact piping plovers or nesting habitat. Formal and informal ESA section 7 consultations are conducted regularly with a number of federal agencies, and the piping plover is considered when the USFWS reviews projects for the National Environmental Policy Act (NEPA). In addition, critical habitat has been identified for the Northern Great Plains breeding area, although the critical habitat designation was remanded in Nebraska (Nebraska Habitat Conservation Coalition v. USFWS 2005).

Piping plovers are also protected by the Migratory Bird Treaty Act (MBTA). While this statute protects plover adults, their active nests, and their young, it does not protect habitat when the birds are not there. Since habitat loss is a major threat facing the species, the species would likely continue to decline without additional habitat protection.

In addition, the states in which piping plovers breed have all identified the piping plover as a species of conservation concern in their State Wildlife Action Plans (Association of Fish and Wildlife Agencies 2007). Wildlife Action Plans are generally voluntary, comprehensive strategic plans that focus attention and funding on rare species, unique habitats and partnership opportunities to benefit both. The protections afforded by designation as species of greatest conservation need vary from state to state, but are not as comprehensive as protections under the ESA (Association of Fish and Wildlife Agencies 2007). All states within the breeding range participate in the International Piping Plover Census, and North Dakota, South Dakota, Nebraska, and Minnesota actively engage in annual management activities to improve reproductive success. The piping plover is a state endangered species in Minnesota and a state threatened species in Colorado, Nebraska, and South Dakota.

The Canadian Species at Risk Act (SARA), enacted in 2001, provides many protections for piping plovers in Canada that parallel those conferred by the ESA. In addition to prohibitions and penalties for killing, harming, or harassing listed species, SARA requires preparation of a recovery strategy, measures to reduce and monitor impacts of projects requiring environmental assessments, and protection of critical habitat (Environment Canada 2003).

Existing state and federal regulatory mechanisms, including the ESA, play a critical role in continuing to recover the piping plover on the Northern Great Plains breeding range. The USFWS, USACE, State, and non-profit organizations spend considerable time and money implementing actions to benefit the species. Because threats are being managed rather than eliminated, these entities would need to continue to manage for the Northern Great Plains piping plover population as described in Recovery Criterion 4 (see page 64).

Oil and gas

In North Dakota and Montana, where oil and gas production coincides with U.S. Northern Great Plains piping plover habitat, mineral rights are largely under private ownership, as are the surface lands. Without a federal nexus, consultation is not required and there is no regulatory requirement for companies to notify the USFWS of oil and gas activities that may have potential to adversely affect piping plovers, although some regulatory protections of the ESA and MBTA for piping plovers are applicable to activities on non-federal lands. Thus, we know very little about many wells that have the potential to impact plover habitat. As shown in Figure 5, this activity is concentrated on the Missouri River Coteau, including most of the U.S. alkaline lakes and the Missouri River system from Lake Sakakawea in North Dakota west (DNRC Montana Board of Oil and Gas 2011; North Dakota Oil and Gas Commission 2011;, USACE 2012; USFWS 2012c). A presidential order (Obama 2012) requires federal agencies to ensure the safety of gas production, but it is not yet clear how this order will impact on-the-ground activities.

Some pipelines are regulated by federal agencies (e.g., the Federal Energy Regulatory Commission or the State Department), and in these cases the USFWS can provide input into the design and placement of the pipe to avoid and minimize impacts to plovers.

Wind power

Unless they are larger than 100 megawatts (an average turbine in 2012 produced 2 megawatts of power, National Wind LLC 2012), wind power facilities (i.e., wind farms) do not require a state permit in North Dakota or South Dakota, and no state permit is required in Montana regardless of facility size (South Dakota Energy Infrastructure Authority *et al.* Undated, Association of Fish and Wildlife Agencies 2007; Montana Department of Environmental Quality 2011; South Dakota Codified Laws 2012). In Nebraska, the Nebraska Power Review Board permits wind projects greater than 80 megawatts, a process which triggers a review by Nebraska Game and Parks Commission (Nebraska Legislature 2010). Wind farms do not require a federal permit unless they are located on federally owned land or federal easements. As with oil and gas activities, while the ESA and MBTA apply, unless the wind farm requires a federal permit, the USFWS may not be aware of the project.

The USFWS is currently collaborating with wind energy developers on a multi-species Habitat Conservation Plan which is expected to result in a framework where participating companies from the wind industry can implement a number of nondiscretionary and discretionary, proactive conservation actions for the piping plover. This Habitat Conservation Plan encompasses most of the piping plover's U.S. NGP breeding grounds. When completed and if approved, this Habitat Conservation Plan is expected to include avoidance, minimization, and mitigation measures.

5. **Factor E. Other natural or manmade factors affecting the species' continued existence:**

Power lines

At the time of listing, the potential threat of power lines to plovers was not known. Additionally, there were many fewer power lines in the Northern Great Plains than there are today (Harris Williams and Co. 2010). As more power is produced in the Northern Great Plains, a large number of new power lines are needed to carry this power to population centers (American Wind Energy Association and Solar Energy Industries Association 2009). Overhead power lines have been documented to pose a strike risk to numerous bird species, including plovers (USFWS 2004; M. Shriner *in litt.* 2007). Since we know very little about plover movements, it is difficult to determine how much of an effect power lines may have on plovers. Marking lines with highly visible reflectors has been shown to be at least partially effective in reducing bird strikes in a number of species (Avian Power Line Interaction Committee 1994). The USFWS recommends that power lines in the whooping crane (*Grus americana*) migration corridor be marked near wetlands that may be used by whooping cranes. This recommendation would overlap nearly all of the plover's range in the United States. The USFWS does not have information indicating how many lines are marked at this time.

Overall, power lines have been documented to kill piping plovers when located in the flight path of two nesting/foraging areas, but it is unknown whether the increasing number of powerlines across the migration routes impact plovers.

Climate change

Climate change has the potential to be a severe threat to the species. According to the Intergovernmental Panel on Climate Change (IPCC) (IPCC 2007), "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" (IPCC 2007, p.1). Average Northern Hemisphere temperatures during the second half of the 20th century were very likely higher than during any other 50-year period in the last 500 years and likely the highest in at least the past 1,300 years (IPCC 2007). It is very likely that over the past 50 years cold days, cold nights, and frosts have become less frequent over most land areas, and hot days and hot nights have become more frequent (IPCC 2007). It is also likely that heat waves have become more frequent over most land areas and that the frequency of heavy precipitation events has increased over most areas (IPCC 2007).

The IPCC (2007) predicts that changes in the global climate system during the 21st century are very likely to be larger than those observed during the 20th century. For the next two decades a warming trend of about 0.2° C (0.4° F) per decade is projected globally; after this, temperature projections increasingly depend on specific emission scenarios (IPCC 2007). Various emissions scenarios suggest that by the end of the 21st century, average global temperatures are expected to increase 0.6 to 4.0° C (1.1 to 7.2° F) with the greatest warming expected over land. Finally, the IPCC projects a high likelihood that hot extremes, heat waves, and heavy precipitation will increase in frequency (IPCC 2007).

The average temperature in the Great Plains already has increased roughly 1.5° F relative to a 1960s and 1970s baseline (U.S. Global Change Research Program 2009). By the end of the century, temperatures are projected to continue to increase by 2.5° F (and up to more than 13° F) compared to the 1960–1979 baseline, depending on future emissions of heat-trapping gases (U.S. Global Change Research Program 2009). Across the U.S. range of the Northern Great Plains piping plover, summer temperatures are projected to increase 5° F to more than 10° F by the end of the century, depending on future emissions (U.S. Global Change Research Program 2009).

Northern areas of the Great Plains are projected to experience a wetter climate by the end of this century (U.S. Global Change Research Program 2009). Across the U.S. range of the Northern Great Plains piping plover, spring precipitation is expected to increase between zero and 15 percent under a lower emissions scenario and between zero and 40 percent under a higher emissions scenario.

This shift in temperature and moisture could have profound effects on piping plover habitat, which is dependent on wet-dry cycles to keep habitat clear of vegetation. Additionally, changing precipitation patterns in the Rockies would likely have profound effects on the amount of inflow into the Missouri River system, also affecting the amount of habitat available there. Precipitation data from 1901 through 2012 show an increase in average precipitation over the time period (NRCS 2012).

Given these projected changes, resource agencies will need to consider the range of possible effects associated with climate change when managing habitat. Recovery efforts will need to be able to monitor conditions and respond to contingencies.

F. CONSERVATION MEASURES

Conservation measures underway to protect the piping plover include habitat management, predator management, monitoring, research, and requirements for Federal protection. Federal listing encourages and results in increased conservation actions by Federal, state and private agencies, groups, and individuals. The ESA provides for possible voluntary land acquisition and cooperation with the states and requires that recovery plans be developed for all listed species. The protection required of Federal and state agencies and the prohibition against certain activities involving listed animals are discussed, in part, below.

1. Regulatory Protection

Federal Protections: The ESA contains several sections that provide regulatory protections for the piping plover. Designation of critical habitat, interagency coordination between the USFWS and other federal agencies on designing federal projects, and prohibitions against harassing, injurious actions, and killing piping plovers are some of the important protections provided by the ESA. The MBTA also protects piping plover adults, nests and chicks from direct, purposeful actions that cause injury or death, although it does not include habitat protection, and injury or death that occurs accidentally from an otherwise lawful activity may not be prohibited (United States of America vs. Brigham Oil and Gas, L.P, Newfield Production Company, Continental Resources, Inc. 2012).

Critical Habitat

The ESA defines critical habitat as (1) the specific areas within the geographical area occupied by those species, at the time it is listed in accordance with the provisions of section 4 of this law, on which are found those physical or biological features essential to the conservation of the species and which may require special management considerations for protection; and (2) specific areas outside the geographical area occupied by the species at the time it is listed in accordance with the provisions of section 4 of the ESA, upon a determination by the Secretary of the Interior (Secretary) that such areas are essential for the conservation and recovery of the species. Except in those circumstances determined by the Secretary, critical habitat shall not include the entire geographical area that can be occupied by the threatened or endangered species. The provisions under section 4 state: "The Secretary shall designate critical habitat, and make revisions thereto, under subsection (a)(3) on the basis of the best scientific data available and after taking into consideration the economic impact, and any other relevant impact, of specifying any area as critical habitat. The Secretary may exclude any area from critical habitat if he/she determines that the benefits of such exclusion outweigh the benefits of specifying such area as part of the critical habitat, unless he/she determines, based on the best scientific and commercial data available, that the failure to designate such area as critical habitat will result in the extinction of the species concerned."

Section 4 of the ESA also requires the Secretary to designate critical habitat, to the maximum extent prudent and determinable, concurrently with the listing of a species as threatened or endangered (16 USC 1533(a)(3)). If critical habitat is not determinable at that time, the Secretary may extend the period for designating such habitat "by no more than one additional year" (16 USC 1533 (b)(6)C(ii)). The final rule listing the piping plover as endangered (USFWS 1985) indicated that designation of critical habitat was not determinable. Thus, in 1986 designation was deferred for one year.

Defenders of Wildlife (Defenders) filed a suit to designate critical habitat for the Great Lakes population in 1996, and for the Northern Great Plains piping plover population in 1997. On February 7, 2000, the United States District Court for the District of Columbia issued an order directing the USFWS to publish a proposed critical habitat designation for nesting and wintering areas of the Great Lakes population of the piping plover by June 30, 2000, and for nesting and wintering areas of the Northern Great Plains piping plover by May 31, 2001. A subsequent order by the Court directed the USFWS to finalize the two critical habitat designations by April 30, 2001, and March 15, 2002, respectively. The USFWS chose to designate critical habitat for the wintering grounds for all piping plovers in a separate rule that was published on July 10, 2001 (USFWS 2001).

Designation of critical habitat does not imply, however, that all areas that may be essential for the species are covered by the designation. The rule acknowledges that other areas may become essential over time or may be considered essential upon availability of better information. Critical habitat also does not establish refuges or wildlife management areas. Activities which may occur within areas designated as critical habitat are subject to the consultation requirements under section 7 of the ESA, but only if there is Federal involvement in the action. Recovery plans, however, address all areas important for the species and identify management and conservation actions needed to recover the species. As such, the recovery actions described in this plan are not limited to the areas designated as critical habitat but apply throughout the range where the species may be found. When addressing habitat concerns, "essential" habitat is often referred to. This differs from critical habitat in several ways. Critical habitat is defined by regulation; thus it is a legal definition of the areas of suitable piping plover habitat that are considered essential to the conservation and recovery of the species. However, because it is not all-inclusive of all habitat areas that are, or that may become, biologically essential to the species, essential habitat is the focus of the recovery plan. Essential habitat, collectively, is all of the area that is essential to piping plovers on their breeding and wintering grounds, and during migration. Federal designation of critical habitat is one mechanism of protecting at least some portion of the essential habitat.

Critical Habitat on the Breeding Grounds

Critical habitat was designated for the Northern Great Plains population of the piping plover on September 11, 2002 (USFWS 2001). Nineteen critical habitat units originally contained approximately 183,422 acres of prairie alkaline wetlands, inland and reservoir lakes, and portions of four rivers totaling approximately 1,207.5 river miles in Montana, Nebraska, South Dakota, North Dakota, and Minnesota. The Nebraska portion of the critical habitat was vacated by U.S. District Court on October 13, 2005 due to incomplete economic analysis. The affected areas include: the portion of the Missouri River adjacent to Nebraska counties; Loup; Niobrara, Elkhorn, and Platte Rivers. Note that the court's decision did not address the biological importance of those areas, only the economic analysis.

Cooperation with States

All of the states within the piping plover's migrating and breeding range have identified the piping plover as a species of conservation concern in their State Wildlife Action Plans (SWAP) (Lester *et al.* 2005; Minnesota Department of Natural Resources 2006; North Dakota Game and Fish Department 2010; Colorado Division of Wildlife 2011; Montana Natural Heritage Program 2011; Schneider *et al.* 2011; Dowd Stukel *et al.* Undated,). The protections associated with this designation vary from state to state. State endangered species protections generally protect the species, but may not protect the habitat when the plovers are not present.

Table 3: State Protections

State	**Status**
Colorado	State Threatened, SGCN SWAP
Minnesota	State Endangered, SGCN SWAP
Montana	Tier 1, SWAP
Nebraska	Tier I, SWAP and State Threatened
North Dakota	Level II, SWAP
South Dakota	State Threatened, SGCN SWAP

SGCN – Species of Greatest Conservation Need

Sources: Colorado Division of Wildlife 2011, Dowd Stukel *et al.* Undated, Lester *et al.* 2005, Minnesota Department of Natural Resources 2006, Montana Natural Heritage Program 2011, North Dakota Game and Fish Department 2010, Schneider *et al.* 2011, Nebraska Revised Statute §37-801-11.

Section 7–Interagency Cooperation among Federal Agencies

Regulations implementing interagency cooperation provisions of the ESA are codified at 50 CFR Part 402. Section 7(a)(2) of the ESA requires Federal agencies to consult with the USFWS when federally permitted, authorized, or funded actions may affect listed species, including the piping plover. This consultation process promotes interagency cooperation in finding ways to avoid or minimize adverse effects to listed species. Section 7(a)(1) requires these agencies to use their authorities to further the conservation of federally listed species.

Section 9–Prohibitions against Take

Section 9 of the ESA prohibits any person subject to the jurisdiction of the United States to "take" listed wildlife species. The term "take" is defined to include harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting. It is also unlawful to attempt such acts, solicit another to commit such acts, or cause such acts to be committed. Regulations implementing the ESA (50 CFR 17.21) define "harm" to mean an act which actually kills or injures wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns including breeding, feeding, or sheltering. "Harass" means an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering. These restrictions apply to all listed species not covered by a special rule.

Section 10–Permits and Funding for Scientific Research and Conservation Actions

Section 10 of the ESA provides for permits to authorize activities otherwise prohibited under section 9 for scientific purposes or to enhance the propagation or survival of a listed species. Section 10 (a)(1)(A) permits have been issued for research, management (predator exclosures), captive rearing, salvage of eggs and carcasses, and banding of piping plovers from the NGP population. Also under section 10, it is legal for employees or designated agents of certain Federal or state agencies to engage in actions that directly take listed species without a permit, if the action is necessary to aid sick, injured, or orphaned animals or to salvage or dispose of a dead specimen. Activities that may proceed are limited by regulation, but may include many recovery research projects that are identified in this plan. The limits on this authority are detailed in 50CFR 17.21 (c)(5).

Section 10 (a)(1)(B) permits can also authorize take of a listed species that is incidental to an otherwise lawful activity, provided certain conditions have been met. In order to obtain an incidental take permit, an applicant must prepare a Habitat Conservation Plan. The Habitat Conservation Plan is designed to offset any harmful effects that the proposed activity may have on the species by minimizing and mitigating the effects of the authorized incidental take.

There is currently a Habitat Conservation Plan under development that will address the potential impacts of wind development on piping plovers in states including parts of Texas, Oklahoma, New Mexico, Colorado, Kansas, Nebraska, South Dakota, Montana and North Dakota. Another Habitat Conservation Plan is in the initial stages that will evaluate the potential impacts of a wind farm in south-central North Dakota.

2. Field-based Conservation Efforts

Surveys and Monitoring

Most sites where plovers are known to nest in the U.S. are surveyed at least once annually in June to determine if the birds are using an area. Along the Missouri, Niobrara (NE), and Platte (NE) Rivers, including a number of sandpits; John Martin Reservoir (CO); and many alkaline lakes; surveys are conducted at least weekly to find and determine success of nests and chicks. Monitoring has been conducted in many places since around the mid-1980's, with fairly consistent coverage of most sites starting in the mid-1990's. Due to budget constraints, a number of areas are not monitored regularly throughout the season.

Monitoring is performed by a variety of entities, including; Alkaline Lakes – USFWS and The Nature Conservancy; Missouri River – USACE and South Dakota Game, Fish and Parks; lower Platte River and Platte River sandpits – Nebraska Tern and Plover Conservation Partnership and Nebraska Game and Parks Commission; central Platte River – Central Platte Natural Resources District, Central Nebraska Public Power and Irrigation, Nebraska Public Power District, and Platte River Recovery Implementation Program; Niobrara – National Park Service and Nebraska Public Power District; North Platte River – Central Nebraska Public Power and Irrigation; and the Loup River – USFWS. In places where monitoring is performed, the information allows managers to identify and mitigate problems such as high levels of predation, human disturbance, and vegetation management needs. Less intensive presence/absence surveys can still give managers an array of valuable information, including; information on whether the population range is shrinking, expanding, or remaining stable, an indication of potential problems facing the population, and background information to evaluate risk to piping plovers from proposed development projects that may impact those areas. A more in-depth discussion and recommendations regarding monitoring can be found in Appendix 3B.

Protection of eggs

Predator exclosures (cages) allow adults to enter and leave, but prevent large predators from accessing the nest. These cages have been shown to increase nesting success on the Missouri River system from approximately 51 percent on non-caged nests to 70 percent on caged nests from 1993 through 2011(Pavelka, *in litt.* 2012). However, these numbers should be interpreted with caution since cages were not applied randomly. In some areas, nests were not caged because managers felt that the risk of predation was low. Interpreting the success of nest exclosure studies is problematic because most studies have lacked proper experimental design (Colwell 2010).

While additional chicks hatched can lead to more fledglings and thus ultimately a larger breeding population, cages should be deployed with care and monitored closely because of the potential risks. A "smart" predator can learn that eggs are associated with cages, and destroy all of the nests in an area, many of which would likely have been undetected without the cage. An increase in mortality of incubating adults may also occur (Murphy *et al.* 2003). Raptors can strike at the cage, causing the adult to flush. The predator then depredates the adult. Since all piping plover models have suggested that adult survival is the most important factor in population dynamics (Melvin and Gibbs 1996, Larson *et al.* 2000, McGowan *et al.* 2011), even a small amount of adult loss can have a negative impact on the population.

Predator Control

In areas where predation levels appear to be driving productivity to extremely low levels, predation control has been implemented. This includes great horned owl and gull control on the Missouri River system; gull control and mammalian trapping on the alkaline lakes; and mammalian poisoning and removal efforts in southeastern Colorado (Mueller 2010, Nelson 2011, USACE and USFWS 2012). Predator control can be effective at increasing chick survival, although results can vary dramatically (Catlin *et al.* 2011). Following gull removal, plovers returned to some nesting islands on the alkaline lakes which had not been used for a number of years (Hultberg 2011, USFWS, pers. comm.). While predation control can be an important tool in stabilizing and maintaining the population, high predation levels have long been associated with lack of sufficient habitat (Mayer 1991, Cote and Sutherland 1997, Kruse *et al.* 2002, Catlin *et al. In review*). Predation control has been demonstrated to be an effective interim measure to improve productivity, but ensuring that sufficient high-quality habitat is available is more effective as high predation rates are symptomatic of insufficient available habitat.

Predator exclosure cages do not exclude all predators; small mammal such as ground squirrels, weasels, and mink may still depredate eggs (Wiens and Cuthbert 1984; Mayer and Ryan 1991a,b; Ivan and Murphy 2005). Also, exclosures may increase the likelihood of nest abandonment (Murphy *et al.* 2003), particularly if exclosures are erected during the laying process, rather than the incubation phase (Colwell 2010; G. Pavelka *in litt.* 2012).

Breeding area protection from human disturbance

On river sandbars and reservoir shorelines with high potential for human disturbance, as well as on active sand and gravel mines in areas where piping plovers are likely to nest, managers erect signs informing the public that the area is closed due to piping plover (and often least tern) nesting. In some cases managers also erect "psychological fencing" made up of twine between signs as a visual barrier to keep people out of nesting areas (Brown *et al.* 2011b). Human piping plover monitors interact with the public on an informal basis as the monitors do their work.

Additionally, federal and state law enforcement officers patrol the areas to enforce compliance with the signage. Unfortunately, due to the large area to cover and limited staff, law enforcement presence may not be sufficient to address public contact needs.

Habitat Creation and Enhancement

On the Missouri River, sandbar islands were mechanically created in South Dakota and Nebraska from 2004 to 2011 (USACE and USFWS 2011; USFWS 2003b). The birds readily and successfully used this habitat for nesting and raising chicks, but breeding success declined dramatically as sandbars aged (Catlin 2009; Felio *et al.* 2009; Catlin *et al. In review*). The decline in reproductive success was likely related to increased density over time, leading to intraspecific aggression and elevated predation (Catlin 2009; Catlin *et al. In review*).

Sandbars have also been created on the central Platte River in Nebraska, and limited vegetation removal was done on the lower Platte River in Nebraska. High flows following these actions, however, have made this habitat unavailable (Jenniges and Plettner 2008; Brown *et al*. 2011b). Habitat has also been created and enhanced on sand and gravel mines along the Platte River system (Baasch 2012b, pers. comm.).

In southeast Colorado at John Martin Reservoir and Adobe Creek Reservoir, habitat is maintained using a combination of manually pulling plants, dragging potential nesting areas to make them barren, and applying herbicide (*Imazapyr*) to kill the remaining vegetation, primarily salt cedar (*Tamarisk* spp.) and cottonwoods (*Populus* spp.) (Nelson 2011). Piping plovers use these areas, although predation is very problematic, despite concerted predation control efforts (Nelson 2011).

3. Education and outreach

Managers in the North Dakota alkaline lakes region have developed and distributed outreach fliers for river users on the Missouri and Platte River systems and for landowners in order to explain piping plover (and least tern) needs. In addition, the Missouri River Recovery Program and the Tern and Plover Conservation Partnership in Nebraska have active outreach efforts. These are often aimed at school-age children through classroom presentations, or by developing and promoting classroom curriculum for use by teachers. Additionally, both programs participate in numerous festivals and events that reach both children and adults.

The Tern and Plover Conservation Partnership also has a number of additional outreach methods, including appearing on a monthly radio talk show in Lincoln, NE; having numerous newspaper and radio interviews; appearing on local access television; developing and promoting videos; and making numerous press releases. They actively engage with local and state government, including; local zoning and community planning boards; State senators (and legislative aides)

U.S. Senators and Representatives (and legislative aides); Lower Platte River Weed Management Area; County extension agents; Lower Platte River Corridor Alliance; Nebraska Natural Legacy Project; and the Nebraska Bird Partnership. Additionally, the Tern and Plover Conservation Partnership works with private homeowners and industry and engages sand and gravel mine operators whose work creates habitat that piping plovers use for breeding. The Partnership also works with housing developers and individual homeowners who build on the shorelines of lakes constructed specifically for housing development or on the shorelines of lakes left after sand and gravel mining has been complete. In addition, they have placed a "plover-cam" on a plover nest which is streamed on-line so that the public can watch the nest's progress and worked with Michael Forsberg (a wildlife photographer) and Nebraska Educational Television on a Platte River Time Lapse Photography project.

Nature Saskatchewan in Canada runs a Plovers on Shore (POS) voluntary habitat stewardship program whereby landowners sign a voluntary agreement to conserve shoreline habitat. Nature Saskatchewan has a variety of outreach materials available, including POS program brochures, a general brochure about the Piping Plover, as well as newsletters, a gate sign for interested POS participants, POS magnets, and a species at risk calendar, which features the Piping Plover (Nature Saskatchewan 2012).

4. Research

Research studies on the Northern Great Plains piping plover population have evaluated population dynamics, adult and juvenile survival, age of first breeding, sex and age determination, population movement, reproductive parameters, and habitat selection. Many of these studies have been discussed in previous sections of this document.

There have been a number of population models developed for the Northern Great Plains population (e.g., Prindiville Gaines and Ryan 1988; Ryan *et al.* 1993; Melvin and Gibbs 1996; Plissner and Haig 2000; Larson *et al.* 2002; McGowan and Ryan 2009; Cohen and Gratto-Trevor 2009). As empirical data regarding population parameters such as adult and juvenile survival, age of first breeding, nest success, and renesting rates improve, these models have been refined to incorporate our enhanced understanding of piping plover demographics. All of the models predict a population that is declining over time, with the exception of Cohen and Gratto-Trevor (2011) in Prairie Canada.

Banding studies have been done in the following areas: Saskatchewan, Alberta, Manitoba, Missouri River, including Lake Sakakawea, the Garrison River segment, Lewis and Clark Lake, and the Gavins Point River segment, Nebraska on the Platte River and sandpits, and on the alkaline lakes. Beginning in 2014, a banding study will begin on Lake Oahe (Missouri River) and expanded in the alkaline lakes. In addition, some birds banded on the wintering grounds to study the effects of the Deepwater Horizon Oil spill have been observed on the breeding grounds.

PART II. RECOVERY

A. Breeding Recovery Criteria for the Northern Great Plains Population

All of the recovery criteria for the Northern Great Plains population of the piping plover can be found in the Executive Summary section. Here, we only present those recovery criteria that relate to the breeding grounds.

Criterion 1: Using the most current estimates of region-specific breeding population and population growth (λ), the NGP plover population model indicates that the upper 95 percent confidence limit on the probability of a regional population going extinct within the next 50 years is < 0.05. This criterion is satisfied for all four regions (Figure 3). In addition, the following are met:

1. **for every region, population growth is stable or increasing (≥ 1.0) over a 10-year average, and is projected to remain steady or increasing over the next 50 years, and**
2. **the population will be distributed so that at least 15 percent of the population is in each of the following regions:**
    a. **Southern Rivers (Missouri River system from Fort Randall Dam, South Dakota to Ponca, Nebraska, the Niobrara River, the Loup River system and the Platte River system)**
    b. **Northern Rivers (Missouri River system from Fort Peck Lake, Montana to Pierre, South Dakota)**
    c. **U.S. Alkaline Lakes**
    d. **Prairie Canada (see discussion on page 60)**

Purpose: 1) To demonstrate that the breeding population is viable and projected to remain viable into the foreseeable future; and 2) to ensure that the breeding population is distributed across the range so that a catastrophic regional event does not negatively impact the entire population.

In order for recovery to be achieved, the breeding population should have been stable or increasing over a ten-year average (this time period can begin prior to the finalization of the recovery plan) and be projected to be stable or increasing into the reasonably foreseeable future. The population should be broadly distributed to reduce the risk of loss of a significant portion of the population. It is important for the population to be distributed throughout the range to maximize viability into the future and to reduce the risk of a stochastic event impacting a large proportion of the population. During the 2001 and the 2006 International Census (Elliott-Smith *et al.* 2009), no region contained less than 15 percent of the total number of breeding birds. We did not use the results from the 2011 International Census (Unpublished Data), because bird detection and therefore numbers were believed low throughout the range due to flooded conditions.

We did not use breeding pair abundance targets as part of this recovery criterion because research evaluating the monitoring program on the Missouri River determined that while trend data was relatively reliable, the population number was missing up to 60 percent of the birds in some areas (Shaffer *et al.* 2013). Improving count accuracy across the range to a level where it could be reliably used as a recovery criterion would be prohibitively expensive. Recovery can be reliably demonstrated without attempting to get a total bird count. Instead, we focus on trend data (which can be obtained through subsampling, see Appendix 3B) and ensuring that there is sufficient habitat (as required in Criterion 2, page 60) to support the population at a population level that is high enough to be resilient over time.

Banding data suggest that there is minimal interchange between the four regions identified above, with most plovers returning to the same general area from which they fledged (Gratto-Trevor *et al.* 2010; Roche *et al.* 2012; Catlin *et al. In review*), albeit a metapopulation study in Northern Rivers began in 2014 (USGS 2014), no major banding effort was ever undertaken in the U.S. alkali lakes region, and efforts to resight birds in the alkali lakes did not begin until 2008. At this time the best available information suggests that if plovers in one region were extirpated, the area would be unlikely to be recolonized successfully with any great number of birds.

We anticipate that as updated population parameter estimates become available (e.g., adult or juvenile survival, survival to fledging, number of individuals etc.) these will be integrated into the model to update estimates of extinction probability. Extinction probability estimates should be updated, at a minimum, every five years as part of the five-year review process. We also anticipate that the model will likely be updated and improved in the future as new information and modeling techniques become available. Every five years the USFWS, in coordination with the Piping Plover Recovery Team, will evaluate new information to determine if it is scientifically credible and whether the model should be updated or replaced. Thus, the best available science at the time the species is considered for recovery should be used to demonstrate that Criterion 1 is met.

Canadian Portion of the Range

Piping plover recovery can only be achieved by stable populations in both the U.S. and Canada. There is a Canadian recovery team for the Northern Great Plains portion of the population and biologists regularly coordinate across the border. We anticipate that the Canadian and U.S. biologists will continue to work together towards recovery. If the goals in the current Canadian Recovery Plan are met (Environment Canada 2006), we anticipate that approximately 15 percent of the population will likely be located in Canada.

Criterion 2: A minimum amount of suitable nesting and foraging habitat is available on a Regional Basis, as described below.

a. **1,630 ha (4,030 ac) in Southern Rivers (Missouri River system from Fort Randall Dam, South Dakota to Ponca, Nebraska, the Niobrara River, the Loup River system and the Platte River system)**
b. **1,320 ha (3,270 ac) in Northern Rivers (Missouri River system on Fort Peck Lake, Montana to Pierre, South Dakota)**
c. **1,460 ha (3,600 ac) in the U.S. Alkaline Lakes**
d. **1,460 ha (3,610 ac) in Prairie Canada (Provided for information only. We defer to the Prairie Canada Recovery Plan. See discussion about Canadian recovery criteria below.)**

Habitat is cyclical on the Northern Great Plains, so the habitat should be available, on average, a minimum of three-out-of-four years. For example, the criteria would be met if there were habitat available for a six year period in a region, followed by two years of high water when most of the habitat was flooded. This criterion should be met for a minimum of 12 years prior to initiating delisting.

Purpose: To ensure that there is sufficient habitat broadly distributed on the breeding grounds to support a stable population.

The major threat facing the species on the breeding grounds is a lack of sufficient habitat available frequently enough to support the population at recovery levels. Many of the other threats facing the species (e.g., increased predation, inadequate forage, human disturbance) are directly or indirectly related to insufficient habitat on the breeding grounds. We recognize that piping plover habitat is by nature ephemeral, with good habitat available for several years after a high water event before becoming vegetated or eroded until it is flooded, starting the cycle again. Using the natural cycle and piping plover life history as a guide, we designed this criterion so that recovery can be achieved even if habitat is available on average in three years out of four. For example, habitat may be available for six years in an eight year period and still meet the recovery criterion even if habitat were limited in the remaining two years. Habitat should be measured on a regional basis; it does not necessarily need to be available in every location within the region at this frequency. For example, as long as there is 1,080 ha (2,670 ac) available overall in three out of four years in the Southern Rivers region, the criterion would still be met even if the Platte River system did not meet the requirement.

Twelve years was selected as the time period for the criterion to be met to encompass approximately three-to-four plover generation times. Also, as discussed below in the *Frequency of Habitat Availability* Section (page 62), we estimate that a habitat forming event likely occurred historically approximately every six-to-eight years, and the population would remain stable with a flood event (i.e., little to no habitat available during that year) occurring every four-to-eight years. Therefore, a 12 year period is long enough for several habitat forming events and a stationary population over time, albeit with fluctuations within that period as habitat forms and degrades.

Stepping down the habitat goal:
We recognize that the amount of habitat in specific areas will need to be stepped down further to provide local managers with goals specific to their area. We encourage managers within and between regions to start a dialogue to determine how much habitat each area can reasonably provide. We recognize that habitat is closely tied to population abundance, so areas with more habitat can be expected to support a larger percentage of the population.

Approach to the habitat criterion:
We used a model-based approach to determine the amount of breeding habitat necessary for a stable or increasing population in each region of the breeding range with a 95 percent confidence interval (i.e. less than 5 percent risk of extinction over the next 50 years). We used the best available information at the time of writing (2015) as input parameters for the model for life history traits (e.g., juvenile and adult survival). Since we recognize that efforts to estimate the population may not be accurate (Shaffer *et al.* 2013), we included observation error in the model. As additional research is conducted and better information becomes available, the model can be updated in the future and the amount of habitat required for recovery may change accordingly. The Northern Great Plains Piping Plover Recovery Team will evaluate new information and update the model as they deem appropriate. The model is described in detail in Appendix 1B.

Habitat needed per breeding pair:
As discussed in the *Habitat Acreage Requirements* section (page 25) and in Appendix 1B, modeling has found that 0.5 -0.67 ha (1.2-1.7 ac) is needed per breeding pair. From the information currently available, habitat should be available to support a density of no greater than 1.5–2 pairs/ha (0.58-0.61 pairs/acre) during each breeding season over the long term. So for each pair, 0.5-0.67 ha (1.2-1.7 acres) would be needed. Using the higher end of this range, 0.67 ha per pair should account for the fact that not all habitat identified remotely (the only feasible way of quantifying amount of habitat rangewide) will actually be suitable for piping plover breeding and foraging (see Prindiville-Gaines and Ryan 1988 and Anteau *et al.* 2012 for descriptions of piping plover habitat).

Frequency of habitat availability:

There are no historical data about annual habitat availability throughout the range. Therefore, we used proxy measures to estimate how often habitat would have been historically available. We used two independent approaches to evaluate how often habitat was likely available for piping plovers in the Northern Great Plains.

Recommendations for measuring habitat:
In order to determine how much habitat is necessary to support the population at a stable level into the future, we evaluated how much habitat was available in the various areas in years when reproductive success appeared to be adequate for a stable to increasing population and determined approximately how much habitat was necessary per adult pair (see discussion in the *Habitat Needed per Breeding Pair* section).

Ideally, habitat would be estimated several times throughout the breeding season, in early-to-mid June for peak nest initiation, and again in early July, when most chicks are on the ground. Recognizing that these data can be difficult and expensive to acquire and analyze, the most important data acquisition period is the first two weeks of June, to correspond with the time when habitat is likely most limiting because of the need for chicks to forage on the shoreline near where they hatched. Because both plovers and least terns are monitored in riverine areas, a data acquisition time in the first two weeks of June would provide information suitable for use with both species. Habitat data do not necessarily need to be collected annually, but we encourage entities to collect information on a regular schedule (e.g., every three to five years) so that habitat can be tracked over time and linked to bird numbers. Habitat can be evaluated remotely, using satellite data or other imagery with sufficient ground-truthing to ensure that the remote classifications are sufficiently accurate.

We recognize that not all of the habitat that is mapped as having the features associated with piping plover reproduction (bare, sandy/gravelly lightly vegetated sandbars or shorelines along rivers, reservoirs, or alkaline lakes) will be used by piping plovers for a variety of reasons, so the amount of habitat estimated from imagery will be an overestimate (but see Anteau *et al.* 2014b, 2014c). It is impractical to exclude the unused habitat across the range, but it is likely to be a relatively small subset of the total available habitat, and be roughly proportional to the total amount of habitat available (i.e., when there is a lot of habitat available, there will be more suitable habitat that is not used, when there is less total habitat available, there will be less unused habitat). There is likely some benefit to the birds, i.e., reduced risk of predation and reduced nest density-related issues, when birds are not crowded into limited suitable habitat. Continued study of habitat suitability will improve the definition of ‘suitable’ habitat and will aid in determining the appropriate amounts and densities needed to achieve recovery.

On rivers that have more naturalized hydrographs (e.g., the lower Platte and Niobrara Rivers in Nebraska), habitat may be estimable through proxy targets such as stream flow and channel width. These relationships need to be established and tested.

With the exception of portions of the Missouri River, the habitat has not been mapped throughout much of the range. For both the Northern and Southern Rivers, the habitat goal has been exceeded three times since 1998, and within 20 percent five times on Southern Rivers and four times on Northern Rivers (USACE 2012, USACE 2013). Note that these figures only represent a portion of the habitat available even in these regions.

Canada:

We are providing habitat goals for Canada here for informational purposes only. Since Canada also actively manages piping plovers and has developed their own recovery plan, we defer to their plan for that portion of the population.

We are following the goals set out in the Canadian Recovery Plan (Goosen *et al*. 2002):

- Increase piping plover populations to at least 1,626 adults (813 pairs) and maintain this population average over two additional consecutive international censuses with no net loss of habitat due to human action.
- Increase and maintain a median chick fledging rate of greater than 1.25 chicks/pair/year (based on population simulations, M.A. Larson, pers. comm.).
- Achieve minimum provincial population targets as follows: Alberta 300; Saskatchewan 1,200; Manitoba 120; Ontario (Lake of the Woods) 6.

Criterion 3 relates to coastal migration and wintering habitat. It can be found in detail in Volume II.

Criterion 4: Ensure commitments are in place and functioning as anticipated to provide long-term funding, protection, and conservation management activities in essential breeding and wintering grounds.

a. **Southern Rivers (Missouri River system from Fort Randall Dam, South Dakota to Ponca, Nebraska, the Niobrara River, the Loup River system and the Platte River system)**
b. **Northern Rivers (Missouri River system from Fort Peck Lake, Montana to Pierre, South Dakota)**
c. **in U.S. Alkaline Lakes**
d. **U.S. Wintering Grounds**

Purpose: To make sure that management commitments necessary for piping plovers' continued persistence are in place and functioning, and will continue to operate after the species is recovered.

In order for piping plover recovery to be assured into the future it is important for management entities to have commitments to provide habitat and to have demonstrated that they can and will implement these commitments into the future. In the breeding range, the flow and sediment dynamics on most of the river systems have been altered such that habitat has been eliminated or the quantity and quality has been drastically reduced.

Focused management efforts have attempted to recreate habitat lost by human alterations of river systems. However, some of these efforts have been unsuccessful. Those actions that are most likely to succeed are those actions that increase the dynamic function and capacity of river systems where breeding habitat is created and maintained by natural riverine processes. For river systems to be able to be run to approximate their natural processes, changes to floodplain management and, in some cases water allocation, would need to be addressed so that flows can occur without negative impacts on human infrastructure.

Changes in water timing and volume in riverine systems as a result of climate change may also require alterations in water resources and socioeconomic response to river management, requiring novel cooperative solutions..

We recommend that surveys be conducted to determine if plovers are present prior to constructing new projects, or modifying or protecting existing projects that may impact piping plovers or coastal habitat function. We recommend following the protocol laid out in Appendix 2W.a of the wintering portion of the plan (Volume II), performing multiple surveys over the course of an entire migration and wintering season. If surveys are not possible, plover use should be assumed if the Primary Constituent Elements for wintering habitat are present. If piping plovers may use the area, projects should be designed so that features necessary for plover wintering use are not impacted.

Projects within the wintering grounds should be designed so that the natural dynamic processes of the coastal environment are retained. Overwash events and channel migration should be allowed to create, restore, and enhance piping plover wintering habitat. In general habitat should be protected from new development, or modifications to existing development that stabilize shorelines and inlets, or that otherwise prevent natural processes from replenishing plover habitat. Human and pet access to roosting and foraging areas should be sufficiently restricted so that birds can feed and rest without being disturbed (activities should not significantly alter or disrupt the birds' behavior). Development and implementation of an outreach strategy that raises public awareness of the presence and foraging/roosting needs of plovers and other shorebirds would help to diminish this disturbance.

While the wintering grounds presumably extend into Mexico, we do not have good information about the percentage of the population that winters in Mexico. If more information becomes available suggesting that the Gulf in Mexico supports a large percentage of the birds, this issue will need to be revisited, in conjunction with Mexican biologists and managers.

At this time, because the USFWS has no authority outside of the U.S., we are not setting targets outside of the U.S., but acknowledge that for recovery, piping plovers and their habitat will likely require protection both in the U.S. and outside the nation's borders where they breed and winter. We encourage international partnerships to be developed and maintained to address piping plover recovery together (e.g., Association of Fish and Wildlife Agencies 2014).

Additional factors beneficial to the species but not known to be critical for recovery at this time:
While the following factors are not necessary for species' recovery, and therefore are not included as recovery criteria, they do represent potentially important considerations from a population dynamics standpoint. We encourage further research and monitoring work.

Additional Factor 1B: Maintaining the breeding population in the outer extents of the range
We recognize the importance of having a geographically dispersed population, and are cognizant of the risks associated with a shrinking range. As such, we encourage continued monitoring and management of the small populations in Colorado and Lake of the Woods, Minnesota to increase and stabilize the populations in these areas.

In particular, Lake of the Woods may have represented a route of interchange between the Northern Great Plains and the Great Lakes piping plover populations based on the presence of a larger population that was documented there as recently as the 1980s. Although an individual banded in the Southern Rivers portion Missouri River was documented attempting to nest in Lake of the Woods, these birds are currently isolated from the rest of the Northern Great Plains population and were not considered essential to the actual recovery of the Northern Great Plains piping plover population as a whole. However, we do encourage continued efforts to restore these populations in the hopes that they will flourish and contribute to the larger Northern Great Plains population in the future.

D. Stepdown Recovery Action Outline: Breeding

The stepdown outline lists actions to help to meet the recovery objective for the breeding portion of the recovery plan (for the winter actions see pages 75-119 in Volume II of the plan) The recovery objective could most successfully be accomplished by: 1) habitat protection, management, restoration and creation, 2) public outreach to minimize human disturbance and promote favorable land management, 3) regulatory commitments, 4) tracking population trends and monitoring reproduction, 5) tracking and evaluating species' response to climate change, and

6) evaluating this recovery plan regularly and evaluating success.

Following Recovery Plan guidance (48 CFR 43098), we have prioritized the recovery actions from 1-3. Following each action, the priority number is in parentheses.

The definitions are as follows:

Priority 1a An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

Priority 1b An action that by itself will not prevent extinction, but is needed to carry out a Priority 1a action.

Priority 2 An action that must be taken to prevent a significant decline in species population/habitat quality, or some other significant negative impact short of extinction.

Priority 3 All other actions necessary to provide for full recovery of the species.

The recovery tasks needed to meet the recovery criteria are outlined below. Each task is described in detail in section E. *Narrative for Recovery Actions: Breeding*. Estimated costs are outlined in the Implementation Schedule.

1B Habitat Protection, Management, Restoration, and Creation

1.1B Protect habitat on the breeding grounds to support piping plovers at recovery level goals. (1a)

1.1.1B Purchase easements or land in fee-title to protect piping plover habitat and the nearby watershed. (1a)

1.1.2B Measure habitat on the breeding grounds. (1b)

1.1.3B Evaluate existing data to determine plover movement between the Northern Great Plains regions to better understand movement over the long-term as local habitat conditions fluctuate. If data are lacking, work with partners to fill in major gaps in our understanding of regional movement. (2)

1.1.4B Establish carrying capacity (maximum number of pairs per ha of habitat) in various habitat types. (1b)

1.1.5B Identify areas where breeding habitat is limiting population growth. (1b)

1.1.6B Provide additional habitat in areas where habitat is limiting. (1a)

1.2B River system management: Ensure that river management mimics the natural system to the extent possible and furnishes sufficient high-quality nesting habitat to be available at a level to support piping plovers at recovery goals. (1a)

1.2.1B Design and implement the hydrograph in managed river systems so that sandbars are created and scoured by natural processes. On the Missouri

River, this will likely include transporting sediment past dams. (1a)

1.2.2B Identify and protect (through fee-title, easements, or some other conservation means) floodplain areas that can serve to increase the capacity of the channel so that natural flooding can occur to create sandbar habitat without impacting human structures. (1a)

1.2.3B Where feasible, remove bankline protection such as rip-rap and hard points so that in-channel features can be created and eroded by natural processes. (2)

1.2.4B Create habitat mechanically and remove vegetation from sandbars on river systems to provide nesting habitat for plovers. (2)

1.2.5B Develop a model to quantify how reservoir dynamics impact the piping plover population over time. In particular, determine conditions under which reservoirs are a source or sink and identify management actions that could be implemented to reduce the likelihood of them being a sink. (1b)

1.2.6B Based on the results of 1.2.5B, implement management actions on the reservoirs to benefit the piping plover population. (1a)

1.3B Alkaline Lakes: Identify and reduce threats in landscape ecology of the alkaline lakes basins such that the basins will provide quality self-sustaining habitat. (1a)

1.3.1B Restore the grasslands and hydrologic processes to areas surrounding nesting wetlands. (1a)

1.3.2B Provide permanent protection for piping plover habitat, including the surrounding watershed, through easements or fee-title. (1a)

1.3.3B Reduce consolidation drainage of wetlands into alkaline lakes. (1a)

1.4B Work with commercial aggregate (also known as sand and gravel) mining companies to operate mines to avoid adversely affecting piping plovers during operations. (3) 1.4.1B Monitor long-term habitat availability and reproductive output over time

on commercial aggregate mines. (3)

1.5B Implement steps to reduce unsustainable levels of predation risk over the long- term through ecosystem restoration. (1a)

1.5.1B Ensure there is sufficient suitable habitat on river/reservoir systems so that plovers do not nest at abnormally high densities. (1a)

1.5.2B Continue use of predator exclosures on nests as a short-term, palliative measure. (2)

1.5.3B Develop decision support tool for managers for caging and fencing decisions. (3)

1.5.4B Evaluate the effectiveness and risk of caging over space and time on hatching success compared to the increased number of fledglings produced and the risk of increased adult mortality. (2)

- 1.5.5 B Develop and implement management plans and/or evaluate habitat conditions for each nesting lake basin, including a minimum one-mile buffer surrounding the basin. (1a)
- 1.5.7 B Work with landowners agreeable to management (replanting with native grasses, fencing, grazing system management, off-site water development, removal of old buildings, rock piles) to improve habitat conditions. (2)
- 1.5.8 B Identify piping plover use areas where dogs and/or feral cats are present. Develop sample regulation(s) to address this situation and share with appropriate governing bodies. (3)
- 1.5.9 B Develop decision support tools for managers to determine when and where predator management is appropriate. (3)
- 1.5.10 B Implement predation control efforts as needed so that nesting and brood-rearing activities can occur successfully. (3)
- 1.5.11 B Investigate if predator removal efforts are effective. (3)

1.6B Protect breeding plovers and their habitats from impacts of energy development. (1a)

- 1.6.1 B Work with state, tribal, and federal officials to ensure that oil and gas development is constructed with sufficient contingency plans to prevent or ameliorate a spill before it impacts plover habitat, in particular the Missouri River system and alkali lakes. (1a)
- 1.6.2 B Work with state and federal officials and the industry on oil and gas wells and associated infrastructure development (roads, pipelines, saltwater disposal wells, etc.) to avoid impacts to plover areas. (2)
- 1.6.3 B Work with state and federal officials and industry developers to ensure that development does not impact alkaline lakes hydrology. (1a)
- 1.6.4 B Share locations of key plover areas with state and federal officials and industry and information about piping plover biology and threats to ensure they understand and observe a sufficient buffer to minimize disturbance and especially to be able to block potential spills before they reach piping plover habitat. (2)
- 1.6.5 B Work with state and federal regulators and industry representatives to ensure that oil and gas infrastructure (including disposal wells) have sufficient pre-placement information to be able to determine if negative impacts may occur. This should include testing for soil integrity and potential for leaching should a spill occur. (2)
- 1.6.6 B Research the risk of wind turbines on piping plovers on the breeding grounds and in migration. (1b)

1.6.7 B Implement measures to mitigate the risk of wind turbines on piping plovers on the breeding grounds and in migration. (1b – dependent on information from 1.7.6B)

1.6.8 B Evaluate the risk of energy infrastructure. (e.g. power lines) on piping plovers on the breeding grounds and in migration. (1b)

1.6.9 B Implement measures to mitigate the risk of energy infrastructure on piping plovers on the breeding grounds and in migration. (1a – dependent on information from 1.7.8B)

1.7B Identify and control plant species, with an emphasis on invasives, that may make habitat unsuitable. (2)

1.7.1 B Research effective treatments to remove invasive vegetation, especially on alkali wetland basins. (1b)

1.7.2 B Identify and eradicate non-native plant species that may overtake plover habitat. (1a)

1.7.3 B Replant areas near breeding habitat with native species and remove trees from nearby prairie. (2)

2B Public Outreach to Minimize Human Disturbance and Promote Favorable Land Management

2.1B Develop and implement comprehensive plans, reflective of local conditions, to manage and avoid conflicts and to address the social and public relations challenges resulting from restrictions placed on human activities and interests such as recreation, residency, economic development and commerce. Actions should be focused on areas where management actions intended to protect piping plovers may interfere with human activities. (1a)

2.1.1 B Engage area stakeholders and provide opportunities for them to participate in policy development and decision making regarding shared, private or public resources (1b)

2.1.2 B Conduct human dimensions studies at sites where human–Piping Plover conflicts occur, or have the potential to occur, to better understand the source of the conflicts and identify possible resolutions of those conflicts. Use the results of these on-going studies to develop education and outreach programs, adjust existing education and outreach programs and refine management actions so they are best adapted to the local environment and changing situations. (1b)

2.1.3 B Use comprehensive planning and implementation strategies to improve compliance with Piping Plover protection measures while avoiding and preventing conflict. (1b)

2.1.4 B Implement seasonal or partial area closures as needed to protect nesting birds from human disturbance. (1a)

2.2B Coordinate among state, federal, and tribal agencies as well as private landowners to ensure that plover protection is incorporated into development plans on or near plover habitat in order to avert negative impacts to plovers. (2)

2.2.1B Work with private landowners who own land that plovers use so that landowners continue to manage the land to benefit plovers. (1a)

3B Regulatory Compliance and Certainty

3.1B Develop a Conservation Strategy for the long-term management of piping plovers and their habitat, including a post de-listing plan. (1b)

3.1.1B Commitments to manage for piping plovers are incorporated into the relevant agencies management plans. (1b)

3.2B Work internally in the USFWS, and with federal and state agencies on projects so that there are no net negative impacts to plover habitat by assisting with design, implementation, permits, or mitigation measures. (3)

3.3B Ensure that conservation measures designed to offset the adverse effects of human activities, developments and management decisions are monitored for effectiveness. (2)

3.4B Ensure that incidental take that may be authorized pursuant to the ESA is consistent with recovery. (2)

4B Population Trends and Reproductive Monitoring

4.1B Continue monitoring efforts on the breeding grounds to track population trends and reproductive success. Monitoring efforts should be coordinated throughout the Northern Great Plains breeding grounds so that overall trends can be tracked across the range (See appendix 3B for a matrix on how this might be done across the range). Input monitoring results into the NGP plover model (see Appendix 2B) to assess progress towards recovery. (1b)

4.1.1B Evaluate monitoring to ensure that the methods are providing sufficient accuracy and information that provides usable input for management decisions. (2)

4.1.2B Continue working with private landowners and other owners/managers of plover nesting areas to allow monitoring and management efforts. (1b)

4.1.3B Develop and implement a post-delisting monitoring plan (3)

4.2B Work with biologists in Canada to identify and find solutions to international problems that may be impacting survival. (2)

4.3B Coordinate between research and monitoring programs across the NGP to determine demographic parameters across time as local and regional conditions change. (1b)

5B Climate Change Planning

5.1B Monitor status of State Wildlife Action Plan revisions and leverage opportunities to provide input on this species. (2)

5.2B Evaluate impacts to the breeding population from projected climate change modeling and analysis. (2)

5.2.1B Protect both existing habitat and suitable habitat in the projected area where the plover population may shift. (2)

6B Plan Evaluation and Revision (3)

E. Narrative for Recovery Actions: Breeding

In evaluating the Recovery Actions, the Recovery Team felt that actions that led to a sustainable ecosystem and that would allow the species to recover without ongoing management input should be given the highest Priority. However, we recognize that there are a number of actions that need to be taken in the interim to stabilize and increase the population, without which portions of the population may disappear. To help the reader identify our interpretation of each action, including the magnitude of the effect of the action, how much of the population it is likely to affect, and how long an action is likely to benefit the species, we included the following descriptors for each action.

Impact
High - has a large sustained benefit for the segment of the population affected by the action, e.g. habitat projects that alter the system in a way that allows for more natural function in the long term.
Medium- has a moderate benefit for the segment of the population affected by the action.
Low - has a net positive benefit for the segment of the population affected by the action.

Scale
Widespread - Benefits all or nearly all of the NGP population.
Regional- Benefits a significant portion of the population (e.g., the Missouri River system).
Local- Benefits only the birds that use a specific area (e.g., nesting on one alkaline (salty) lake).

Timeframe
Long - Benefits accrue into the foreseeable future, e.g. habitat projects that alter the system in a way that allows for more natural function.
Intermediate - Benefits are realized for several years, but for a limited time period.
Short- Benefits are limited to one season or less.

1B Habitat Protection, Management, Restoration, and Creation

1.1B Protect habitat on the breeding grounds to support piping plovers at recovery level goals. (1a) (Impact – High, Scale – Widespread, Timeframe – Long) Loss of habitat was identified as one of the key threats to the species in the original listing. This threat remains. A variety of factors, including increased recreational pressure, home construction in previously unpopulated areas, energy development, and climate change threaten the remaining habitat on breeding and wintering grounds. These habitat types often face unique threats (e.g., habitat on the alkaline lakes may be impacted by energy development, riverine habitat by highly modified flows, and all habitat types may be impacted by climate change and development).

Work with local landowners and managers so that there is sufficient habitat for plovers to thrive into the future.

1.1.1 B Purchase easements or land in fee-title to protect piping plover habitat and the nearby watershed (1a) (Impact – High, Scale – Local, Timeframe – Long) Long-term protection of piping plovers can be assured by purchasing the habitat the plovers use and the surrounding area. Purchasing interest in piping plover habitat or surrounding area can benefit plovers throughout the breeding range, including riverine systems and on the alkaline lakes, since the nearby habitat can help the natural ecosystem functions occur.

1.1.2 B Measure habitat on the breeding grounds. (1b) (Impact – High, Scale – Widespread, Timeframe – Intermediate to Short) To determine how much habitat is available for the piping plover population, the habitat should be measured regularly. Habitat measurement should follow the general parameters discussed in Criterion 2 (pages 60 to 64).

1.1.3 B Evaluate existing data to determine plover movement between the Northern Great Plains regions to better understand movement over the long-term as local habitat conditions fluctuate. If data are lacking, work with partners to fill in major gaps in our understanding of regional movement. (2) (Impact – Medium, Scale – Widespread, Timeframe – Long) Banding studies have found that plovers show strong local fidelity to breeding areas, with little interaction between regions. Coordinating analyses between existing banding projects will help to determine what is known about regional interactions. If necessary, additional research may help to fill in gaps in movement, especially during periods of drought or high water. Research should be designed to help determine actions to take to provide maximum benefit to the population as a whole.

1.1.4 B Establish carrying capacity (maximum number of pairs per ha of habitat) in various habitat types (1b) (Impact - High, Scale – Widespread, Timeframe - Long) Recommendations in this plan point to the availability of habitat as a measure of population size and health. Although estimates of carrying capacity exist, they mostly refer to occupied habitat. As monitoring moves forward, it is likely that remote sensing of habitat will be used to quantify habitat, and therefore progress toward recovery. Better classifications of habitat and then estimates of carrying capacity at a regional scale will be necessary to fully utilize this remotely sensed data and to fine-tune estimates of the amount of habitat needed to support the population.

1.1.5 B Identify areas where breeding habitat is limiting population growth. (1b) (Impact - High, Scale – Widespread, Timeframe - Long) The lack of sufficient suitable habitat was a key factor identified in the original recovery plan as a cause for the species' decline. Sufficient suitable habitat is likely still limiting, particularly in many years for breeding grounds on river systems. Continued development and lack of sediment on the dammed river systems may reduce the available habitat further. Additional habitat will need to be available to support the larger population at recovery levels.

1.1.6 B Provide additional habitat in areas in areas where habitat is limiting. (1a) (Impact - High, Scale – Widespread, Timeframe - Long) In areas where habitat is limiting population growth and stability, identify sustainable ways to provide additional habitat. Ideally, efforts should be focused on methods that serve to increase long-term ecosystem function.

1.2B River system management: Ensure that river management mimics the natural system to the extent possible and furnishes sufficient high-quality habitat to be available at a level to support piping plovers at recovery goals. (1a) (Impact – High, Scale – Regional, Timeframe – Long) The river systems in the Northern Great Plains are highly altered from pre-European times with greatly reduced sediment loads due to dams and reduced hydrographic variation. Currently, flows are rarely sufficient to create new sandbars or scour existing ones. Develop and implement release plans for rivers so that habitat is created and maintained through mimicking natural processes.

1.2.1 B Design and implement the hydrograph in managed river systems so that sandbars are created and scoured by natural processes. On the Missouri River, this will likely include transporting sediment past dams. (1a) (Impact – High, Scale – Regional, Timeframe – Long) Prior to dam construction and wide-scale water withdrawal, the rivers in the Northern Great Plains regularly flooded scoured sandbars and moved their large sediment load downstream. As the waters receded, the sediment settled out, leaving sandbars exposed over the course of the summer when flows were generally low. Today, flows are rarely high enough to scour or create sandbars, and because sediment is trapped behind the dams, the sediment carried on the Missouri River is a fraction of its pre-dam load. Design and implement the hydrograph so that high flow events allow transport of sediment (without flooding human infrastructure) to occur frequently enough to provide natural habitat for plovers. A regular natural hydrograph would likely also benefit other native river species.

1.2.2 B **Identify and protect (through fee-title, easements, or some other conservation means) floodplain areas that can serve to increase the capacity of the channel so that natural flooding can occur to create sandbar habitat without impacting human structures. (1a) (Impact – High, Scale – Regional, Timeframe – Long)** Because of the risk of flooding on the former floodplain, officials are reluctant to include water releases as a management option at sufficient volume to create or scour sandbars. Obtaining floodplain land along the river systems would allow for high water releases without impacting infrastructure. These areas would also reduce the human impacts of flooding during natural flood events. Retaining water in the floodplain of reservoirs (e.g. through keeping wetlands on the land rather than draining them) would also slow the inflows to reservoirs, reducing the mid-summer rise that inundates nesting habitat.

1.2.3 B **Where feasible, remove bankline protection such as rip-rap and hard points so that in-channel features can be created and eroded by natural processes. (2) (Impact – Medium, Scale – Regional, Timeframe – Long)** Many miles of riverine shoreline have been stabilized to direct the river away from the bank, while dams have drastically reduced the amount of sediment entering the system. This has a combined effect of increasing flow rate and erosion as the sediment starved water is more likely to scour in-channel habitat and less likely to be carrying a large enough sediment load to deposit material downstream. Removing hard structures (to allow overland flow in areas without human infrastructure) will reduce the impact of high flows on human structures downstream, allowing planned high flow events that can create and maintain sandbar habitat. For example, hard structures could be removed if areas are purchased as easements or fee-title to allow overland flow. Additionally, some hard points were put in to deflect flow but are not functioning as designed. These may be removed or allowed to degrade rather than maintaining them.

1.2.4 B Create habitat mechanically and remove vegetation from sandbars on river systems to provide nesting habitat for plovers. (2) (Impact – Medium, Scale – Local, Timeframe – Short) In the absence of regular flooding events on the river systems, habitat is generally created too infrequently to sustain or increase the population numbers. Providing habitat through mechanically creating sandbars (through dredging) or removing vegetation from bars has been demonstrated to be a successful technique to provide nesting plover habitat. As an interim step until the river systems are returned to more normalized flow and sediment regime, habitat may need to be constructed and maintained artificially to maintain the population.

The cost of these actions differs considerably. Vegetation removal is estimated to cost approximately $750/acre, while mechanically creating sandbars costs approximately $31,000/acre (USACE 2011). From a monetary standpoint, vegetation removal is clearly preferable, but the method cannot be the only method of creating riverine habitat for the following reasons. Because of regulated releases from dams, flows are rarely high enough to create new sandbars, so they tend to erode under normal flow conditions, decreasing the amount of available habitat. Also, vegetation removal has not always been effective at providing suitable habitat for piping plover use. If an area is heavily vegetated, it may be very difficult to impossible to create habitat using vegetation control without some mechanical component.

1.2.5 B Develop a model to quantify how reservoir dynamics impact the piping plover population over time. In particular, determine conditions under which reservoirs are a source or sink and identify management actions that could be implemented to reduce the likelihood of them being a sink. (1b)(Impact – High, Scale – Regional, Timeframe – Long) Under low-water levels, especially following a year with high water levels, reservoirs are very productive as vast expanses of suitable habitat are exposed for nesting and brood rearing. However, substantial water rises during the nesting season can result in reservoirs functioning as ecological traps because birds nest on habitat that is exposed in the spring, only to become inundated over the course of the season. A study/model to determine the long term effect of reservoirs on the population is needed. The study should include recommendations to reduce, and if necessary offset, the likelihood that the reservoirs are functioning as a sink.

1.2.6 B Based on the results of 1.2.5B, implement management actions on the reservoirs to benefit the piping plover population. (1a) (Impact – High, Scale – Regional, Timeframe – Long) Based on the results from 1.2.5B, implement actions on the reservoirs systems so that they do not function as a sink to the piping plover population. It may be necessary to provide additional habitat on the riverine reaches to offset the reservoir losses. The study may identify other options as well.

1.3B Alkaline Lakes: Identify and reduce threats in landscape ecology of the alkaline lakes basins such that the basins will provide quality self-sustaining habitat. (1a) (Impact – High, Scale – Regional, Timeframe – Intermediate) In general, the alkaline lakes area has been altered less from pre-colonial times than the riverine portions of the breeding grounds, although as discussed in Action 1.3.3B, wetland consolidation may now threaten alkaline lake habitat. However, grassland habitat has been converted to other uses, trees have been planted, and smaller wetlands have been drained into larger ones; factors changing sediment inflow, possibly predation pressure, and the piping plover forage base. In areas where the nearby habitat has been altered, identify features that can be manipulated to return the alkaline basins to a self-sustaining ecosystem so that plovers can complete the breeding cycle successfully without human intervention.

1.3.1 B Restore the grasslands and hydrologic processes to areas surrounding nesting wetlands. (1a-dependent on information from 1.3.1B) (Impact: Medium, Scale – Regional, Timeframe – Long) Manage for a grassland matrix in the basin surrounding the plover wetland.

1.3.2 B Provide permanent protection for piping plover habitat, including the surrounding habitat, through easements or fee-title. (1a) (Impact – High, Scale – Widespread, Timeframe – Long) Providing permanent protection to areas with documented plover use will ensure that documented nesting areas are protected through time. Acquiring interest in the wetlands plovers use for breeding and foraging in addition to as much of the watershed as possible is also recommended since this will reduce disturbance and the risk that upland activities change the hydrology, predation matrix, or other elements important to high-quality piping plover habitat.

1.3.3 B Reduce consolidation drainage of wetlands into alkaline lakes. (1a) (Impact-High, Scale – Regional, Timeframe – Long) As discussed on page 18, consolidation drainage, in which small wetlands are drained into larger ones to increase the agricultural land base, can change the hydrology of the wetlands, making them more stable and thus reducing the amount of bare exposed shoreline for nesting as well as changing the forage community. Work with landowner to keep the wetland hydrology unaltered. Some options include wetland and grassland easements, or purchasing the land base.

1.4B Work with commercial aggregate (also known as sand and gravel) mining companies to operate mines to avoid adversely affecting piping plovers during operations.
(3) (Impact – Low, Scale – Local, Timeframe – Short) Up to several hundred piping plovers nest within sand and gravel mines, lakeshore housing developments, and other dredging operations in Nebraska. Conservation organizations assist companies and property owners to avoid actions that may adversely affect nesting plovers during commercial operations. These habitats have finite lifespans and become vegetated unless they are continually managed or disturbed. Managing these areas for piping plovers while they are in operation provides additional habitat for nesting and brood-rearing in the Platte River floodplain. These areas also provide nesting habitat for the endangered interior least tern.

1.4.1B Monitor long-term habitat availability and reproductive output over time on commercial aggregate mines. (3) (Impact – Low, Scale – Local, Timeframe – Short) Habitat at artificial habitats such as aggregate mines and lakeshore development near pits requires long-term management if it is to remain suitable for piping plovers.

1.5B Implement steps to reduce unsustainable levels of predation risk over the long-term through ecosystem restoration. (1a) (Impact – High, Scale – Local, Timeframe – Short) Like other ground nesting birds, plovers likely always had a relatively high predation rate, but due to changes in the landscape and drastically reduced available habitat in some locations, predation pressure has increased to a level where some nesting areas are a reproductive sink. Predation control efforts have been demonstrated to be successful under some circumstances at improving chick daily survival. More research is needed to determine when control should be used and what predator species to focus on. However, even when effective, predation control is at best a short-term solution. Taking steps to restore the ecosystem should reduce unsustainable predation pressure for piping plovers and other native species. Short term fixes may involve predation control, but managers should work towards ecosystem approaches that do not require continued predation control.

1.5.1 B **Ensure there is sufficient suitable habitat on river/reservoir systems so that plovers do not nest at abnormally high densities. (1a) (Impact – High, Scale – Regional, Timeframe - Intermediate)** Research has indicated that predation risk is closely tied with the amount of available habitat. As amount of suitable nesting habitat dwindles, plovers nest in smaller patches closer to vegetation and/or more densely, making them much more susceptible to predation. Ensure that sufficient habitat is available on a regular basis for the population to nest without excessive predation pressure.

1.5.2 B **Continue use of predator exclosures on nests as a short-term, palliative measure. (2) (Impact – Low, Scale – Local, Timeframe – Short)** Use of predator-exclosure cages (that allow plovers to enter the cage but preclude larger predators) has been widespread throughout the NGP. Research evaluating caging effectiveness has indicated mixed results; some studies suggest that caging is effective, while others suggest that fledging success does not increase. Cages can also increase adult mortality from predation. In some instances, caging can be effective at improving reproductive success, but it is a tool that should be used with care on a case-by-case basis. Since caging does not solve the underlying problem causing increased predation, it should be considered a palliative method, to be used to sustain the population until habitat improvements can be enacted that will provide long-term self-sustaining solutions.

1.5.3 B **Develop decision support tool for managers for caging and fencing decisions. (3) (Impact – Medium, Scale – Regional, Timeframe – Long)** A decision tool clearly laying out under what circumstances cages and fencing should be implemented will help managers make rational, informed decisions about when and where to apply caging. Guidelines may have some general principles across the range, but managers from each entity should develop a customized plan for their region. The plans should include an evaluation component to ensure that caging and fencing are protecting plovers as anticipated.

1.54B **Evaluate the effectiveness and risk of caging over space and time on hatching success compared to the increased number of fledglings produced and the risk of increased adult mortality. (2) (Impact – High, Scale – Local to Widespread, Timeframe - Long)** As discussed above (1.6.2B), studies have shown mixed results in the effectiveness of caging at increasing fledging success and may negatively impact adult survival. In places where caging is regularly used, perform rigorous studies to determine whether caging has an overall positive impact on reproductive success and does not negatively impact adults. Caging should be evaluated regularly to ensure that it is effective in the goal of increasing population size.

1.5.5B Develop and implement management plans and/or evaluate habitat conditions for each nesting lake basin, including a minimum one-mile buffer surrounding the basin. (2) (Impact – Medium, Scale – Local, Timeframe - Long) Evaluating the individual needs of local areas will allow managers to identify specific needs of an area, effectively engage with local landowners, and pursue specific actions to benefit plovers. Some factors that should be considered include removing anthropogenic features that may provide habitat for predators (e.g. man-made islands that are now attracting gulls, rock piles, old buildings). Predation pressure has increased to unnaturally high levels in some locations due to human caused factors. On the alkali lakes, there were likely historically very few trees before European settlement. Tree removal in the prairie near alkali lakes can reduce habitat for predators. Replacing cropland with grass may also reduce unnatural predation pressure.

1.5.7B Work with landowners agreeable to management (replanting with native grasses, fencing, grazing system management, off-site water development, removal of old buildings, rock piles) to improve habitat conditions. (2) Working with willing landowners on projects in the landscape to make piping plover nesting areas more successful will improve conditions for piping plovers and will also provide some benefits to the landowners. If landowners are willing, placing the land in permanent protection, for example in wetland and grassland easements, will provide long-term protection for piping plovers.

1.5.8B Identify piping plover use areas where dogs and/or feral cats are present. Develop sample regulation(s) to address this situation and share with appropriate governing bodies. (3) (Impact – High, Scale – Local, Timeframe - Long) Piping plovers move away from dogs, even if they are leashed, and dogs on the breeding grounds can eat eggs and chicks. Feral cat impacts on piping plovers are not as well documented; however there is a documented report of a plover killed in Texas by a feral cat. Identify areas where dog and cat use may overlap with piping plover breeding or wintering habitat and take steps to ensure that pet dogs and cats are kept away from nesting and roosting areas and feral cat colonies are eliminated.

1.5.9B **Develop decision support tools for managers to determine when and where predator management is appropriate. (3) (Impact – low, Scale – Regional, Timeframe - Long)** If predator management is used, managers should be reasonably certain that it will be effective in improving piping plover productivity. A decision support tool, including an adaptive management component whereby managers can learn from the effectiveness of their own and other managers' previous actions, would help to ensure that predator management is used effectively.

1.5.10B **Implement predation control efforts as needed so that nesting and brood-rearing activities can occur successfully. (3) (Impact – Low, Scale – Local to Regional, Timeframe – Short)** In some cases predation pressure is so high that nesting does not occur, or eggs and/or chicks do not survive without predation control measures. In these cases, predation management may be necessary to maintain the population until long-term ecosystem solutions can be implemented.

1.5.11B **Investigate if predator removal efforts are effective. (3) (Impact – Medium, Scale – Local, Timeframe - Short)** Several monitoring programs in the NGP implement predation control on a regular basis. Different species of predators are implicated for a variety of reasons, including direct observation of predation and observations of tracks or individuals in breeding areas. However, there is often little evidence that the predators blamed are actually the species causing the predation problems on the breeding plovers. Monitor the predator population to identify which, if any, species should be targeted for removal to improve plover survival and productivity; determine if predation control efforts are actually effective.

1.6B **Protect breeding plovers and their habitats from impacts of energy development. (1a) (Impact – High, Scale – Widespread to Local, Timeframe - Long)** With the increase in energy development over much of the U.S. range, especially in the Northern Rivers and U.S. Alkaline Lakes regions, plover habitat is at risk of contamination due to spills or other releases. Site energy features such that discharges are unlikely to impact piping plover habitat, ensure that these features include safety measures, and have robust response plans for when spills do occur. Additionally, plovers may be at risk of striking wind turbines. More research is needed about the strike risk for plovers. These features should be placed so as to minimize the risk of a plover strike.

1.6.1 B Work with state, tribal, and federal officials to ensure that oil and gas development is constructed with sufficient contingency plans to prevent or ameliorate a spill before it impacts plover habitat, in particular the Missouri River system and alkali lakes. (1a) (Impact – High, Scale – Widespread to Local, Timeframe - Long) A large percentage of the U.S. population of piping plovers nest on the Missouri River system and alkaline lakes in North Dakota, at the heart of the Bakken formation, an oil formation currently being developed. A spill could impact a large percentage of the population, especially if it occurred on the Missouri River. Ensure that spill contingency plans are in place to respond to a spill under all weather conditions and to prevent a spill from having catastrophic effects. The contingency plan should include a post-spill monitoring plan, both of the habitat and of the plovers themselves so that any impacts can be identified and remediated.

Oil and gas development should incorporate all possible features so that when spills occur, piping plover habitat is not impacted, and spill response plans are in place to ensure the spill response is quick and efficient to minimize impacts to piping plover habitat. Soil and water tests should be conducted prior to development so that if a spill occurs, the change in habitat quality can be documented and recovery to pre-existing conditions ensured. Independent funding will likely be required to collect and analyze samples.

1.6.2 B Work with state and federal officials and the industry on oil and gas wells and associated infrastructure development (roads, pipelines, saltwater disposal wells, etc.) to avoid impacts to plover areas. (2) (Impact – Moderate, Scale – Local, Timeframe - Long) Oil and gas development has been increasing exponentially in North Dakota from the mid-2000's through this writing (2015), a trend that is expected to continue. Work with regulators and the industry to locate these features so that they do not impact the watersheds of piping plover use areas and so that the risk of spills impacting piping plover habitat is minimized. Review recommendations regularly to ensure that they are incorporating the most up-to-date BMP's.

1.6.3 B Work with state and federal officials and industry developers to ensure that development does not impact alkaline lakes hydrology. (1a) (Impact: High, Scale – Regional, Timeframe - Long) In addition to wind turbines or oil and gas wells, energy development requires construction of infrastructure such as roads, pipelines, transmission lines, and other features. Design and locate all of these features to avoid impacting local hydrology and to ensure that best management practices trap all sediment so it does not reach the alkaline lakes.

1.6.4 B Share locations of key plover areas with state and federal officials and industry. Also share information about piping plover biology and threats to ensure they understand and observe a sufficient buffer to minimize disturbance and especially to be able to block potential spills before they reach piping plover habitat. (2) (Impact - Medium, Scale – Widespread, Timeframe –Intermediate) Regulatory agencies and energy industry planners are often not aware of sensitive areas like piping plover habitat that they should avoid. Provide regulators and industry representatives with maps of historical nesting areas and USFWS contacts to answer questions to assist them with placing features so that they design projects to avoid plover breeding areas. Regularly remind regulators and industry representatives of the need to incorporate plover habitat in planning. Seek opportunities to participate in early planning activities.

1.6.5 B Work with state and federal regulators and industry representatives to ensure that oil and gas infrastructure (including disposal wells) have sufficient pre-placement information to be able to determine if negative impacts may occur. This should include testing for soil integrity and potential for leaching should a spill occur. (2) (Impact: High, Scale – Regional, Timeframe - Long) Depending on placement and soil type, an oil and gas pad has the potential to erode or slump, increasing the likelihood of a spill occurring or spilled material flowing off the pad. Additionally, depending on soil type, a subsurface spill has the potential to leach for miles, potentially impacting a large area. Work with regulators to require that soil type is tested and pads are placed in areas where the likelihood of erosion is low and the soil would not readily leach spilled material.

1.6.6 B Research the risk of wind turbines on piping plovers on the breeding grounds and in migration. (1b) (Impact – Medium, Scale – Widespread, Timeframe - Long) Wind energy development is often located in areas nearby plover breeding areas, and there are many wind farms being constructed along the migration corridor. With little information available about how plovers move about, either within a season or during migration, the risk of a strike is not known. Evaluate plover movement to determine if plovers are likely to strike a wind turbine.

1.6.7B **Implement measures to mitigate the risk of wind turbines on piping plovers on the breeding grounds and in migration. (1b – dependent on information from 1.7.6B)** If research indicates that there is a high risk to piping plovers from wind turbines, take steps to mitigate this risk. Until information is known about the risks, take interim measures to reduce the likelihood of plovers hitting a turbine (maintaining a minimum distance from breeding habitat, and not placing turbines between areas where plovers are likely to regularly fly for forage).

1.6.8B **Evaluate the risk of energy infrastructure. (e.g., power lines) on piping plovers on the breeding grounds and in migration. (1b) (Impact – Medium, Scale – Widespread, Timeframe - Long)** As energy development has expanded across the Northern Great Plains, the amount of associated infrastructure has also increased dramatically. Plovers have been documented to strike transmission lines and be hit by cars when these features are between nesting and foraging habitat. However, the likelihood of this happening when plover use areas that are some distance apart is not known. Evaluate plover movement to determine the likelihood of a plover striking a transmission line or being struck by a vehicle.

1.6.9B **Implement measures to mitigate the risk of energy infrastructure on piping plovers on the breeding grounds and in migration. (1a – dependent on information from 1.7.8B)** If research indicates that there is a high risk to piping plovers from energy infrastructure, take steps to mitigate these risks. For example, placing bird strike diverters on transmission lines near plover use areas to make them more visible may reduce the strike risk. As more information becomes available, develop and implement guidelines to minimize the risk of energy infrastructure auxiliary features on plovers. In the interim, design and locate features to minimize the risks.

1.7B Identify and control plant species, with an emphasis on invasives, that may make habitat unsuitable. (2) (Impact – Medium, Scale – Widespread to Local,

Timeframe – Intermediate) Some invasive plant species, for example Kentucky bluegrass (*Poa pratensis*) on alkaline beaches, may take over the bare substrate that plovers require and may be much more difficult to remove than the native plant community. In addition, large-scale invasions have potential to alter wetland hydrology, making habitat unsuitable for nesting plovers.

1.7.1B Research effective treatments to remove invasive vegetation, especially on alkali wetland basins. (1b) (Impact – Medium, Scale – Regional, Timeframe - Intermediate) Removing invasive vegetation is expensive and can use potentially toxic chemicals with potentially negative side effects. More cost-effective and less toxic methods of plant removal need to be identified.

1.7.2B Identify and eradicate non-native plant species that may overtake plover habitat. (1a) (Impact – High, Scale – Local, Timeframe - Intermediate) Some non-native species may be more tolerant of alkaline soils or the regular inundation and drying characteristic of plover habitat in the Northern Great Plains than native species are. Work with public and private landowners to identify invasive species early and work to eradicate them before they spread.

1.7.3B Replant areas near breeding habitat with native species and remove trees from nearby prairie. (2) (Impact – Medium, Scale – Local, Timeframe - Intermediate) The areas that plovers use for nesting, roosting, and foraging are open or sparsely vegetated, but replanting the surrounding areas with native species makes it less likely that non-natives will be able to recolonize the surrounding area and invade the areas that the plovers use directly. Trees near plover roosting areas can increase predation risk and make otherwise suitable habitat unattractive. Removing trees and replanting those areas using low native cover removes habitat for avian predators.

2B Public Outreach to Minimize Human Disturbance and Promote Favorable Land Management

2.1B Develop and implement comprehensive plans, reflective of local conditions, to manage and avoid conflicts and to address the social and public relations challenges resulting from restrictions placed on human activities and interests such as recreation, residency, economic development and commerce. Actions should be focused on areas where management actions intended to protect

Piping Plovers may interfere with human activities. (1a) (Impact – High, Scale – Widespread, Timeframe – Short) Shoreline and sandbar habitat used by piping plovers also are often areas where human activities are concentrated. This intense human use creates a great need and opportunity for public outreach and education. Managers should identify areas where conflict may be high or increasing and focus outreach efforts there so that the public understands and abides by regulations to protect plovers. With increased public awareness, the general public should become somewhat self-policing, with mindful individuals keeping out of nesting areas and encouraging others to do so. We anticipate that continued public outreach will be necessary to remind the public of known nesting areas and to inform newcomers.

2.1.1 B Engage area stakeholders and provide opportunities for them to participate in policy development and decision making regarding shared, private or public resources. (1b) (Impact – High, Scale – Local to Regional, Timeframe – Long) Direct education and outreach to area stakeholders by including them in policy development and decision making. Having ownership in the process will encourage stakeholders to be active partners in Piping Plover management.

2.1.2 B Conduct human dimensions studies at sites where human–piping plover conflicts occur, or have the potential to occur, to better understand the source of the conflicts and identify possible resolutions of those conflicts. Use the results of these on-going studies to develop education and outreach programs, adjust existing education and outreach programs and refine management actions so they are best adapted to the local environment and changing situations. (1b) (Impact – High, Scale – Local, Timeframe – Intermediate) Developing and implementing site specific plan tailored to specific areas' needs should help to improve public understanding, acceptance, and compliance with restrictions to benefit piping plovers.

2.1.3 B Use comprehensive planning and implementation strategies to improve compliance with Piping Plover protection measures while avoiding and preventing conflict. (1b) (Impact – High, Scale – Local, Timeframe – Intermediate) Efforts should use the appropriate combination of education and outreach, stakeholder participation, and law enforcement actions adapted for each situation to achieve optimal outcomes. Enforcing protected areas is an important step to ensure that the public respects closures. Even if people are not cited, having law enforcement patrol areas regularly helps build public awareness of the closed areas. Law enforcement officers often also provide outreach by explaining to people why the areas are closed.

2.1.4B Implement seasonal or partial area closures as needed to protect nesting birds from human disturbance. (1a) (Impact – High, Scale – Local, Timeframe – Short) Seasonal closures of breeding areas allow the birds using those areas to successfully nest and fledge chicks without being disturbed by human activities. Closing areas seasonally has proven effective in the past (e.g., sandbars on the Missouri River are signed to inform the public that they are off-limits until the birds fledge, portions of active sandpits are not mined during the summer to allow plovers to complete their breeding cycle there, and recreation is restricted to portions of the Lake McConaughy shoreline so that piping plovers can breed there successfully).

2.2B Coordinate among state, federal, and tribal agencies as well as private landowners to ensure that plover protection is incorporated into development plans on or near plover habitat in order to avert negative impacts to plovers. (2) (Impact – High, Scale – Regional, Timeframe – Long) There are many competing uses for the land that plovers use, and many activities may conflict with plover needs. Work with landowners and managers to ensure that plover needs are considered in land management decisions and protection measures are included in planning.

2.2.1B Work with private landowners who own land that plovers use so that landowners continue to manage the land to benefit plovers. (1a) (Impact – High, Scale – Regional, Timeframe – Intermediate) Over half of the piping plovers nesting on the alkaline lakes are on private property, as are plovers on sandpits and some riverine islands. In most cases, the local plover site managers have developed a relationship with these landowners and worked with them to monitor the birds and in some cases, to develop projects that are mutually beneficial (e.g., removing trash piles that might house predators). Continue to develop and expand these relationships so that monitoring can continue and encourage landowners to continue managing their land with plover needs in mind. If possible, purchase easements from willing sellers to protect the wetland and surrounding watershed from future development. Create incentives for landowners to manage their land to benefit piping plovers and other wildlife. This may include recognition of landowners whose practices contribute to piping plover conservation. The “Plovers on Shore” program in Saskatchewan has developed a landowner recognition program that could be transferred to the U.S.

3B Regulatory

3.1B Develop a Conservation Strategy for the long-term management of piping plovers and their habitat, including a post de-listing plan. (1b) (Impact – High, Scale – Widespread, Timeframe – Long) Many areas where piping plovers nest are highly managed systems with a number of operational needs to be balanced (e.g. Platte River, Missouri River, Lake Diefenbaker). A Conservation Strategy that explicitly describes the long-term commitments to ensure that piping plover needs are met will help to ensure that actions to ensure the continued presence of piping plovers are incorporated into ongoing management. We recommend that the Conservation Strategy include a Memorandum of Agreement (MOA) co-signed by all major players to ensure that piping plover management is explicitly agreed upon. The Conservation Strategy and MOA can become the basis for a post-delisting plan. Ideally, the effectiveness of the post-delisting plan will have already been demonstrated prior to de-listing.

3.1.1B Commitments to manage for piping plovers are incorporated into the relevant agencies’ management plans. (1b) (Impact – High, Scale – Widespread, Timeframe – Long) To demonstrate that the commitments included in the Conservation Strategy will be implemented, the Service recommends that the commitments related to piping plover management be incorporated into the relevant agencies’ management plans. Implementation of these plans prior to delisting will demonstrate that the commitments can be followed and that they will result in the anticipated benefits on the piping plover population.

3.2B Federal and state agencies work collaboratively on projects so that there are no net negative impacts to plover habitat by assisting with design, implementation, permits, or mitigation measures. (3) (Impact – High, Scale – Local, Timeframe – Long) Piping plovers may not be considered in the design or implementation of state projects if there is no federal nexus (a nexus would occur if there were federal funding or a permit required). While projects with a federal nexus are required to be evaluated for impacts to threatened and endangered species under Section 7 of the Endangered Species Act, even with Section 7 consultation, projects that impact piping plover use areas may incrementally reduce piping plover habitat. Ensure that future projects either do not impact piping plover habitat or mitigate so that there is no net loss of amount or functionality of habitat.

3.2B Ensure that conservation measures designed to offset the adverse effects of human activities, developments and management decisions are monitored for effectiveness. (2) (Impact – High, Scale – Regional, Timeframe - Intermediate) An adaptive management strategy is recommended to evaluate the effectiveness of conservation actions undertaken. Through a robust adaptive management strategy, piping plover response to conservation actions could be evaluated and adjusted over time to maximize benefit to the species. .

3.3B Ensure that incidental take authorized under the ESA is consistent with recovery. (2) (Impact – Medium, Scale – Regional, Timeframe - Intermediate) Modeling has suggested that the NGP piping plover population has little or no resilience to human activities that reduce the reproductive success. Ensure that the cumulative effects of take from all actions across the range (including on the wintering grounds) are considered when analyzing the likely effects of incidental take.

4B Population Trends and Reproductive Monitoring

4.1B Continue monitoring efforts on the breeding grounds to track population trends and reproductive success. Monitoring efforts should be coordinated throughout the Northern Great Plains breeding grounds so that overall trends can be tracked across the range (See appendix 3B for a matrix on how this might be done across the range)**. Input monitoring results into the NGP plover model (see Appendix 2B) to assess progress towards recovery. (1b) (Impact: High, Scale – Widespread, Timeframe - Short)** A variety of state, federal, and non-profit organizations have been monitoring breeding plovers for more than 20 years. This monitoring has helped to provide insight to the threats facing the species as well as with solutions to address these threats. Those involved in population monitoring are a strongly committed, grass-roots pool of people who continue to work together and in their own areas to find ways to recover the species. Monitoring data at a population level are vital to assess the species' recovery. Work with various local monitoring entities to develop and implement monitoring programs that collect data that can be pooled to address population-scale plover issues.

4.1.1B Evaluate monitoring to ensure that the methods are providing sufficient accuracy and information that provides usable input for

management decisions. (2) (Impact – Medium, Scale – Widespread, Timeframe - Long) In large part, the monitoring programs were developed independently to address local managers' needs to ensure their management actions for the benefit of piping plovers were having the expected response. Evaluate monitoring at a local and population-wide scale to ensure that the various monitoring programs are answering the questions they are intended to address.

4.1.2B Continue working with private landowners and other owners/managers of plover nesting areas to allow monitoring and management efforts. (1b) (Impact – High, Scale – Regional, Timeframe - Short) Over half of the plovers on the Northern Great Plains nest on private land or land managed by a local entity. Accessing these areas to evaluate plover numbers and reproduction is critical to understanding the population as a whole. Continue to work with landowners to ensure access to monitor plovers on these areas.

4.13B Develop and implement a post-delisting monitoring plan (3) (Impact – Low, Scale – Widespread, Timeframe – Long) The ESA requires that after a species has been removed from the list, it must be monitored for a minimum of 5-years to ensure that it no-longer needs the protections afforded by the ESA. Prior to delisting the piping plover, we recommend that a post-delisting monitoring plan be in place and running to ensure that it is functional before the species is delisted. We anticipate that the post-delisting monitoring plan will be based on a monitoring matrix similar to that described in Appendix 3B and developed as described in 4.1B. We recognize that the monitoring done post-delisting will likely be less intensive than the monitoring done when the species is still threatened, so some adjustments may be made to the monitoring protocol to reduce it's intensity while still making it rigorous enough to track trends effectively post-delisting.

4.2B Work with biologists in Canada to identify and find solutions to international problems that may be impacting survival. (2) (Impact – Medium, Scale – Widespread, Timeframe - Intermediate) A large percentage of the Northern Great Plains population nests in Canada. US and Canadian biologists have contributed to this plan and are working together to identify and find solutions for problems on the breeding grounds. Work with biologists in Canada and to identify and find solutions to problems there that may be impacting survival.

4.3B Coordinate between research and monitoring programs across the NGP to determine demographic parameters across time as local and regional conditions change. (1b) (Impact – High, Scale – Widespread, Timeframe – Long) There are a number of programs that work to protect plovers and monitor adult numbers and reproductive success. Because the data are collected using different methods, they are not readily comparable. Adjust monitoring techniques so that the local entities get the information they need while also collecting data that can be pooled to better understand population dynamics. Many populations in the Northern Great Plains have been monitored for more than two decades. To the extent possible, updated monitoring programs should be designed so that this valuable long-term dataset can be incorporated into the new monitoring regime. The new monitoring programs should be compatible with the existing dataset. Rangewide monitoring data can be used to determine the overall trend of the population to evaluate if it is recovering as well as to determine if regional populations are responding to management actions as anticipated.

5B Climate Change Planning

5.1B Monitor status of State Wildlife Action Plan revisions and leverage opportunities to provide input on this species. (2) (Impact – Medium, Scale – Widespread, Timeframe - Intermediate) All states within the piping plovers' range developed Wildlife Action Plans to outline the steps needed to conserve wildlife and habitat. Cumulatively, these plans are intended to provide a national action agenda to prevent the decline of wildlife species such that they would become endangered. Work with the various states within the range to ensure that as they update their plans, they include plovers in their modeling to ensure that the shifts in suitable habitat predicted by climate change models are incorporated in planning to retain sufficient habitat.

5.2B Evaluate impacts to the breeding population from projected climate change modeling and analysis. (2) (Impact – Low, Scale – Widespread, Timeframe – Long) Climate change models predict that the Northern Great Plains will get warmer and wetter, with more frequent large weather events. Determine how the predicted changes will impact availability of suitable piping plover nesting habitat. Develop "thunderstorm maps" of piping plover distribution (similar to the duck maps previously developed by the USFWS) and use these to help project potential changes in piping plover distribution.

5.2.1B Protect both existing habitat and suitable habitat in the projected area where the plover population may shift. (2) (Impact – High, Scale – Widespread, Timeframe – Long) Preferred areas for plover nesting may shift as climate patterns make some currently used areas unsuitable. Protect areas that are projected to provide suitable habitat as these shifts occur. Purchase easements or land in fee title in areas piping plover's are likely to use under projected future climate conditions.

6B **Plan Evaluation and Revision (3) (Impact – Low, Scale – Widespread, Timeframe – Long)** Recovery will take the concerted efforts by many parties across the breeding and wintering range. To be most effective, progress should be reviewed regularly and results shared so that successes and failures can be understood and acted upon across the range. As new information comes available, parties should re-evaluate existing actions and goals to ensure that they are consistent with the best available information (an adaptive management approach). Tasks should be updated as needed. The recovery team should meet at least annually to assess the status of the species and any new or increasing threats that need to be addressed.

F. Threats Tracking Table

The threats tracking table is used as a planning tool to ensure that the identified threats are being addressed by recovery criteria and that, in turn, each of these threats are adequately addressed by recovery actions. Each of the identified threats is categorized by its corresponding listing factor. This is done to build continuity between the listing package and the recovery plan. Because some recovery actions may apply to multiple threats (i.e., monitoring provides information about habitat quality and disease), some recovery actions are listed more than once. The recovery criteria and recovery action(s) developed are presented in relation to their corresponding threat. This table also allows stakeholders a quick reference to the recovery criteria and the companion actions developed to address the threats.

Table 5. Threats Tracking Table: Identified threats for piping plovers, by the five listing factors, with associated recovery criteria and recovery actions.

Listing Factor	Threat	Recovery Criteria	Recovery Action
Factor A The present or threatened destruction, modification, or curtailment of its habitat or range	Habitat Protection on the Breeding Grounds	2	Identify and ensure protection of habitat on the breeding grounds in the U.S. and Canada to support piping plovers at recovery goals. (1B, 1.1B, 1.1.1B, 1.1.2B, 1.1.3B, 1.1.4B, 1.1.5B, 1.1.6B, 1.2.5B, 1.2.6B, 1.3B, 1.3.1B, 1.3.2B, 1.3.3B, 1.5.1B, 1.7B, 1.7.1B, 1.7.2B, 1.7.3B, 2.2B, 3.1B, 3.2B, 3.3B, 4.2B, 5.2.1B)
	Habitat Availability on River Systems	2	Ensure river management allows sufficient habitat renewed frequently enough to support piping plovers at recovery goals to occur by natural processes. (1.2B, 1.2.1B, 1.2.2B, 1.2.3B, 1.2.4B, 1.2.5B, 1.2.6B, 1.6.1B, 1.8B, 1.8.1B, 1.8.2B, 2.1B, 2.1.3B, 2.2B, 3.3B)
	Habitat Quality on Alkaline Lakes	2	Identify and reduce threats in landscape ecology of the alkaline lakes basins such that the basins will provide quality self-sustaining habitat. (1.4B, 1.4.1B, 1.4.2B, 1.5.1B, 1.7B, 1.7.1B, 1.7.2B, 1.7.3B, 1.7.4B, 1.7.5B, 1.8B, 1.8.1B, 1.8.2B, 2.2B, 2.2.1B, 3.3B, 4.1.2B, 5.2.1B)
	Sand and Gravel Mines	1, 2	Monitor long-term habitat availability and reproductive output over time. (1.4B, 1.4.1B)

Listing Factor	Threat	Recovery Criteria	Recovery Action
	Migration Habitat Needs*	Additional Measure 2	Research migration habitat needs and implement measures to ensure that important stopover sites are managed to benefit plovers. (2.2B)
	Land Management	1, 2	Coordinate between state, federal, and tribal agencies as well as private landowners to ensure that plover protection is incorporated into plans to develop areas, or convert habitat on or near plover habitat for other uses that may negatively impact plovers. (1.5.5B, 1.5.6B, 1.6B, 1.6.1B, 1.6.2B, 1.6.3B, 1.6.4B, 1.6.5B, 1.6.6B, 1.6.7B, 1.6.8B, 1.6.9B, 2.2B, 2.2.1B)
Factor B Overutilization for commercial, recreational, scientific, or educational purposes	Human Disturbance	1, 2	Develop and implement outreach plans focused on key areas where direct human/plover conflict is high or increasing, or has the potential to become high. (2.1B, 2.1.1B, 2.1.2B, 2.1.3B, 2.1.4B)
Factor C Disease or predation	Predation Control	1, 2	Implement predation control efforts (to be evaluated on a site-by-site basis). (1.5B, 1.5.1B, 1.5.2B, 1.5.3B, 1.5.4B, 1.5.5B, 1.5.7B, 1.5.8B, 1.5.9B, 1.5.10B, 1.5.11B)
Factor D The inadequacy of existing regulatory mechanisms	Regulatory Compliance	4	Ensure that actions committed to by regulatory agencies are consistent with recovery and that actions are performed as described. (3.2B, 3.3B, 3.4B)
	Long-term Regulatory Agreements	4	Develop and implement long-term agreements to ensure that ongoing necessary actions are in place and will continue after recovery. (2.2B, 3.1B, 3.1.3B, 5.1B, 6B)
	Energy Development on the Breeding Grounds and in Migration*	1, 2, 4	Work with state and federal officials to ensure that energy development and associated features are carefully located to avoid impacts and that contingency plans are in place to prevent and respond to spills. (1.6B, 1.6.1B, 1.6.2B, 1.6.3B, 1.6.4B, 1.6.5B, 1.6.6B, 1.6.7B, 1.6.8B, 1.6.9B)

Listing Factor	Threat	Recovery Criteria	Recovery Action
Factor E Other natural or manmade factors affecting its continued existence	Invasive species	2	Identify, eradicate, and, where appropriate, replant with natives in and nearby plover nesting areas. (1.2.4B, 1.3.2B, 1.7B, 1.7.1B, 1.7.2B
	Climate Change	2	Evaluate and protect both existing habitat and suitable habitat in the projected area where the plover population may shift. (5.1B, 5.2B, 5.2.1B)
	Monitoring	1	Monitor on the breeding grounds to ensure that the population is responding as expected to the management actions taken. (1.1.1B, 1.1.2B, 1.6.5B, 4.1B, 4.1.1B, 4.1.2B, 4.1.3B, 4.2B, 4.3B, 5.2B, 5.2.1B)

*Volume I of the plan includes in-land migration needs. Coastal migration is covered in Volume II of the Recovery Plan.

Listing Factors:
Factor A: The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or range
Factor B: Overutilization for Commercial, Recreational, Scientific, Educational Purposes (not a factor)
Factor C: Disease or Predation
Factor D: The Inadequacy of Existing Regulatory Mechanisms
Factor E: Other Natural or Manmade Factors Affecting Its Continued Existence

PART III. BREEDING IMPLEMENTATION SCHEDULE

The following implementation schedule outlines the recovery actions with associated time and cost estimates for the Northern Great Plains piping plover recovery program. The schedule is a guide for meeting the recovery objectives and criteria within this plan. It provides the action number, a description of the action to be performed, and an assigned priority for the recovery action. It also identifies the agency(s) and/or other parties that are the best candidates for accomplishing the recovery action. The schedule is laid out by the recovery actions and associated actions needed to help achieve each recovery action. Recovery action priorities, time and cost estimates, and responsible parties are not assigned to the overarching recovery actions. The reader should refer to the recovery narrative outline for a full description of all identified recovery actions. Initiation of the recovery actions is subject to availability of funds.

In developing this plan, the Recovery Team emphasized a recovery approach whereby to the extent practicable, recovery is achieved through restoring ecosystem function. We anticipate that this approach will be both cheaper and more effective in the long-run. Restoring ecosystem function will also benefit a variety of shorebirds, sea-shore obligates, and aquatic species that use the same habitat as piping plovers as well as grassland and riparian forest species that rely on the surrounding ecosystem. A fully functioning ecosystem also provides important goods and services to the human population in many forms including reduced flooding, clean water, and enhanced recreational opportunities. While some ongoing management will likely be needed, especially in areas where human recreation may impact plovers, with a more fully functioning ecosystem, the need for the majority of management-intensive recovery actions will be reduced or eliminated. Ecosystem restoration is in keeping with the goal of the ESA, whose purpose is to "protect and recover imperiled species and **the ecosystems on which they depend** (emphasis added)."

The Implementation Schedule (Table 5) includes all actions identified to recover the species. We provide our best estimate of the cost of recovery, including a period of time for management changes to be implemented to improve ecosystem function. If actions are implemented more quickly, the cost would decrease. Restoring the ecosystem reduces other costs as well. For example, when more habitat is available for nesting, the need for actions to deter predators is also eliminated.

The Implementation Schedule includes a number of actions necessary for recovery that also benefit other species and the human population. For example, careful siting of oil and gas facilities, and a quick and effective spill response, are necessary so that plovers and their habitat are not impacted by oil production.

Following Recovery Plan guidance (48 CFR 43098), we have prioritized the recovery actions from 1-3. Following each action, the priority number is in parentheses.

The definitions are as follows:
Priority 1a – An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.
Priority 1b – An action that by itself will not prevent extinction, but is needed to carry out a Priority 1 (a) action. Any action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.
Priority 2 - Any action that must be taken to prevent a significant decline in the species population, habitat quality, or some other significant negative impact short of extinction. **Priority 3 -** All other actions necessary to provide full recovery.

Table 5: Breeding Recovery Implementation Schedule

Recovery Action #	Description	Priority #	Recovery Action Duration	Responsible Organization		Total Estimated Cost (X $1,000)						Comments
				USFWS	Other[1]	FY 16	FY 17	FY 18	FY 19	FY 20	Total Assuming recovery occurs in 2035	
1B	**Habitat Protection, Management, Restoration, and Creation**											
1.1B	Protect habitat on the breeding grounds to support piping plovers at recovery level goals.	1a	ongoing	R6 ES R6 RW	NGO SWA USACE	Included in all of 1B actions						
1.1.1B	Purchase easements or land in fee-title to protect piping plover habitat and the nearby watershed.	1a	ongoing (dependent on willing sellers)	R6 ES R6 RW	NGO NGPC SWA USACE	200	200	200	200	200	4000	
1.1.2B	Measure habitat on the breeding grounds.	1b	ongoing	R6 ES R6 RW	NGO USACE	100	100	100	100	100	2000	Can be measured remotely
1.1.3B	Evaluate existing data to determine plover movement between the Northern Great Plains regions to better understand movement over the long-term as local habitat conditions fluctuate. If data are lacking, work with partners to fill in major gaps in our understanding of regional movement.	2	3-5 years	R6 ES R6 RW	NGO NGPC SWA USACE	300	300	300	300		1200	
1.14B	Establish carrying capacity (maximum number of pairs per ha of habitat) in various habitat types.	1b	3 years, evaluating rangewide data in conjunction with ongoing studies	R6 ES R6 RW	NGO SWA USACE	60	60	60			180	
1.1.5B	Identify areas where breeding habitat is limiting population growth.	1b	2 years, revisited every 5 years	R6 ES R6 RW	NGO NGPC SWA	100	100				200	

Recovery Action #	Description	Priority #	Recovery Action Duration	<u>Responsible Organization</u>		<u>Total Estimated Cost (X $1,000)</u>						Comments
				USFWS	Other[1]	FY 16	FY 17	FY 18	FY 19	FY 20	Total Assuming recovery occurs in 2035	
					Rsch USACE							
1.1.6B	Provide additional habitat in areas where habitat is limiting.	1a	as needed, dependent on findings from 1.1.2B	R6 ES R6 RW	NGO SWA USACE	Dependent on amount of habitat needed and method used to provide it. Therefore, it is not practicable to provide a cost estimate at this time.						
1.2B	River system management: Ensure that river management mimics the natural system and furnishes sufficient high-quality habitat to be available at a level to support piping plovers at recovery goals.	1a	policy change required	R6 ES	NGO USACE	Included in 1.2.1B						
1.2.1B	Design and implement the hydrograph in managed river systems so that sandbars are created and scoured by natural processes. On the Missouri River, this will likely include transporting sediment past dams.	1a	5 years	R6 ES	NGO USACE	2000	1000	1000	1000	1000	60000	Would be optimized if sediment could be moved through the dams
1.2.2B	Identify and protect (through fee-title, easements, or some other conservation means) floodplain areas that can serve to increase the capacity of the channel so that natural flooding can occur to create sandbar habitat without impacting human structures.	1a	ongoing until complete	R6 ES	NGO USACE	Depends on amount of habitat necessary to widen the channel and cost of land. Therefore, it is not practicable to provide a cost estimate at this time.						
1.2.3B	Where feasible, remove bankline protection such as rip-rap and hard points so that in-channel features can be created and eroded by natural processes.	2	ongoing	R6 ES	USACE	1000	1000	1000	1000	1000	5000	
1.2.4B	Create habitat mechanically and remove vegetation from sandbars on river systems to provide nesting habitat for plovers	2	as needed	R6 ES	NGO USACE	1970 00	6000	6000	6000	6000	442000	Will work best if a large amount of habitat is constructed periodically,

Recovery Action #	Description	Priority #	Recovery Action Duration	Responsible Organization		Total Estimated Cost (X $1,000)						Comments
				USFWS	Other[1]	FY 16	FY 17	FY 18	FY 19	FY 20	Total Assuming recovery occurs in 2035	
												followed by several years of maintenance. Assume will take 10 years to complete 1.2.1B after which 1.2.4 will no longer be necessary.
1.2.5B	Develop a model to quantify how reservoir dynamics impact the piping plover population over time. In particular, determine conditions under which reservoirs are a source or sink and identify management actions that could be implemented to reduce the likelihood of them being a sink.	1b	3 years	R6ES	USACE SWA Rsch	100	100	100			300	
1.2.6B	Based on the results of 1.2.5B, implement management actions on the reservoirs to benefit the piping plover population.	1a	as needed	R6ES	USACE SWA	100	100	100	100	100	2500	Will likely be part of management change from 1.2.1B
1.3B	Alkaline Lakes: Identify and reduce threats in landscape ecology of the alkaline lakes basins such that the basins will provide quality self-sustaining habitat.	1a	ongoing	R6 ES R6 RW	SWA	40	40	40	40	40	800	
1.3.1B	Restore the grasslands and hydrologic processes to areas surrounding nesting wetlands.	1a-dependent on info. from 1.4.1B	10 years	R6 ES R6 RW	NGO USACE	5000	5000	5000	5000	5000	50000	

Recovery Action #	Description	Priority #	Recovery Action Duration	Responsible Organization		Total Estimated Cost (X $1,000)						Comments
				USFWS	Other[1]	FY 16	FY 17	FY 18	FY 19	FY 20	Total Assuming recovery occurs in 2035	
1.3.2B	Provide permanent protection for piping plover habitat, including the surrounding habitat, through easements or fee-title.	1a	ongoing until complete	R6 ES R6 RW	NGO SWA	Included in 1.1.1B						
1.3.3B	Reduce consolidation drainage of wetlands into alkaline lakes.	1a	ongoing until complete	R6 ES R6 RW	NGO SWA	Included in 1.1.1B						
1.4B	Work with commercial aggregate (also known as sand and gravel) mining companies to operate mines to avoid adverse affects to nesting piping plovers.	3	ongoing	R6 ES	SWA NGO	60	60	60	70	80	1530	
1.4.1B	Monitor long-term habitat availability and reproductive output over time on commercial aggregate mines	3	annual	R6 ES	SWA NGO	Included in 1.5B						
1.5B	Implement steps to reduce unsustainable levels of predation risk over the long term through ecosystem restoration.	1a	ongoing	R6 ES R6 RW	NGO SWA USACE	Would require changes in river management and agreements (easements, fee title etc.) with landowners adjacent to river and reservoir habitat and alkaline lakes. Therefore, it is not practicable to provide a cost estimate at this time.						
1.5.1B	Ensure there is sufficient suitable habitat on river/reservoir systems so that plovers do not nest at abnormally high densities	1a	annual	R6 ES	NGO USACE	Included in 1.2.4B						
1.5.2B	Continue predator exclosure use on nests as a short-term palliative measure.	2	as needed	R6 ES R6 RW	SWA NGO	Included in 4.1B						Caging may not be necessary especially if 1.3.1B-1.3.3B and 1.4B are completed.
1.5.3B	Develop decision support tool for managers for caging and fencing decisions.	3	1 year	R6 ES R6 RW	NGO SWA USACE	200					200	
1.5.4B	Evaluate the effectiveness and risk of caging over space and time on hatching success compared to the	2	3 years	R6 ES R6 RW	NGO Rsch	200	200	200			600	

Recovery Action #	Description	Priority #	Recovery Action Duration	Responsible Organization		Total Estimated Cost (X $1,000)						Comments
				USFWS	Other[1]	FY 16	FY 17	FY 18	FY 19	FY 20	Total Assuming recovery occurs in 2035	
	increased number of fledglings produced and the risk of increased adult mortality.				USACE							
1.5.5B	Develop and implement management plans and/or evaluate habitat conditions for each nesting lake basin, including a minimum one-mile buffer surrounding the basin.	1a	10 years (5 years to develop plans, 5 additional years to implement)	R6 ES R6 RW	NGO SWA	50	50	150	150	150	1050	Assuming implementation begins in year 3
1.5.6B	Implement management plans developed under 1.5.5B.	1a		R6 ES R6RW	NGO SWA	100	100	100	100	100	1000	
1.5.7B	Work with landowners agreeable to management (replanting with native grasses, fencing, grazing system management, off-site water development, removal of old buildings, rock piles) to improve habitat conditions.	2	10 years (as access available on private lands)	R6 ES R6RW	NGO SWA	Included in 1.5.6B						
1.5.8B	Identify piping plover use areas where dogs and/or feral cats are present. Develop sample regulation(s) to address this situation and share with appropriate governing bodies.	3	5 years	R6 ES R6 RW LE	NGO SWA USACE	10	10	10	10	10	50	
1.5.9B	Develop decision support tools for managers to determine when and where predator management is appropriate.	3	3 years	R6 ES R6 RW	NGO SWA USACE	50	50	50			150	
1.5.10B	Implement predation control efforts as needed so that nesting and brood-rearing activities can occur successfully.	3	as needed	R6 ES R6 RW	NGO SWA USACE USDA	300	300	300	300	300	6000	Permits required from state wildlife agencies for predation removal efforts.

Recovery Action #	Description	Priority #	Recovery Action Duration	**Responsible Organization**		**Total Estimated Cost (X $1,000)**						Comments
				USFWS	Other[1]	FY 16	FY 17	FY 18	FY 19	FY 20	Total Assuming recovery occurs in 2035	
												May not be necessary if 1.3.1B-1.3.3B and 1.4B are completed.
1.5.11B	Investigate if predator removal efforts are effective.	3	3 years	R6 ES R6 RW	NGO Rsch USACE	200	200	200			600	
1.6B	Protect breeding plovers and their habitats from impacts of energy development.	1a	ongoing	R6 ES RW	BIA SRA SWA Tribes USACE WAPA	30	30	30	30	30	600	Part of a biologist's time to work with other agencies
1.6.1B	Work with state, tribal, and federal officials to ensure that oil and gas development is constructed with sufficient contingency plans to prevent or ameliorate a spill before it impacts plover habitat, in particular the Missouri River system and alkali lakes.	1a	ongoing	R6 ES R6RW	BIA SRA SWA Tribes USACE	68	68	68	68	68	1360	
1.6.2B	Work with state and federal officials and the industry on oil and gas wells and associated infrastructure development (roads, pipelines, saltwater disposal wells, etc.) to avoid impacts to plover areas.	2	ongoing	R6 ES R6RW R6 LE	BIA SRA SWA Tribes USACE WAPA	100	100	100	100	100	2000	
1.6.3B	Work with state and federal officials and industry developers to ensure that development does not impact alkaline lakes hydrology.	1a	ongoing	R6 ES R6RW	BIA SRA SWA USACE WAPA	100	100	100	100	100	2000	

Recovery Action #	Description	Priority #	Recovery Action Duration	Responsible Organization		Total Estimated Cost (X $1,000)						Comments
				USFWS	Other[1]	FY 16	FY 17	FY 18	FY 19	FY 20	Total Assuming recovery occurs in 2035	
1.6.4B	Share locations of key plover areas with state and federal officials and industry and information about piping plover biology and threats to ensure they understand and observe a sufficient buffer to minimize disturbance and especially to be able to block potential spills before they reach piping plover habitat.	2	ongoing	R6 ES R6 RW	BIA SRA SWA NGO USACE WAPA	68	68	68	68	68	1360	
1.6.5B	Work with state and federal regulators and industry representatives to ensure that oil and gas infrastructure (including disposal wells) have sufficient pre-placement information to be able to determine if negative impacts may occur. This should include testing for soil integrity and potential for leaching should a spill occur.	2	ongoing	R6 ES R6 RW	BIA SRA SWA Tribes USACE	100	100	100	100	100	2000	
1.6.6B	Research the risk of wind turbines on piping plovers on the breeding grounds and in migration.	1b	5 years	R6 ES R6 RW	Rsch WAPA	60	60	60	60	30	270	
1.6.7B	Implement measures to mitigate the risk of wind turbines on piping plovers on the breeding grounds and in migration.	1a – dependent on info. from 1.7.6B	as needed	R6 ES R6 RW	SRA SWA WAPA	Dependent on measures taken. E.g. area avoidance may not cost more than planning costs. Therefore, it is not practicable to provide a cost estimate at this time.						
1.6.8B	Evaluate the risk of energy infrastructure. (e.g. power lines) on piping plovers on the breeding grounds and in migration.	1b	5 years	R6 ES	SRA Rsch WAPA	60	60	60	60	30	270	
1.6.9B	Implement measures to mitigate the risk of energy infrastructure on piping plovers on the breeding grounds and in migration.	1a – dependent on info. from 1.7.8B	as needed	R6 ES	SRA SWA WAPA	Dependent on measures taken. E.g. area avoidance may not cost more than planning costs. Therefore, it is not practicable to provide a cost estimate at this time.						
1.7B	Identify and control plant species, with an emphasis on invasives, that may make habitat unsuitable.	2	as needed	R6 ES R6 RW	NGO SWA	600			600		2400	Reduced effort may be required if

Recovery Action #	Description	Priority #	Recovery Action Duration	Responsible Organization		Total Estimated Cost (X $1,000)						Comments
				USFWS	Other[1]	FY 16	FY 17	FY 18	FY 19	FY 20	Total Assuming recovery occurs in 2035	
					USACE							1.3.1B-1.3.3B and 1.4B are completed.
1.7.1B	Research effective treatments to remove invasive vegetation, especially on alkali wetland basins.	1b	5 years	R6 ES R6 RW	NGO SWA	250	250	250	60	60	870	
1.7.2B	Identify and eradicate non-native plant species that may overtake plover habitat.	1a	annual	R6 ES R6 RW	NGO SWA USACE	Included in 1.7B						
1.7.3B	Replant areas near breeding habitat with native species and remove trees from nearby prairie.	2	10 years	R6 ES R6 RW	NGO SWA USACE	Contingent on acres managed, approximately $1,000/acre to remove trees, prep site, and plant with diverse native seed mix. Therefore, it is not practicable to provide a cost estimate at this time.						
2B	**Public Outreach to Minimize Human Disturbance and Promote Favorable Land Management**											
2.1B	Develop and implement comprehensive plans, reflective of local conditions, to manage and avoid conflicts and to address the social and public relations challenges resulting from restrictions placed on human activities and interests such as recreation, residency, economic development and commerce. Actions should be focused on areas where management actions intended to protect Piping Plovers may interfere with human activities	1a	5 years to develop plans, implementation is ongoing	PA R6 ES R6 RW	NGO SWA USACE	100	100	100	100	100	2000	
2.1.1B	Engage area stakeholders and provide opportunities for them to participate in policy development and decision making regarding shared, private or public resources	1b	ongoing	PA R6 ES R6 RW	NGO SWA USACE	50	50	50	50	50	1000	
2.1.2B	Conduct human dimensions studies at sites where human–Piping Plover conflicts occur, or have the potential to occur, to better understand the source of the conflicts and identify possible resolutions of those	1b	5 years to develop plans, implementation is	PA R6 ES	NGO SWA USACE	100	100	100	100	100	2000	

Recovery Action #	Description	Priority #	Recovery Action Duration	Responsible Organization		Total Estimated Cost (X $1,000)						Comments
				USFWS	Other[1]	FY 16	FY 17	FY 18	FY 19	FY 20	Total Assuming recovery occurs in 2035	
	conflicts. Use the results of these on-going studies to develop education and outreach programs, adjust existing education and outreach programs and refine management actions so they are best adapted to the local environment and changing situations.		ongoing									
2.1.3B	Use comprehensive planning and implementation strategies to improve compliance with Piping Plover protection measures while avoiding and preventing conflict.	1b	ongoing	PA R6 ES R6 RW LE	NGO SWA USACE	Included in 2.1.1B-2.1.3B, and 2.1.4B-2.2.1B						
2.1.4B	Implement seasonal or partial area closures as needed to protect nesting birds from human disturbance.	1a	ongoing	R6 ES R6 RW	NGO SWA USACE	100	100	100	100	100	2000	
2.2B	Coordinate among state, federal, and tribal agencies as well as private landowners to ensure that plover protection is incorporated into development plans on or near plover habitat in order to avert negative impacts to plovers.	2	ongoing	R6 ES R6 RW	BIA NGO SWA Tribes USACE	100	100	100	100	100	2000	
2.2.1B	Work with private landowners who own land that plovers use so that landowners continue to manage the land to benefit plovers.	1a	ongoing	R6 ES R6 RW	NGO SWA	80	80	80	80	80	1600	
3B	**Regulatory Compliance and Certainty**											
3.1B	Develop a Conservation Strategy for the long-term management of piping plovers and their habitat, including a post de-listing plan	1b	3 years	R6 ES R6 RW	BIA NGO SWA Tribes USACE	2000	2000	2000			6000	
3.1.1B	Commitments to manage for piping plovers are incorporated into the relevant agencies management plans.	1b	3 years			Included in 3.1B						

Recovery Action #	Description	Priority #	Recovery Action Duration	Responsible Organization		Total Estimated Cost (X $1,000)						Comments
				USFWS	Other[1]	FY 16	FY 17	FY 18	FY 19	FY 20	Total Assuming recovery occurs in 2035	
3.2B	Federal and state agencies work collaboratively on projects so that there are no net negative impacts to plover habitat by assisting with design, implementation, permits, or mitigation measures.	3	ongoing	R6 ES R6 RW	BIA NGO SRA SWA Tribes USACE WAPA	56	56	56	56	56	1120	
3.3B	Ensure that conservation measures designed to offset the adverse effects of human activities, developments and management decisions are monitored for effectiveness.	2	ongoing	R6 ES R6 RW LE	BIA NGO USACE WAPA	42	42	42	42	42	840	
3.4B	Ensure that incidental take authorized under ESA is consistent with recovery.	2	part of the consultation process in 3.2B	R6 ES R6 RW		2	2	2	2	2	20	
4B	**Population Trends and Reproductive Monitoring**											
4.1B	Continue monitoring efforts on the breeding grounds to track population trends and reproductive success. Monitoring efforts should be coordinated throughout the Northern Great Plains breeding grounds so that overall trends can be tracked across the range. Input monitoring results into the NGP plover model (see Appendix 2B) to assess progress towards recovery.	1b	ongoing	R6 ES R6 RW	NGO SWA	2000	2000	2000	2000	2000	40000	
4.1.1B	Evaluate monitoring to ensure that the methods are providing sufficient accuracy and information that provides usable input for management decisions.	2	3 years	R6 ES R6 RW	NGO Rsch SWA USACE	100	100	100			300	
4.1.2B	Continue working with private landowners and other owners/managers of plover nesting areas to allow monitoring and management efforts.	1b	ongoing	R6 ES R6 RW	NGO USACE	Included in 4.1B						

Recovery Action #	Description	Priority #	Recovery Action Duration	**Responsible Organization**		**Total Estimated Cost (X $1,000)**						Comments
				USFWS	Other[1]	FY 16	FY 17	FY 18	FY 19	FY 20	Total Assuming recovery occurs in 2035	
4.1.3B	Develop and implement a post-delisting monitoring plan.	3	5 years	R2 ES R3 ES R4 ES R6 ES R2 RW R4 RW R6 RW	NGO SWA USACE	100	100	100	100	100	500	Costs listed here are just for development, implementation is covered in 4.1B
4.2B	Work with biologists in Canada to identify and find solutions to international problems that may be impacting survival.	2	ongoing	R6 ES R6 RW	Intn	2	2	2	2	2	50	
4.3B	Coordinate between research and monitoring programs across the NGP to determine demographic parameters across time as local and regional conditions change.	1b	3-years (on-going information exchange)	R6 ES R6 RW	NGPC NGO USACE	34	34	4	4	4	140	
5B	**Climate Change Planning**											
5.1B	Monitor status of State Wildlife Action Plan revisions and leverage opportunities to provide input on this species.	2	as revised – generally every 5 years	R6ES R6 RW	SWA	40					160	
5.2B	Evaluate impacts to the breeding population from projected climate change modeling and analysis.	2	as needed, 4B, monitoring will provide information	R6 ES	NGO Rsch SWA USACE	100		100		100	1000	
5.2.1B	Protect both existing habitat and suitable habitat in the projected area where the plover population may shift.	2	As needed	R6 ES R6 RW	NGO SWA USACE						10000	Assume doesn't start for 10 years if climate change alters

Recovery Action #	**Description**	**Priority #**	**Recovery Action Duration**	**Responsible Organization**		**Total Estimated Cost (X $1,000)**						**Comments**
				USFWS	Other[1]	FY 16	FY 17	FY 18	FY 19	FY 20	Total Assuming recovery occurs in 2035	
												habitat
6B	**Plan Evaluation and Revision**	3	annual recovery-team meeting, revise as needed	R6ES R6 RW	Intl NGO Rsch SWA USACE	10	10	10	10	10	200	
	TOTAL										603420	

[1]Does not commit identified party to doing the work; it just identifies the best candidate for completing the action

Total estimated cost: $603,420,000

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Appendix 1B

Background information for development of habitat quantity and frequency of availability

Habitat Acreage Requirements

We found only five studies that included metrics of amount of habitat available, number of pairs, and reproductive success; one on the East Coast; two on the U.S. alkaline lakes; one on the Missouri River on Lewis and Clark Lake and below the Gavins Point Dam; and one on Lake Sakakawea, a Missouri River reservoir.

Cohen *et al.* (2009) followed the growth and decline of plovers at a site that capitalized on a storm event that created nesting and foraging habitat on Long Island, New York. The authors compared the washover site to an adjacent, degraded site where thick vegetation restricted access to the back side of the barrier island (location of high quality foraging habitat). Piping plovers responded positively in the first years after the breach, and as development, vegetation growth, predators, etc. encroached on the new site, the population decreased. During the period, the degraded reference site maintained a relatively stable population at lower numbers and densities than the washover site. The study suggests that plover populations appear to nest in higher densities in higher quality habitat.

The authors compared realized population growth (λ) for each of the sites to nesting density. The authors provide an equation for this relationship that we can use to examine optimal densities, by solving the equation for a growth rate that we deem reasonable for long term persistence.

$$High\ Quality\ \lambda = -0.8 \times \ln(Nesting\ Density) + 0.71$$

$$Reference\ \lambda = -0.67 \times \ln(Nesting\ Density) + 0.41$$

If we set each of the lambdas to 1.0 (stable population growth) and solve for nesting density, we obtain a density of 0.70 pairs/ha (0.28 pairs/ac) for the high quality site and 0.41 pairs/ha (0.17 pairs/ac) for the reference site.

The average density for both sites between the years 1998–2004, corresponded with the peak and decline of the population at the high quality site, a time when one might consider the population to be at peak density. The average was 0.83 pairs/ha (0.34 pairs/ac) (95 percent CI 0.70 – 0.96) and 0.51 pairs/ha (0.21 pairs/ac) (95 percent CI 0.43 – 0.58) for the high-quality and reference sites, respectively. As would be expected, these numbers are larger (comparison between “optimal” and “peak” density), but the lower confidence limits for the peak estimates are close to the point estimates for optimal density. This suggests that maximum density is not static, but is higher when habitat is good and lower when habitat is poor.

Licht (2001) studied habitat and reproductive success on the alkaline lakes. The author compared hydrological data to piping plover breeding data from 1988 to 1997 on alkaline wetlands in North Dakota. While the study was not designed to evaluate density, habitat area is included in the model. We used the information available to predict plover density. Using these data, we estimated that there may be 0.12 to 1.71 plovers/ha (0.05-0.69 pairs/ac) under conditions similar to those in this study. However, this number is likely biased low if the study included the entire wetland as habitat, not just the portion used by plovers. Moreover, there was no metric tying reproductive output or population growth to density, so we do not know if the estimates provided are optimal, peak, or perhaps sustainable densities. Therefore, we present these data for completeness, but are not including it in our estimate of habitat acreage requirements.

Ryan (unpublished manuscript) included data from 11 years of research on an alkaline lake in North Dakota and compared the average number of breeding pairs, habitat available, and breeding density between “successful” and “unsuccessful” beaches. Successful beaches were defined as having produced at least 1.1 chicks per pair, the value indicated in earlier modeling efforts as necessary to support a stable population (Melvin and Gibbs 1996; Larson *et al.* 2002). The estimates and confidence limits of the densities for both groups ranged from 1.83–4.83 pairs/ha (0.74-1.95 pairs/acre), but the successful beaches averaged 2.37 pairs/ha$^{/}$ (0.96 pairs /ac) (95 percent CI: 1.83–2.91) (Ryan Unpublished Document).

From 2005–2007 on the Missouri River, Catlin (2009) evaluated breeding success on engineered sandbars (which were created through dredging) and sandbars that were created in a high flow event approximately ten years previously. This study found that as density increases, survival and immigration/recruitment (positive forces in population change) decrease and emigration (negative forces in population change) increases.

Results, including two years of data from the three engineered sandbars show a fairly distinct break at ca. 1.5–2 pairs/ha$^{/}$ (0.61-0.58 pairs/ha) on occupied such that above these values survival and particularly recruitment become much lower, and emigration higher above this density (Catlin 2009).

Anteau *et al.* (2014a, 2014b) studied the relationship between amount of habitat and numbers of plover pairs and fledglings at Lake Sakakawea, North Dakota. Density of pairs (pairs/ha) was greater at islands (4.84 ± 1.22 SE) than at mainlands (0.85 ± 0.17 SE) (Anteau *et al.* 2014b). Fledgling density (number of fledged chicks/ha) was 1.94 ± 1.14 SE at islands and 0.62 ± 1.25 at mainlands, but hatchling survival to fledging was lower on islands (24 percent ± 10 SE) than mainlands (45 percent ± 10 SE; M. J. Anteau unpubl. data). Fledging rate increased linearly with hatchlings per hectare when densities were less than 5 hatchlings per hectare (>80 percent of shoreline or island study sites) but exhibited density dependence at greater densities (Anteau *et al.* 2014a). Those authors suggested that <5–15 hatchlings per hectare would lead to a suitable habitat goal for Lake Sakakawea to minimize influences of density dependence on fledging rate. This translates to a target pair density of 6–18 pairs/ha on islands and 3–10 pairs/ha on mainlands if nest success is 25 percent, a rate typical for Lake Sakakawea in many years.

The amount of habitat necessary per pair varies considerably between locations as discussed above. The amount of habitat necessary may be tied to habitat quality (Mayer 1991; Le Fer *et al.* 2008). It has been hypothesized that when habitat quality is good, it supports a higher density of successfully nesting shorebirds than when it is poor (Kruse *et al.* 2002; Colwell 2010), although plovers seem to be able to fledge successfully on habitat of varying quality (Le Fer *et al.* 2008).

Frequency of habitat availability:

There is no historical data about annual habitat availability throughout the range. Therefore, we used proxy measures to estimate how often habitat would have been historically available. We used two independent approaches to evaluate how often habitat was likely available for piping plovers in the Northern Great Plains.

The first approach relies on historical precipitation data for the basins in each recovery region. We assumed that in years with high flow on the rivers and high precipitation on the plains, there would have been very little habitat exposed during the breeding season. In the ensuing drier years, the habitat created during the wet year(s) would be available.

High flow in rivers or high water in the alkaline lakes is largely caused by the amount of runoff, which is in turn closely linked to precipitation. Using precipitation data for the period of record (1901-2012) in the Missouri River watershed, the U.S. alkali lakes region, and the Nebraska rivers watersheds, we calculated which years had precipitation in the upper-decile (top ten percent) (Daly 1994). Since precipitation on average has increased over this time period, we used a thirty-year running average so that the upper decile changes along with the increase in precipitation. We assumed that habitat would have been almost completely inundated during the upper-decile years and thus unavailable for nesting. On the river systems, the upper-decile years would have scoured existing sandbars and created new ones, while on the alkali lakes, high water would kill vegetation that had begun to grow on the beach since the last high-water event. In the years with lower water levels following high-inflow years, habitat would be available for breeding activities. Using this approach, we determined that there would have been a flood frequency of six-to-eight years on average.

As a second approach, we used demographics data (derived from Catlin *et al. In review*) to predict the 10-year average population growth rate under deterministic flood frequency scenarios ranging in frequency from every 0–10 years. The assumptions of this modeling were as follows:

- During a "flood" year, we assumed that adult survival in the flooded area was equal to that of transient adults (mean = 0.51, SE = 0.09) and reproductive output was set at 0 (i.e., no successful reproduction). Previous banding work (Catlin 2009, Catlin *et al. In review*), has shown that transient adults (adults with unknown breeding status) have a lower apparent survival than adults that were known breeders in a given year.
- The sandbars that the Corps created on the Missouri River through dredging (hereafter engineered sandbars) are similar to individual sandbars that would naturally be created through deposition caused by high flows. Thus, the reproductive response measured on the engineered sandbars, with high initial reproductive success decreasing over time as they became more densely populated and more vegetated, also occurs over time on naturally

created sandbars. During the study period (2005–2011, Catlin and Fraser 2006a, Catlin and Fraser 2006a, b, Catlin and Fraser 2007, Felio *et al.* 2009, Felio *et al.* 2010a, Felio *et al.* 2010b, Hunt *et al.* 2012) there were also sandbars that had been created naturally during the high flows in 1996-1997 (hereafter natural sandbars). Since these bars were 9–15 years old during the study period, the reproductive success on them represents the reproductive success we would expect to see on older habitat. It should be noted that the engineered sandbars are not similar to naturally created sandbars in that they do not reflect a system-wide increase in habitat as happens when sandbars are created through flow. Because the engineered sandbars are in only a few, discrete locations within a reach, the birds are disproportionately drawn to them. This can lead to a large percentage of the birds being impacted by predictable, but locally stochastic events such as predation, hail, human disturbance, as well as lack of sufficient forage because the birds are nesting so densely.

- Following a "flood" year (the year after a sandbar was constructed), we used the reproductive output based on estimates of the decrease in nest success relative to the age of engineered habitat (range: 0.07–0.73). Because the oldest engineered sandbar during the study period was only 7 years old, from years 8–10 we used the values for natural sandbars (mean = 0.27, SE = 0.08).
- We used mean chick survival to fledging from engineered sandbars (mean = 0.57, SE = 0.08).
- First-year survival (survival from fledging to first-year breeding) is not a function of which type of habitat the individual was fledged on. We used true survival (Barker 1997) estimates from 2005–2011 (mean = 0.53, SE = 0.04)
- Adult survival varied with habitat age, from years 1–7 we used adult survival from engineered sandbars (mean = 0.80, SE = 0.07) and from years 8–10 years we used adult survival from natural sandbars (mean = 0.77, SE = 0.07).

We used methods similar to Melvin and Gibbs (1996) and Cohen and Gratto-Trevor (2011) to calculate yearly values of λ. We used the following equation (Cohen and Gratto-Trevor 2011):

$$\lambda = S_{adult} + RPBS_{postfledge} + R(1 - P)BS_{adult}S_{postfledge}$$

- λ is the population growth rate.
- S_{adult} is adult survival (Catlin *et al. in review*).
- $S_{postfledge}$ is first-year survival
- R is the sex ratio at hatch (assumed to be 0.5; Cohen and Gratto-Trevor 2011)
- P is the probability that a returning juvenile female will breed in its first year (0.68; Gratto-Trevor *et al.* 2010, Cohen and Gratto-Trevor 2011).
- B is the rate of birth (defined as chicks produced pair^{-1}), which was derived from nest and chick survival estimates.

As seen in Figure A1, if there is a flood frequency occurring from four to eight years, the average values for lambda (population growth) were approximately at or above the value required for a stationary population (1.0). The figure shows lambda to be slightly below the stationary population level with a five-year flood frequency. All simulations begin following a 'flood' event and have the resultant high reproductive output in year 1. The flood events are deterministic and occur at set intervals. Therefore, the four-year flood model has poor years in year 4 and 8, but good years in year 1, 5, and 9 with declining productivity thereafter. The five-year frequency model only has two post-flood, good years, year 1 and year 6, and it has longer declines between good years than the four-year model. The slight decline of lambda is a result of this deterministic model.

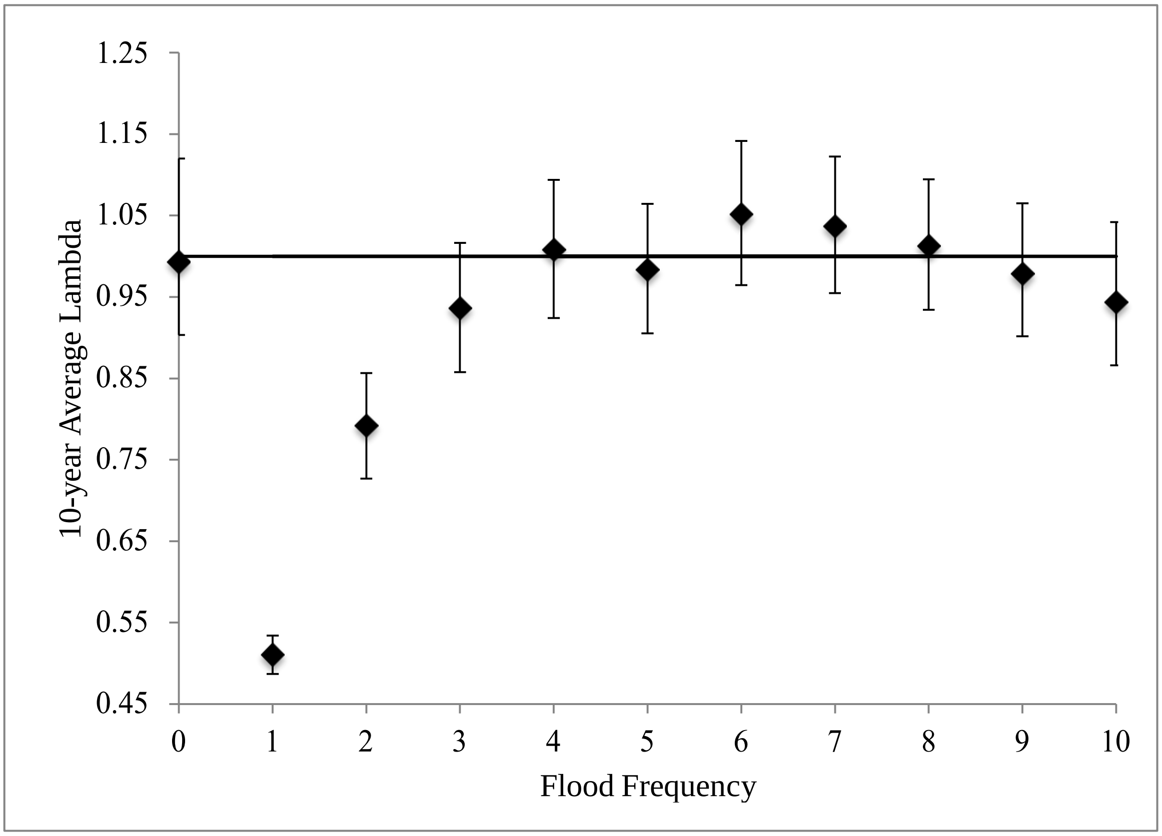


Figure A1: the 10-year average lambda compared with flood frequency.

For population stability, lambda must be greater than or equal to 1 (the horizontal line). As the figure shows, lambda is approximately at or above one when modeling estimates a flood frequency of every four to eight years. As explained in the text, for year five, lambda shows as being slightly below one as an artifact of our modeling methodology.

Habitat availability in the recent past:

To date, habitat has only been measured on the Missouri River portions of the Southern Rivers region and the riverine portion of the Northern Rivers region. Thus, the estimates of how much habitat were available historically are limited. As Tables 2 and 3 show, in these reaches habitat has approached the amount the model estimates as needed for recovery only after high flow events which moved a large amount of sediment.

Table 6: Habitat estimates by year on the Missouri River portions of Southern Rivers

	Gavins		**Lewis & Clark**		**Fort Randall**		**Total Habitat Estimate, Missouri River Southern Rivers region**	
	Hectares	**Acres**	**Hectares**	**Acres**	**Hectares**	**Acres**	**Hectares**	**Acres**
1998	1191	2944	229	566	119	295	**1540**	**3805**
1999	503	1242	232	574	302	746	**1037**	**2562**
2000	712	1760	116	287	76	189	**905**	**2236**
2001	445	1100	58	144	167	413	**671**	**1657**
2002	367	907	29	72	100	248	**497**	**1227**
2003	858	2120	15	36	103	254	**975**	**2410**
2004	492	1216	237	586	351	867	**1080**	**2669**
2005	356	880	57	142	52	128	**465**	**1150**
2006	188	464	7	17	55	137	**250**	**618**
2007	282	696	197	487	180	444	**658**	**1627**
2008	604	1492	51	125	140	346	**794**	**1963**
2009	180	445	89	220	12	30	**281**	**695**
2010	67	166	91	226	2	6	**161**	**398**
2011	0	1	47	117	0	0	**48**	**118**
2012	1872	4627	1009	2494	843	2084	**3725**	**9205**

Source: USACE 2013

Table 7: Habitat estimates by year on the Missouri River riverine portions of Northern Rivers (Reservoirs excluded).

	Garrison		**Fort Peck**		**Total Habitat Estimate, Missouri River, Riverine portions (no reservoir data available)**	
	Hectares	**Acres**	**Hectares**	**Acres**	**Hectares**	**Acres**
1998	836	2066	74	183	**910**	**2249**
1999	90	223	401	993	**491**	**1216**
2000	254	628	299	740	**553**	**1368**
2001	1269	3137	600	1486	**1870**	**4623**
2002	198	490	112	278	**311**	**768**
2003	163	402	111	275	**274**	**677**
2004	282	697	119	295	**401**	**992**
2005	238	588	100	247	**338**	**835**
2006	166	409	74	184	**240**	**593**
2007	293	725	211	522	**504**	**1247**
2008	313	773	140	346	**453**	**1119**
2009	286	707	83	206	**369**	**913**
2010	203	502	114	282	**317**	**784**
2011	0	0	0	0	**0**	**0**
2012	2009	4965	*	*	**2009**	**4965**

* No data available
Sources: USACE 2012; USACE 2013

Appendix 2B

A meta-population model of the Piping Plover population in the Northern Great Plains for evaluating minimum abundance for viability.

INTRODUCTION

We used a model developed by McGowan et al. (2014) to identify the minimum starting population size required to reduce extinction probability to at least 0.05 under stable population growth in each management region. Full details on the model and the population size assessment analysis are available in McGowan et al. (2014). Below we have excerpted from the text of that paper some of the simulation model structure details, simulation data analysis methodologies and some of the results that a pertinent to this recovery plan.

POPULATION MODEL

Model structure and parameterization

All modeling and analysis of simulated data were developed and executed in program R (R core development team, 2011). The model we developed included spatial structure that divided the northern Great Plains into four breeding/management regions: Southern Rivers (primarily the Platte River and Missouri River in southern South Dakota and along the Nebraska-South Dakota border), Northern Rivers (primarily the Missouri River and its constructed reservoirs in central South Dakota north through North Dakota and Montana), alkali wetlands (i.e., along the Missouri Coteau in North Dakota and Montana), and Prairie Canada (all river, reservoir and wetland habitats in Prairie Canada; Fig. A1). The model included limited exchange of individuals between the breeding regions and can be considered a meta-population model (Hanski 1994). These divisions of the breeding range were supported by the available banding data (see below) from multiple studies in the Great Plains. In addition to reflecting suspected regional boundaries between breeding populations, these sub-population units would likely have differing reproductive rates, different limiting factors, and would therefore require potentially different management strategies. That is, the management actions could be differentially effective among regions given the variation in ecological and physical processes.

The projection equations for the population were crafted as algebraic expressions and the simulation program had one equation for each region. The equations entailed a recruitment term, a survival term, and immigration/emigration terms where annually a small, random percentage of the sub-population could depart each region and move to another region as follows:

$$N_{t+1}^{i} = \left(N_t^i S_t^A\right) + \left(N_t^i F_t^i S_t^Y\right) - \sum\left(\left(N_t^i S_t^A\right) + \left(N_t^i F_t^i S_t^Y\right)\right) T_t^{ij} + \sum\left(\left(N_t^j S_t^A\right) + \left(N_t^j F_t^j S_t^Y\right)\right) T_t^{ji}$$

where N^i is the population size in region *i* , S^A is the annual survival rate of adults, F^i is the annual fecundity rate in region *i* (female fledglings produced per breeding female) and S^Y is the juvenile (first winter) annual survival rate. The subscript *t* indicates the year. The super script *j* indicates any one of the three subpopulations in the model available for immigration or emigration and *T* is the annual transition rate from region *i* to *j* (emigration) or *j* to *i* (immigration). Following McGowan and Ryan (2009), our model assumes that annual adult and juvenile survival does not vary by region but that fecundity does. Analyses distinguishing survival rate by region in the Great Plains have not been conducted/completed, but survival estimates from the Atlantic Coast population suggest that far northern breeding birds (e.g., Nova Scotia) may have lower survival than more southern birds, at least for juveniles (Calvert et al., 2006, Hecht and Melvin, 2009). Without conclusive analyses to support regional survival differences in the Great Plains (Cohen and Gratto-Trevor, 2011, D. Catlin unpublished data), we decided to keep survival consistent among regions. Overall mean adult survival was set at 0.78 (SE = 0.03) and was based on unpublished (D. Catlin, unpublished data) and published estimates (Larson et al., 2000, Cohen and Gratto-Trevor, 2011, Roche et al., 2010). Overall mean juvenile survival was set at 0.52 (SE = 0.12) and was based on unpublished analyses of mark recapture data (D. Catlin, unpublished data) and is similar to published values from Saskatchewan at 0.57 (SE 0.05; Cohen and Gratto-Trevor, 2011). Survival rates were modeled as beta-distributed random variables in the simulation model.

Productivity estimates for each region were based on the best available published estimates or the best available data. The southern rivers region had an estimated 0.77 (SE = 0.24) female fledglings per pair, derived from nest survival, chick survival, clutch size and renesting rate data (D. Catlin, unpublished data) using a Noon and Sauer (1991) approach for estimating fecundity (McGowan and Ryan, 2009). The estimates for southern rivers might be artificially elevated due to recent intensive habitat management by the U.S. Army Corps of Engineers in the area where the data originated (Catlin, 2009). Shaffer et al. (in press) reported that birds produced 0.32 (SE = 0.27) female fledglings per breeding female in the northern rivers region during a three year study. McGowan and Ryan (2009) reported that annual fecundity estimates from alkali wetland habitats were highly variable, but averaged approximately 0.60 (SE = 0.47) female fledglings per female. For the Canadian provinces we used 0.52 (SE = 0.40) females per pair, based on unpublished data (C. Gratto-Trevor, unpublished data) and estimates incorporated into the McGowan and Ryan (2009) population model. Fecundity parameters in each region were modeled as log-normally distributed random variables.

Mean transition rates between breeding regions were assumed to be low. We have scant evidence of birds moving between regions from several multi-year banding studies that have been conducted. Movement data from mark-recapture studies in the Great Plains indicate that long distance dispersal (e.g. from Nebraska to North Dakota) occurs infrequently (D. Catlin, unpublished data, C. Gratto-Trevor, unpublished data) for adults and immature birds/first time breeders. Less than two percent of birds banded in a multi-year mark-recapture study in Saskatchewan were ever observed in another region, although these are largely incidental resight data and do not reflect directed efforts to study and sample interregional movement. Opportunity for interregional movement is probably greatest between Northern Rivers and U.S. Alkali Lakes, given their nearness to one another. Mid-way through the 2013 breeding season, no fewer than 8 adult plovers captured and marked from nests in Northern Rivers Region had been resighted within the Alkali Lakes Region despite limited resighting effort in the Alkali Lakes (U.S. Geological Survey unpublished data). For purposes here we assumed the total emigration rate from each region was 0.02. We divided that rate equally among the other regions (i.e. the immigration rate into any one region from another averaged 0.0066 (SE 0.02) of the population in the origin region in the previous year). We modeled these transition parameters as beta-distributed random variables. We used the method-of-moments calculations to derive the beta distribution scale and shape parameters from the mean and standard error.

The model included a simple ceiling type density dependence function that reduced productivity in a region to zero if the population in that region exceeded a threshold of 6000 individuals. There are no published assessments of density dependence in this population, but some data do indicate density-dependent reproductive success occurs on the nesting beach/island scale (M. Ryan unpublished data, Catlin 2009). It seems logical that there must be some limiting effect of habitat availability on population growth and abundance. McGowan et al. (2011a) published a model with density-dependent juvenile survival, but the density dependent function was generic and not empirically based. The McGowan et al. (2011a) model was developed to demonstrate the interaction of density dependence and incidental take, not to serve as a management model for plovers in the Great Plains. Here we used a common approach of setting a maximum ceiling for the population without speculating on the details or functional form of the density-dependent function, similar to McGowan and Ryan (2009).

The two primary model outputs were mean expected population growth rate and the probability of extinction in year 50. Calculating population growth was simply a matter of dividing current population size by the population size in the previous year:

$$\lambda_t^i = \frac{N_t^i}{N_{t-1}^i},$$

where λ was the population growth rate for the *i*th management region, *N* was the population size and t was the time step. Population growth was calculated for each time step and the geometric mean of λ was calculated for each iteration. We also calculated the mean population growth rate across iterations to obtain the overall expected mean population growth rate.

We calculated regional quasi-extinction probability (hereafter, extinction probability) using a Boolean-logic function that recorded a one if the population was less than 50 individuals and a 0 if the population was greater than 50 individuals for each year in each region for each iteration. Quasi-extinction thresholds are frequently used in population modeling as surrogates of true extinction to account for the complexities of demographic stochasticity in a mathematically simple way. Similarly, for the entire Great Plains population we set a quasi-extinction threshold of 100 individuals. At the end of each simulation, we summed the number of extinction events for each year and divided by the number of iterations. We tracked extinction every year but for the post-simulation analyses (see below) we looked only at the number of iterations where the population was extinct at year 50 to allow regions to be recolonized naturally by dispersal events from other regions. At the regional level, this is not the same as a cumulative extinction probability for each region, but more analogous to a single year probability of extinction 50 years into the future. The state of the system 50 years into the future is the end result of 50 years of stochastic events, including previous extinction and colonization and thus our tracking of regional extinction incorporates the accumulation of those stochastic events. The overall population estimate of extinction probability is equivalent to a cumulative extinction probability because our model does not allow for recolonization from outside the Great Plains.

Uncertainty

There is a great deal of uncertainty embedded in our model. Several of the parameters had no empirical estimates, were based on limited data, or inferred from studies not directly estimating the parameter of interest. Even the parameters that are empirically estimated (e.g. survival or productivity,) are subject to sampling variation causing parametric uncertainty. The individuals that are captured and studied and even the years that a study took place can influence the mean estimates of demographic parameters and the estimates of annual variation in those parameters (McGowan et al. 2011b). Parametric uncertainty due to sampling variance can have large effects on model predictions and those effects should be incorporated into population projection models, especially when modeling in a management context (McGowan et al. 2011b). We followed the recommendations of McGowan et al. (2011b) for incorporating parametric uncertainty into our model for survival, fecundity and regional transition parameters. We sampled mean values for each parameter in each replicate of the population projection (sampling variability). The mean values for each replicate were then used to create new statistical distributions to select parameter values for each year in that replicate projection, mimicking temporal variability in annual demographic rates. This hierarchical approach allows the model to include both parametric uncertainty and temporal variability into the projections and assessment of extinction probability (Fig. A2).

Our model also allowed us to include observation uncertainty on abundance and population growth outputs. Our ability to assess population status and management effectiveness is partly dependent on our ability to observe the population accurately. However, piping plovers are difficult to count given their cryptic coloration and elusive behavior and the vastness of some breeding areas (e.g., shorelines of large reservoirs). Models, on the other hand, predict precisely the expected number of individuals in the population given survival and productivity, and estimates of future abundance or extinction risk are derived from those precise predictions. Our application of model-based prediction of extinction probability, as it relates back to population size and population growth rate, assumes highly accurate or near perfect ability to detect and count a population through monitoring programs. Recovery criteria based on those model predictions may lead to premature or delayed delisting of a species due to imperfect monitoring and population status assessment. Temporal and parametric uncertainty accounts for variability in parameter estimates or stochastic variation in the environment, but does not account for imperfect monitoring of a population. We included a post-projection randomized adjustment to number of birds in the population and subsequently to population growth. We took the actual number of breeding birds from the simulation and the number of offspring produced in each year and multiplied each by a uniform random number between 0.5 and 1.1. Our uniform random distribution multiplier allows for both over and undercounting of individuals in any region in any year but the distribution is skewed towards undercounting because one study supported frequent and significant undercounting for current monitoring efforts in the Northern Rivers region and consistent but less significant undercounting in the Southern Rivers region (Shaffer et al., in press). We recorded the actual and the observed abundances and population growth rates separately and used the two to assess the effect of monitoring error on predicting extinction probability.

Parameter sensitivity simulations

We used the model to predict extinction risk region by region and for the whole population at 50 years if current demographics and management effort continues for the next 50 years. Initial population size and regional distributions were set to reflect the 2006 international "census" and the demographic parameters were set at the baseline levels described above. We tested the sensitivity of extinction risk to changes in the density-dependent ceiling and to the magnitude of inter-regional movement parameters, the two sets of model parameters with the least amount of empirical support. In one scenario we increased the density-dependent ceiling from 6000 per region to 10000 per region. In a separate simulation, restoring the ceiling to 6000, we increased the immigration rates between regions from 0.0066 annually to 0.012 annually uniformly across regions.

Simulating extinction risk related to initial conditions

We ran simulations to identify the minimum population size and population growth rates required to reduce extinction risk to an acceptably low threshold. This set of simulations input random starting values for initial population abundance, regional distribution of the population and overall mean values for fecundity (Fig A2). Initial population size was drawn from a uniform random distribution bounded by 1000 and 10000, mean fecundity was drawn from a uniform random distribution bounded between 0.2 and 1.2 females produced per breeding female, adult survival was drawn from a uniform distribution bounded by 0.65 and 0.85, and first year survival was drawn from a uniform distribution bounded by 0.35 and 0.65. The regional distribution parameters were also drawn from a uniform random distribution and the four parameters were set to sum to one. We ran 1000 replicates under these conditions to generate 1000 extinction probabilities and expected population growth rates, one for each starting scenario (Fig A2). With those input and output data we evaluated a set of candidate regression models to investigate the relationship between extinction probability (the response variable) and total population size, regional population size, population growth rate, mean fecundity, mean adult survival and mean first year survival (the predictor variables; abundance covariates were input as raw values or log transformed values in different competing models) for both the actual and observed data output from the simulations. We used AIC model selection to compare and select the best model to describe variation in extinction risk in each region due to those independent variables (i.e., the model with the lowest AIC score and highest model weight was considered best and if additional models fell within 2.0 AIC units of the best model we relied on multi-model inference; Burhnam and Anderson, 2002). We used the regression parameter estimates from that model to populate a decision table that described the population size and predicted population growth combinations required to achieve the pre-determined acceptable extinction risk threshold. We argue that the decision table can serve as a delisting criterion for the population (i.e., the "decision" is whether to delist).

RESULTS

Under current conditions with low inter-regional transition probabilities and a low density-dependent ceiling, the mean population growth rate was 1.001 (S.D. = 0.029), extinction probability was 0.033 and median abundance at 50 years was 11379 (2.5 percentile = 63, 97.5 percentile = 24858) females for the entire Great Plains population. The southern rivers region, where intensive habitat management has occurred in recent years had the lowest extinction probability (0.043) and seemed to insulate the overall population from extinction risk. Extinction probability in the other three regions exceeded 8% at 50 years (Fig. A3). Increasing the density dependent ceiling from 6000 birds in each region to 10000 birds in each region did not greatly change overall extinction risk (0.043 to 0.030) but did increase the predicted median abundance over time (~13100 to ~21600 at 50 years) for the whole Great Plains population. That same pattern was observed in each of the individual regions. Increasing the interregional transition probabilities resulted in a slight decrease in extinction risk for the entire Great Plains population (0.043 with low transition rate, 0.031 with higher transition rates), and very little change in the total abundance (11379 with low transition rate, 12383 with higher transition rates). Region by region there was very little change in extinction risk and all regions exhibited increases in median abundance at 50 years when the transition probability between regions was doubled.

The best regression model to explain variability in extinction risk under perfect observability for the whole Great Plains population had the natural log of population size (b = -0.659; SE = 0.005) and the mean population growth rate over 50 years (b = -32.7; SE = 0.074) as covariates (*intercept* = 35.2, S.E.= 0.086, AIC = 30434, ΔAIC = 0.00, w = 1.00). That same model structure garnered all the AIC weight at the whole population scale and for each of the four population/management regions, therefore our results and discussion focus on the whole population scale for simplicity and brevity. Under an expected population growth of 1.0 and a minimum extinction threshold of 0.05, a total initial population of approximately 4000 females is required. Whereas, a minimum extinction threshold of 0.01 and an expected population growth of 1.00 requires a total initial population of >5600 females (Table 2). While the top model only included population growth and initial population size, population growth rate may not be easily measured in the field. It may be more useful to use other, more empirically based metrics such as fecundity. If the purpose is to establish useful measureable attributes of the fundamental objectives (i.e., eliminating or reducing extinction risk; e.g., Keeney and Gregory, 2005, McGowan et al., in review) using the top AIC model for inference may be unnecessary; it may be prudent to limit the candidate metrics in the regression analysis to only those that are easily measureable for a specific species; the metrics included in this model comparison essentially become the alternatives in a recovery criteria decision analysis. A minimum extinction threshold of 0.05 requires a mean fecundity (female chick produced per female) of 1.20 and an initial population of approximately 3200 females. Each regression parameter has an associated variance and it may be important to represent this uncertainty in the output of the analysis. One approach would be to calculate the 95% C.I. of each regression parameter, then build additional extinction probability tables for the upper and lower bound, or any other relevant and useful percentile of expected variation.

When the observation model was applied to model output data, accounting for imperfect observations of the population, the strongest linear regression model in the AIC analyses for the whole Great Plains population had log of counted initial population size (*b* = -0.665; SE = 0.005) and expected population growth rate (*b* = -32.5; SE = 0.074) as covariates in the regression. The top model for the adjusted output data was the same model as the perfect detection output but with different regression parameter estimates (*intercept* = 35.7, S.E. = 0.087). That same model structure garnered all the AIC weight in each of the four population/management regions when the observation model was applied to the data. Again, required population size was dependent on the desired level of extinction probability and the desired population growth rate. Under all starting population size and growth rate combinations, the estimated extinction probability was 7.9% greater when observation error was applied compared to perfect detection. Under an expected population growth of 1.0 and a minimum extinction threshold of 0.05, a total initial population of approximately 5600 females is required. Whereas, a minimum extinction threshold of 0.01 and an expected population growth of 1.00 requires a total initial population much greater 5600 females. Alternatively, a population growth rate of 1.2 and an initial population size of 3600 females would achieve a minimum extinction threshold of 0.05. The numeric value of the regression parameter estimates are not substantially different when using the observation adjusted model from the perfect observation model but the recovery criteria using the same extinction risk threshold would be much larger.

We used the results of the regression analysis to estimate the number of habitat hectares required to support each regional population. With recovery criteria 1 requiring a maximum of 0.05 extinction probably in any single region and criteria 2 requiring a stable or increasing population (i.e., $\lambda \geq 1.00$), we used the regression parameters from the binomial GL modeling and the logit link function to back calculate the number required number of breeding females to achieve the extinction population growth rate thresholds:

$$P_e = \frac{1}{1+exp\left(-\left(Intercept+(b_{Ni} \times lnN_i)+(b_\lambda \times \lambda)\right)\right)} \;,$$

$$N_i = exp\left(\frac{\left(ln\left(1/P_e - 1\right)+Intercept+(b_\lambda \times \lambda)\right)}{-b_{Ni}}\right).$$

We then multiplied the number of individual required in each region by 0.67 (the estimated number of hectares required for a breeding pair to successfully fledge offspring; D. Catlin unpublished data) to estimate the required number of habitat Hectares for each region (Table A1).

Table A1: Estimated number of hectares of habitat required for each required for each regional population, based on the maximum tolerable extinction probability (0.05 per region) and required population growth (λ= 1.0) for recovery, and derived using the logit link function and a minimum number of 0.67 hectares per breeding pair.

	Intercept	Lambda beta (bλ)	Population size beta (bNi)	Extinction probability (Pe)	Lambda (λ)	Starting Female Population size (Ni)	Habitat hectares
Southern rivers	45.504	-41.793	-0.854	0.050	1.000	2436.232	1632.275
Northern rivers	46.077	-41.927	-0.935	0.050	1.000	1975.773	1323.768
Alkali wetlands	46.195	-42.076	-0.919	0.050	1.000	2175.914	1457.863
Prairie Canada	46.259	-42.031	-0.933	0.050	1.000	2181.019	1461.283

Figure A2: Map of the Northern Great Plains piping plover population range depicting the primary management and sub-population units in the meta-population model. Animals can move between regions inter-annually at limited rates.

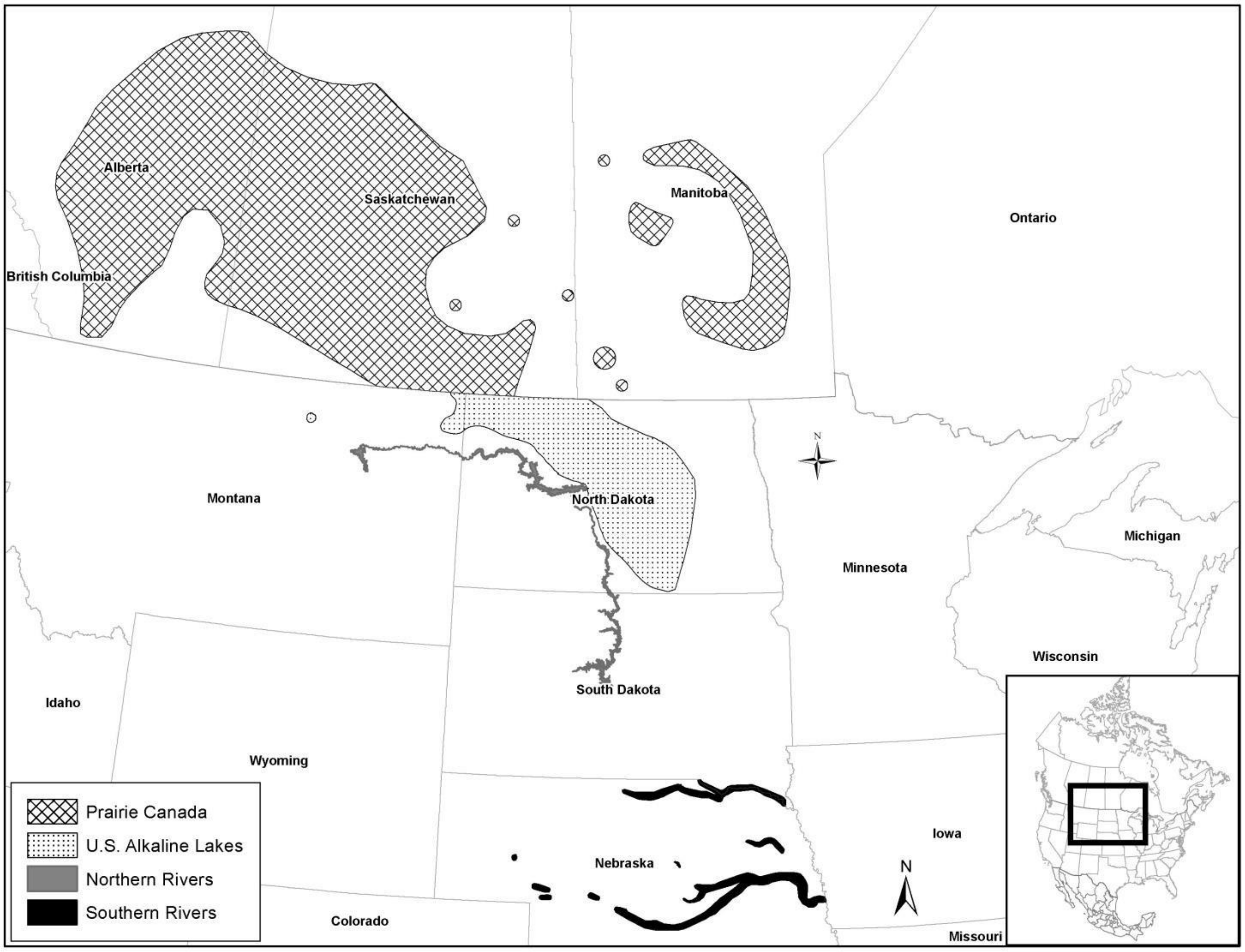


Figure A3: Hierarchical loop structure of the simulation demonstrating how our model selected initial values and overall means in the outer loop, applied sampling variance in the replicate loop, and applied temporal variation in the annual loop.

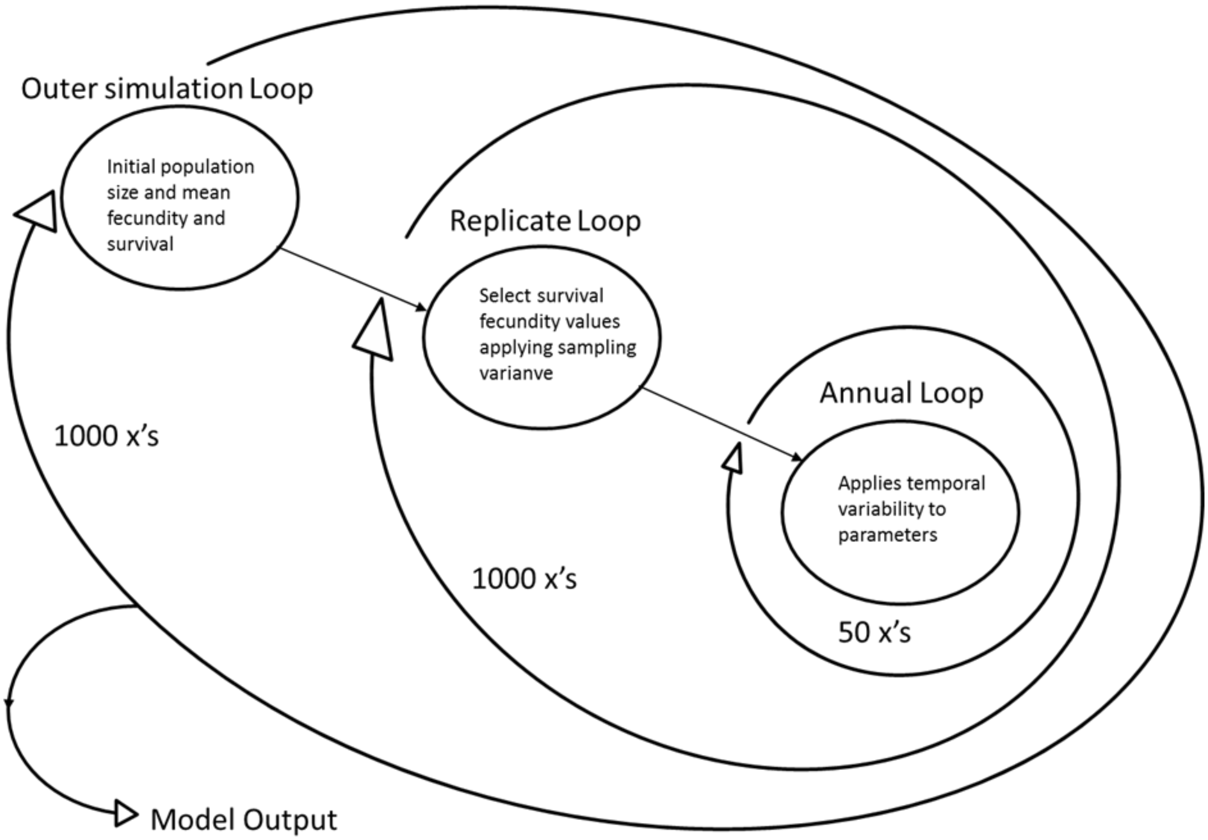
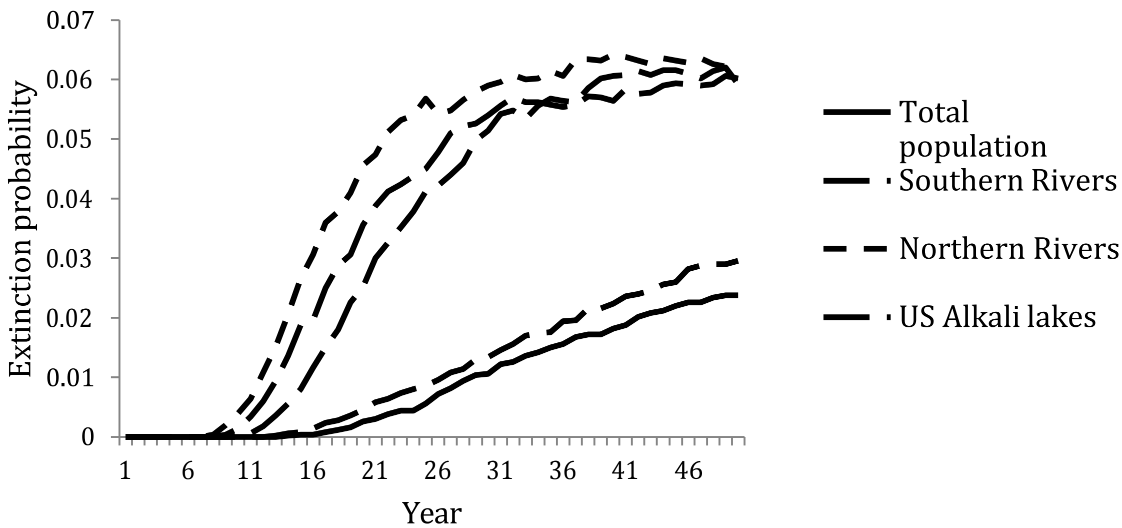


Figure A4: Probability of extinction of Piping Plovers for the entire Great Plains population and by individual management region (Southern Rivers, Northern Rivers, US Alkali Lakes and Prairie Canada) as estimated by a meta-population model in each of 50 years.



R code for the Great Plains Piping plover meta-population simulation model.

```
#Piping Plover population model to simulate population viability in the Northern Great
#Plains.  The model is intended to support the recovery planning process to identify
#population targets/goals. Written by Conor P. McGowan, started on July 10, 2012, revised on 8/29/14.
####################
#Set the working directory where data and files will be saved, this line may not be necessary
#setwd("C:/Users/cpm0014/Documents/PIPL")

#First step is to declare data arrays for variable inputs in the outer loop function
####
#Number of replicate simulations
Rep = 1000

#Initial total population and regional population size randomization
P = matrix(round(runif(Rep,1000,10000)), Rep, 1)#4662/2 #4662/2
# Pr1 = matrix(0, Rep, 1)
Pr2 = matrix(0, Rep, 1)
Pr3 = matrix(0, Rep, 1)
Pr4 = matrix(0, Rep, 1)
mpr1= matrix(0, Rep, 1)
mpr2= matrix(0, Rep, 1)
mpr3= matrix(0, Rep, 1)
mpr4= matrix(0, Rep, 1)

#Geographic distribution randomization
K2=replicate(Rep, diff(c(0, sort(runif(3)), 1)))#K/100
```

```
#Mean fecundity randomization
Fr1 = matrix(runif(Rep,0.1,1.2), Rep, 1)#.77#
Fr2 = matrix(runif(Rep,0.1,1.2), Rep, 1)#0.399#
Fr3 = matrix(runif(Rep,0.1,1.2), Rep, 1)#0.6#
Fr4 = matrix(runif(Rep,0.1,1.2), Rep, 1)#0.52#
#Adult and Juvenile survival randomization
SA = matrix(runif(Rep,0.65,0.85), Rep, 1)#0.78#
SJ = matrix(runif(Rep,0.35,0.65), Rep, 1)#0.52#

#Set up data arrays for simulation output data, used in post simulation regression
analysis data.summary = matrix(0,Rep,21)
data.summary1 = matrix(0,Rep,15)
data.summary2 = matrix(0,Rep,15)
data.summary3 = matrix(0,Rep,9)
data.summary4 = matrix(0,Rep,11)

#Initiate outer Loop function with a "for" statement. This creates 1000 (n=Rep) replicate simatulions.
for(y in 1:Rep){

#Next, declare data arrays for parameters and variables in each of the simulations
#####
#4 management/population regions with with an abundance, each with its own Productivity
#parameter and there is a single adult and juvenile survival estimate
#Initial distributions from 2006 "census" for "current viability" simulation
#0.365293865 #CA
#0.202059202 #Alk
#0.277134277 #SR
#0.155512656 #NR
```

```
#assign Uniform random distribution parameters to each region
Pr1[y] =  K2[1,y]   #Southern Rivers
Pr2[y]  =  K2[2,y]  #Northern  Rivers
Pr3[y]  =  K2[3,y]  #Alkali  Wetlands
Pr4[y] =  K2[4,y]   #Canada

# Declare the variables
###
r = 1000          #number of replicates in the simulation
t = 50            #number of years in the simulation

#population size arrays for perfect observation data (N)
Nr1 = matrix(0,r,t)     #population size region 1, Southern rivers
Nr2 = matrix(0,r,t)    #population size region 2, Northern rivers
Nr3 = matrix(0,r,t)   #population size region 3, US Alkali lakes
Nr4 = matrix(0,r,t) #population size region 4, Canadian provences

Nt = matrix(0,r,t)         #total population size array

#Population size based on number of counted individuals, including counting error (C)
Cr1 = matrix(0,r,t)       #population size region 1, Southern rivers
Cr2 = matrix(0,r,t)     #population size region 2, Northern rivers
Cr3 = matrix(0,r,t)   #population size region 3, US Alkali lakes
Cr4 = matrix(0,r,t) #population size region 4, Canadian provinces

Ct = matrix(0,r,t)         #total population size array
```

```
#Arrays for calculating the proportion of the population in each region in each year
mpr11=matrix(0,r,t)
mpr22=matrix(0,r,t)
mpr33=matrix(0,r,t)
mpr44=matrix(0,r,t)

#Lambda arrays based on actual population size
Lar1 = matrix(0,r,t)
Lar2 = matrix(0,r,t)
Lar3 = matrix(0,r,t)
Lar4 = matrix(0,r,t)
Lat = matrix(0,r,t)

Ltr1 = matrix(0,r,1)
Ltr2 = matrix(0,r,1)
Ltr3 = matrix(0,r,1)
Ltr4 = matrix(0,r,1)
Ltt = matrix(0,r,1)

#Lambda arrays based on observed count of individuals
cLar1 = matrix(0,r,t)
cLar2 = matrix(0,r,t)
cLar3 = matrix(0,r,t)
cLar4 = matrix(0,r,t)
cLat = matrix(0,r,t)

cLtr1 = matrix(0,r,1)
cLtr2 = matrix(0,r,1)
```

```
cLtr3 = matrix(0,r,1)
cLtr4 = matrix(0,r,1)
cLtt = matrix(0,r,1)

### DEMOGRAPHIC RATES
### First we establish the shape parameters for the parametric uncertainty loop,
### then create the data arrays for the annual replicated loop following McGowan et al.
### 2011 The annual parameter values are drawn from an iteration specific random value to
### virtually represent the effects of sampling variance and parametric uncertainty on the
### population predictions

#fecundity parameters by region. These parameters are derived from the randomly generated mean
#in the outer loop

###region 1, Southern Rivers (0.77 females per female in current viability simulations)
F1lnsd = .5
F1ln = log(Fr1[y])-1/2*F1lnsd#-.3#
F1sd = 0.2
F1i = matrix(0,r,1)
F1iln=matrix(0,r,1)
F1ilnsd=matrix(0,r,1)
F1t=matrix(0,r,t)

##region 2 Mean = 0.399 females per female
F2lnsd = .5
F2ln = log(Fr2[y])-1/2*F2lnsd#-1.12
F2sd = 0.02
F2i = matrix(0,r,1)
```

```
F2iln=matrix(0,r,1)
F2ilnsd=matrix(0,r,1)
F2t=matrix(0,r,t)

##region 3 mean = 0.6 females per female
F3lnsd = .5
F3ln = log(Fr3[y])-1/2*F3lnsd#-.75#
F3sd = 0.2
F3i = matrix(0,r,1)
F3iln=matrix(0,r,1)
F3ilnsd=matrix(0,r,1)
F3t=matrix(0,r,t)

##region 4 mean = 0.52 females per female
F4lnsd = .5
F4ln = log(Fr4[y])-1/2*F4lnsd# -.85#
F4sd = 0.2
F4i = matrix(0,r,1)
F4iln=matrix(0,r,1)
F4ilnsd=matrix(0,r,1)
F4t=matrix(0,r,t)

#adult survival parameters. These parameters are derivred from the randomly generate mean
#in the outer loop

S.m = SA[y]
S.sd = 0.03
S.SD.m = 0.03
```

```
S.SD.sd = 0.02
#Sia= S.m*((S.m*(1-S.m)/S.sd)-1)
Sia = S.m*((S.m*(1-S.m)/(S.sd^2))-1)
Sib= (1-S.m)*((S.m*(1-S.m)/(S.sd^2))-1)
Si = matrix(0,r,1)
Si.sd=0.001#matrix(0,r,1)#0.0012
S.t.a=matrix(0,r,1)
S.t.b=matrix(0,r,1)
S.t=matrix(0,r,t)

#juvenile survival parameters. These parameters are derived from the randomly generated mean
#in the outer loop

Sj.m = SJ[y]
Sj.sd = 0.08
Sj.SD.m = 0.12
Sj.SD.sd = 0.002
Sjia=Sj.m*((Sj.m*(1-Sj.m)/(Sj.sd^2))-1)
Sjib=(1-Sj.m)*((Sj.m*(1-Sj.m)/(Sj.sd^2))-1)
Sji = matrix(0,r,1)
Sji.sd= 0.2 # matrix(0,r,1)
Sj.t.a=matrix(0,r,1)
Sj.t.b=matrix(0,r,1)
Sj.t=matrix(0,r,t)

#inter-regional transition parameters; all transitions average 0.06% annually (baseline alpha = 0.19, baseline beta =
28) T.12 = matrix(0,r,t) #interannual transition from region 1 to 2
T.12a = 0.19
```

T.12b=28
T.13 = matrix(0,r,t) #interannual transition from region 1 to 3
T.13a=0.19
T.13b=28
T.14 = matrix(0,r,t) #interannual transition from region 1 to 4
T.14a=0.19
T.14b=28
T.21 = matrix(0,r,t) #interannual transition from region 2 to 1
T.21a=0.19
T.21b=28
T.23 = matrix(0,r,t) #interannual transition from region 2 to 3
T.23a=0.19
T.23b=28
T.24 = matrix(0,r,t) #interannual transition from region 2 to 4
T.24a=0.19
T.24b=28
T.31 = matrix(0,r,t) #interannual transition from region 3 to 1
T.31a=0.19
T.31b=28
T.32 = matrix(0,r,t) #interannual transition from region 3 to 2
T.32a=0.19
T.32b=28
T.34 = matrix(0,r,t) #interannual transition from region 3 to 4
T.34a=0.19
T.34b=28
T.41 = matrix(0,r,t) #interannual transition from region 4 to 1
T.41a=0.19
T.41b=28

```
T.42 = matrix(0,r,t) #interannual transition from region 4 to 2
T.42a=0.19
T.42b=28
T.43 = matrix(0,r,t) #interannual transition from region 4 to 3
T.43a=0.19
T.43b=28

#Arrays for counting population extinction
et =matrix(0,r,t)
er1 =matrix(0,r,t)
er2 =matrix(0,r,t)
er3 =matrix(0,r,t)
er4 =matrix(0,r,t)

for(i in 1:r){  #begin 2nd replication loop

#incorporating sampling variance / parametric uncertainty for model survival and fecundity parameters

#Adult Survival:
Si[i] = rbeta(1,Sia,Sib)
Si.sd[i]= .001#rbeta(1,0.3,0.0002)

# calculate alpha shape parameter for each iteration
S.t.a[i] = Si[i]*((Si[i]*(1-Si[i])/(Si.sd[i]^2))-1)#89.6#

# Calculate beta shape parameter for each iteration
S.t.b[i] =(1-Si[i])*((Si[i]*(1-Si[i])/(Si.sd[i]^2))-1)#54.8#
```

```
#juvenile survival
Sji[i] = rbeta(1,Sjia,Sjib)
Sji.sd[i]=0.12

# calculate alpha shape parameter for each iteration
Sj.t.a[i] = Sji[i]*((Sji[i]*(1-Sji[i])/(Sji.sd[i]^2))-1)

# Calculate beta shape parameter for each iteration
Sj.t.b[i] = (1-Sji[i])*((Sji[i]*(1-Sji[i])/(Sji.sd[i]^2))-1)

#fecundity R1
F1i[i] <- rlnorm(1,F1ln, F1lnsd)
F1ilnsd[i] = log((F1sd^2)/(F1i[i]^2) + 1)
F1iln[i] = log(F1i[i])-1/2*F1ilnsd[i]
#fecundity R2
F2i[i] <- rlnorm(1, F2ln, F2lnsd)
F2ilnsd[i] = log((F2sd^2)/(F2i[i]^2) + 1)
F2iln[i] = log(F2i[i])-1/2*F2ilnsd[i]
#fecundity R3
F3i[i] <- rlnorm(1,F3ln, F3lnsd)
F3ilnsd[i] = log((F3sd^2)/(F3i[i]^2) + 1)
F3iln[i] = log(F3i[i])-1/2*F3ilnsd[i]
#fecundity R4
F4i[i] <- rlnorm(1,F4ln, F4lnsd)
F4ilnsd[i] = log((F4sd^2)/(F4i[i]^2) + 1)
F4iln[i] = log(F4i[i])-1/2*F4ilnsd[i]

#Begin the annual loop
```

```
for(j in 1:t){

#Annual fecundity values drawn from a log normal distribution restricted by DD deiling
if (j>1 && Nr1[i,j-1]>6000) F1t[i,j]=0 else F1t[i,j]=rlnorm(1,F1iln[i],F1ilnsd[i])
if (j>1 && Nr2[i,j-1]>6000) F2t[i,j]=0 else F2t[i,j]=rlnorm(1,F2iln[i],F2ilnsd[i])
if (j>1 && Nr3[i,j-1]>6000) F3t[i,j]=0 else F3t[i,j]=rlnorm(1,F3iln[i],F3ilnsd[i])
if (j>1 && Nr4[i,j-1]>6000) F4t[i,j]=0 else F4t[i,j]=rlnorm(1,F4iln[i],F4ilnsd[i])

#Annual survival parameters, drawn from beta distributions
S.t[i,j] = rbeta(1,S.t.a[i],S.t.b[i])
Sj.t[i,j] = rbeta(1,Sj.t.a[i],Sj.t.b[i])

#annual regional transition parameters, drawn from beta distributions
T.12[i,j] = rbeta(1,T.12a,T.12b)
T.13[i,j] = rbeta(1,T.13a,T.13b)
T.14[i,j] = rbeta(1,T.14a,T.14b)
T.21[i,j] = rbeta(1,T.21a,T.21b)
T.23[i,j] = rbeta(1,T.23a,T.23b)
T.24[i,j] = rbeta(1,T.24a,T.24b)
T.31[i,j] = rbeta(1,T.31a,T.31b)
T.31[i,j] = rbeta(1,T.31a,T.31b)
T.32[i,j] = rbeta(1,T.32a,T.32b)
T.34[i,j] = rbeta(1,T.34a,T.34b)
T.41[i,j] = rbeta(1,T.41a,T.41b)
T.42[i,j] = rbeta(1,T.42a,T.42b)
T.43[i,j] = rbeta(1,T.43a,T.43b)
```

#Regional population projection equations, Year one is set to P[y] * Pri[y]

if (j==1)Nr1[i,j] = round(P[y]*Pr1[y]) else
Nr1[i,j] = round((Nr1[i,j-1]*S.t[i,j-1]) + (Nr1[i,j-1]*F1t[i,j-1]*Sj.t[i,j-1]) + ((Nr2[i,j-1]*S.t[i,j-1]) + (Nr2[i,j-1]*F2t[i,j-1]*Sj.t[i,j-1]))*T.21[i,j-1] +
((Nr3[i,j-1]*S.t[i,j-1]) + (Nr3[i,j-1]*F3t[i,j-1]*Sj.t[i,j-1]))*T.31[i,j-1] + ((Nr4[i,j-1]*S.t[i,j-1]) + (Nr4[i,j-1]*F4t[i,j-1]*Sj.t[i,j-1]))*T.41[i,j-1]
-
((Nr1[i,j-1]*S.t[i,j-1]) + (Nr1[i,j-1]*F1t[i,j-1]*Sj.t[i,j-1]))*T.12[i,j-1] - ((Nr1[i,j-1]*S.t[i,j-1]) + (Nr1[i,j-1]*F1t[i,j-1]*Sj.t[i,j-1]))*T.13[i,j-1]
-
((Nr1[i,j-1]*S.t[i,j-1]) + (Nr1[i,j-1]*F1t[i,j-1]*Sj.t[i,j-1]))*T.14[i,j-1])
#calculate regional lambda, assign 0 if pop is extinct
if (j>1 && Nr1[i,j-1]>0)Lar1[i,j] = Nr1[i,j]/Nr1[i,j-1] else Lar1[i,j] = 0
#Counting error model applied to projection output.
Cr1[i,j]=round(Nr1[i,j]*runif(1,.5,1.1))
if (j>1 && Cr1[i,j-1]>0)cLar1[i,j] = Cr1[i,j]/Cr1[i,j-1] else cLar1[i,j] = 0

if (j==1)Nr2[i,j] = round(P[y]*Pr2[y]) else
Nr2[i,j] = round((Nr2[i,j-1]*S.t[i,j-1]) + (Nr2[i,j-1]*F2t[i,j-1]*Sj.t[i,j-1]) + ((Nr1[i,j-1]*S.t[i,j-1]) + (Nr1[i,j-1]*F1t[i,j-1]*Sj.t[i,j-1]))*T.12[i,j-1] +
((Nr3[i,j-1]*S.t[i,j-1]) + (Nr3[i,j-1]*F3t[i,j-1]*Sj.t[i,j-1]))*T.32[i,j-1] + ((Nr4[i,j-1]*S.t[i,j-1]) + (Nr4[i,j-1]*F4t[i,j-1]*Sj.t[i,j-1]))*T.42[i,j-1]
-
((Nr2[i,j-1]*S.t[i,j-1]) + (Nr2[i,j-1]*F2t[i,j-1]*Sj.t[i,j-1]))*T.21[i,j-1] - ((Nr2[i,j-1]*S.t[i,j-1]) + (Nr2[i,j-1]*F2t[i,j-1]*Sj.t[i,j-1]))*T.23[i,j-1]
-
((Nr2[i,j-1]*S.t[i,j-1]) + (Nr2[i,j-1]*F2t[i,j-1]*Sj.t[i,j-1]))*T.24[i,j-1])

if (j>1 && Nr2[i,j-1]>0)Lar2[i,j] = Nr2[i,j]/Nr2[i,j-1] else Lar2[i,j] = 0
Cr2[i,j]=round(Nr2[i,j]*runif(1,.5,1.1))
if (j>1 && Cr2[i,j-1]>0)cLar2[i,j] = Cr2[i,j]/Cr2[i,j-1] else cLar2[i,j] = 0

```
if (j==1)Nr3[i,j] = round(P[y]*Pr3[y]) else
Nr3[i,j] = round((Nr3[i,j-1]*S.t[i,j-1]) + (Nr3[i,j-1]*F3t[i,j-1]*Sj.t[i,j-1]) + ((Nr1[i,j-1]*S.t[i,j-1]) + (Nr1[i,j-1]*F1t[i,j-1]*Sj.t[i,j-
1]))*T.13[i,j-1] +
((Nr2[i,j-1]*S.t[i,j-1]) + (Nr2[i,j-1]*F2t[i,j-1]*Sj.t[i,j-1]))*T.23[i,j-1] + ((Nr4[i,j-1]*S.t[i,j-1]) + (Nr4[i,j-1]*F4t[i,j-1]*Sj.t[i,j-1]))*T.43[i,j-1]
-
((Nr3[i,j-1]*S.t[i,j-1]) + (Nr3[i,j-1]*F3t[i,j-1]*Sj.t[i,j-1]))*T.31[i,j-1] - ((Nr3[i,j-1]*S.t[i,j-1]) + (Nr3[i,j-1]*F3t[i,j-1]*Sj.t[i,j-1]))*T.32[i,j-1]
-
((Nr3[i,j-1]*S.t[i,j-1]) + (Nr3[i,j-1]*F3t[i,j-1]*Sj.t[i,j-1]))*T.34[i,j-1])

if (j>1 && Nr3[i,j-1]>0)Lar3[i,j] = Nr3[i,j]/Nr3[i,j-1] else Lar3[i,j] = 0
Cr3[i,j]=round(Nr3[i,j]*runif(1,.5,1.1))
if (j>1 && Cr3[i,j-1]>0)cLar3[i,j] = Cr3[i,j]/Cr3[i,j-1] else cLar3[i,j] = 0

if (j==1)Nr4[i,j] = round(P[y]*Pr4[y]) else
Nr4[i,j]= round((Nr4[i,j-1]*S.t[i,j-1]) + (Nr4[i,j-1]*F4t[i,j-1]*Sj.t[i,j-1]) + ((Nr1[i,j-1]*S.t[i,j-1]) + (Nr1[i,j-1]*F1t[i,j-1]*Sj.t[i,j-
1]))*T.14[i,j-1] +
((Nr2[i,j-1]*S.t[i,j-1]) + (Nr2[i,j-1]*F2t[i,j-1]*Sj.t[i,j-1]))*T.24[i,j-1] + ((Nr3[i,j-1]*S.t[i,j-1]) + (Nr3[i,j-1]*F3t[i,j-1]*Sj.t[i,j-1]))*T.34[i,j-1]
-
((Nr4[i,j-1]*S.t[i,j-1]) + (Nr4[i,j-1]*F4t[i,j-1]*Sj.t[i,j-1]))*T.41[i,j-1] - ((Nr4[i,j-1]*S.t[i,j-1]) + (Nr4[i,j-1]*F4t[i,j-1]*Sj.t[i,j-1]))*T.42[i,j-1]
-
((Nr4[i,j-1]*S.t[i,j-1]) + (Nr4[i,j-1]*F4t[i,j-1]*Sj.t[i,j-1]))*T.43[i,j-1])

if (j>1 && Nr4[i,j-1]>0)Lar4[i,j] = Nr4[i,j]/Nr4[i,j-1] else Lar4[i,j] = 0
Cr4[i,j]=round(Nr4[i,j]*runif(1,.5,1.1))
if (j>1 && Cr4[i,j-1]>0)cLar4[i,j] = Cr4[i,j]/Cr4[i,j-1] else cLar4[i,j] =
0 # Sum regions for population total
Nt[i,j]=Nr1[i,j]+Nr2[i,j]+Nr3[i,j]+Nr4[i,j]
```

```
if (Nt[i,j] < 1) Nt[i,j]=0 #set population to 0 if <1 individual
remains Ct[i,j]=round(Nt[i,j]*runif(1,.5,1.1))
#set regional popultaion to 0 if <1 individaul remains
if (Nr1[i,j] < 1) Nr1[i,j]=0
if (Nr2[i,j] < 1) Nr2[i,j]=0
if (Nr3[i,j] < 1) Nr3[i,j]=0
if (Nr4[i,j] < 1) Nr4[i,j]=0
#calculate total population lambda
if (j>1 && Nt[i,j-1]>0)Lat[i,j] = Nt[i,j]/Nt[i,j-1] else Lat[i,j] = 0
#calculate lambda for counting error data
if (j>1 && Ct[i,j-1]>0)cLat[i,j] = Ct[i,j]/Ct[i,j-1] else cLat[i,j] = 0

#calculate proportion of population is each region
mpr11[i,j] = Nr1[i,j]/Nt[i,j]
mpr22[i,j] = Nr2[i,j]/Nt[i,j]
mpr33[i,j] = Nr3[i,j]/Nt[i,j]
mpr44[i,j] = Nr4[i,j]/Nt[i,j]


#count #on population trajectories that go quasi-
extinct if (Nt[i,j] < 100)  et[i,j]=1
if (Nr1[i,j] < 50) er1[i,j]=1
if (Nr2[i,j] < 50) er2[i,j]=1
if (Nr3[i,j] < 50) er3[i,j]=1
if (Nr4[i,j] < 50) er4[i,j]=1
```

```
} #close annual loop
Ltr1[i] = (exp(mean(log(Lar1[i,]+1))))-1
Ltr2[i] = (exp(mean(log(Lar2[i,]+1))))-1
Ltr3[i] = (exp(mean(log(Lar3[i,]+1))))-1
Ltr4[i] = (exp(mean(log(Lar4[i,]+1))))-1
Ltt[i] = (exp(mean(log(Lat[i,]+1))))-1
cLtr1[i] = (exp(mean(log(cLar1[i,]+1))))-1
cLtr2[i] = (exp(mean(log(cLar2[i,]+1))))-1
cLtr3[i] = (exp(mean(log(cLar3[i,]+1))))-1
cLtr4[i] = (exp(mean(log(cLar4[i,]+1))))-1
cLtt[i] = (exp(mean(log(cLat[i,]+1))))-1

}#Close iteration loop

#Output and summary stats
#calculate mean
Lambda Olr1 =
mean(Ltr1)
Olr2 = mean(Ltr2)
Olr3 = mean(Ltr3)
Olr4 = mean(Ltr4)
Olt = mean(Ltt)
#calculate mean "count data"
lambda cOlr1 = mean(cLtr1)
cOlr2 = mean(cLtr2)
cOlr3 = mean(cLtr3)
cOlr4 = mean(cLtr4)
cOlt = mean(cLtt)
```

```
#Calculate Total extinction probability
set = apply(et,2,sum)
pet = set/r
pet
#Calculate region 1 extinction probability
ser1 = apply(er1,2,sum)
per1 = ser1/r
per1
#Calculate region 2 extinction probability
ser2 = apply(er2,2,sum)
per2 = ser2/r
per2
#Calculate region 3 extinction probability
ser3 = apply(er3,2,sum)
per3 = ser3/r
per3
#Calculate region4 extinction probability
ser4 = apply(er4,2,sum)
per4 = ser4/r
per4

#calculate median population size for total and in each region
mNt = apply(Nt,2,median)
mNt
mNr1 = apply(Nr1,2,median)
mNr1
mNr2 = apply(Nr2,2,median)
```

```
mNr2
mNr3 = apply(Nr3,2,median)
mNr3
mNr4 = apply(Nr4,2,median)
mNr4

#upper and lower bound for population sizes
lbnt = apply(Nt, 2, quantile, probs = c(0.025))
ubnt = apply(Nt,2,quantile, probs = c(0.975))

lbr1 = apply(Nr1, 2, quantile, probs = c(0.025))
ubr1 = apply(Nr1,2,quantile, probs = c(0.975))

lbr2 = apply(Nr2, 2, quantile, probs = c(0.025))
ubr2 = apply(Nr2,2,quantile, probs = c(0.975))

lbr3 = apply(Nr3, 2, quantile, probs = c(0.025))
ubr3 = apply(Nr3,2,quantile, probs = c(0.975))

lbr4 = apply(Nr4, 2, quantile, probs = c(0.025))
ubr4 = apply(Nr4,2,quantile, probs = c(0.975))

#median population size for count
data cmNt = apply(Ct,2,median)
cmNr1 = apply(Cr1,2,median)
cmNr2 = apply(Cr2,2,median)
cmNr3 = apply(Cr3,2,median)
cmNr4 = apply(Cr4,2,median)
```

```
mpr1[y] = mean(mpr11)
mpr2[y] = mean(mpr22)
mpr3[y] = mean(mpr33)
mpr4[y] = mean(mpr44)

#upper and lower bound for counted population
sizes lbnt = apply(Nt, 2, quantile, probs = c(0.025))
ubnt = apply(Nt,2,quantile, probs = c(0.975))

lbr1 = apply(Nr1, 2, quantile, probs = c(0.025))
ubr1 = apply(Nr1,2,quantile, probs = c(0.975))

lbr2 = apply(Nr2, 2, quantile, probs = c(0.025))
ubr2 = apply(Nr2,2,quantile, probs = c(0.975))

lbr3 = apply(Nr3, 2, quantile, probs = c(0.025))
ubr3 = apply(Nr3,2,quantile, probs = c(0.975))

lbr4 = apply(Nr4, 2, quantile, probs = c(0.025))
ubr4 = apply(Nr4,2,quantile, probs = c(0.975))


#Compile data into output arrays
data.t<-cbind(mNt,lbnt,ubnt,pet,Olt,cmNt)
data.r1<-cbind(mNr1,lbr1,ubr1,per1,cmNr1,Olr1)
data.r2<-cbind(mNr2,lbr2,ubr2,per2,cmNr2,Olr2)
data.r3<-cbind(mNr3,lbr3,ubr3,per3,cmNr3,Olr3)
```

```
data.r4<-cbind(mNr4,lbr4,ubr4,per4,cmNr4,Olr4)

#Further compile data into output arrays...this process could easily be streamlined.
data.summary1[y,]<-c(P[y],data.t[t,4],Olt, Pr1[y], data.r1[t,4],Olr1, Pr2[y], data.r2[t,4],Olr2, Pr3[y], data.r3[t,4],Olr3, Pr4[y],
data.r4[t,4],Olr4)
data.summary2[y,]<-c(cmNt[1],data.t[t,4],cOlt, Pr1[y], data.r1[t,4],cOlr1, Pr2[y], data.r2[t,4],cOlr2, Pr3[y], data.r3[t,4],cOlr3, Pr4[y],
data.r4[t,4],cOlr4)
data.summary4[y,]<-c(SA[y],SJ[y],data.t[t,4], Fr1[y], data.r1[t,4], Fr2[y],data.r2[t,4], Fr3[y],data.r3[t,4], Fr4[y], data.r4[t,4])

# report number of iterations
print(y)
} #Close outter loop

#Begin analysis of  output data
# assign names for column headers in output files
names<-c("Ipop","Pet","T-
Lambda","Pr1","Per1","R1Lambda","Pr2","Per2","R2Lambda","Pr3","Per3","R3Lambda","Pr4","Per4","R4Lambda")
names1<-c("cIpop","Pet","cT-
Lambda","Pr1","Per1","cR1Lambda","Pr2","Per2","cR2Lambda","Pr3","Per3","cR3Lambda","Pr4","Per4","cR4Lambda")

#Create output files with summary data
write.table(data.summary1,file="datasummary1-101-200.csv",sep=",",col.names=names)
write.table(data.summary2,file="datasummary2-101-200.csv",sep=",",col.names=names1)
write.table(data.summary4,file="datasummary4-101-200.csv",sep=",")

#Create Initial population size objects for actual and for count
data # These will be used in the Linear steps modeling below
r1Ipop = (data.summary1[,1]*data.summary1[,4])
```

```
r2Ipop = (data.summary1[,1]*data.summary1[,7])
r3Ipop = (data.summary1[,1]*data.summary1[,10])
r4Ipop = (data.summary1[,1]*data.summary1[,13])

cr1Ipop = (data.summary2[,1]*data.summary1[,4])
cr2Ipop = (data.summary2[,1]*data.summary1[,7])
cr3Ipop = (data.summary2[,1]*data.summary1[,10])
cr4Ipop = (data.summary2[,1]*data.summary1[,13])

#calculate weighted average Fecundity (weight be region)
WF=((Pr1*Fr1)+(Pr2*Fr2)+(Pr3*Fr3)+(Pr4*Fr4))

LamT =  data.summary1[,2]
lm1 = lm(data.summary3[,3]~data.summary3[,2])
lm2 = lm(data.summary3[,5]~data.summary3[,4])
lm3 = lm(data.summary3[,7]~data.summary3[,6])
lm4 = lm(data.summary3[,9]~data.summary3[,8])


#Linear models to explain variation in overall extinction probability
LMNFS = glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ (log(data.summary1[,1])+ WF),
family=binomial)#((mpr1*data.summary4[,4])+(mpr2*data.summary4[,6])+(mpr3*data.summary4[,8])+(mpr4*data.summary4[,10])))
LMPet1 = glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ data.summary1[,1], family=binomial)
LMPet2 = glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ data.summary1[,3], family=binomial)
LMPet3 = glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ (data.summary1[,1] + data.summary1[,4]),
family=binomial)
LMPet42 = glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ (data.summary1[,1] + data.summary1[,3]),
family=binomial)
```

```
LMPet5 = glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ (log(data.summary1[,1])), family=binomial)
LMPet6 = glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ (log(data.summary1[,1])+ data.summary1[,3]),
family=binomial)
LMPet7 = glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ data.summary2[,1], family=binomial)
LMPet8 = glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ data.summary2[,3], family=binomial)
LMPet9 = glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ (data.summary2[,1]+ data.summary2[,3]),
family=binomial)
LMPet10 = glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ log(data.summary2[,1]), family=binomial)
LMPet11 = glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ (log(data.summary2[,1])+ data.summary2[,3]),
family=binomial)
LMPet14 = glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ (data.summary2[,1] + data.summary2[,3] +
data.summary1[,4]), family=binomial)
LMNFS2=glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ (log(data.summary1[,3])+ data.summary4[,1] +
data.summary4[,2]),
family=binomial)#((mpr1*data.summary4[,4])+(mpr2*data.summary4[,6])+(mpr3*data.summary4[,8])+(mpr4*data.summary4[,10])))
LMNFS3=glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ data.summary4[,1] + data.summary4[,2],
family=binomial)#((mpr1*data.summary4[,4])+(mpr2*data.summary4[,6])+(mpr3*data.summary4[,8])+(mpr4*data.summary4[,10])))
LMNFS4=glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ WF+ data.summary4[,1] + data.summary4[,2],
family=binomial)#((mpr1*data.summary4[,4])+(mpr2*data.summary4[,6])+(mpr3*data.summary4[,8])+(mpr4*data.summary4[,10])))
MG=glm(cbind(round(data.summary1[,2]*Rep),round((1-data.summary1[,2])*Rep))~ log(data.summary1[,1])+
data.summary1[,3]+data.summary1[,4]+WF+ data.summary4[,1] + data.summary4[,2],
family=binomial)#((mpr1*data.summary4[,4])+(mpr2*data.summary4[,6])+(mpr3*data.summary4[,8])+(mpr4*data.summary4[,10])))


#Linear models for region 1
LMPer11 = glm(cbind(round(data.summary1[,5]*Rep),round((1-data.summary1[,5])*Rep))~ r1Ipop, family=binomial)
LMPer12 = glm(cbind(round(data.summary1[,5]*Rep),round((1-data.summary1[,5])*Rep))~ data.summary1[,6], family=binomial)
```

LMPer13 = glm(cbind(round(data.summary1[,5]*Rep),round((1-data.summary1[,5])*Rep))~ (r1Ipop + data.summary1[,6]), family=binomial)
LMPer14 = glm(cbind(round(data.summary1[,5]*Rep),round((1-data.summary1[,5])*Rep))~ (r1Ipop + data.summary1[,7] + data.summary1[,7]), family=binomial)
LMPer15 = glm(cbind(round(data.summary1[,5]*Rep),round((1-data.summary1[,5])*Rep))~ (log(r1Ipop)), family=binomial)
LMPer16 = glm(cbind(round(data.summary1[,5]*Rep),round((1-data.summary1[,5])*Rep))~ (log(r1Ipop)+ data.summary1[,6]), family=binomial)
LMPer17 = glm(cbind(round(data.summary1[,5]*Rep),round((1-data.summary1[,5])*Rep))~ cr1Ipop, family=binomial)
LMPer18 = glm(cbind(round(data.summary1[,5]*Rep),round((1-data.summary1[,5])*Rep))~ data.summary2[,6], family=binomial)
LMPer19 = glm(cbind(round(data.summary1[,5]*Rep),round((1-data.summary1[,5])*Rep))~ ((cr1Ipop)+ data.summary2[,6]), family=binomial)
LMPer110 = glm(cbind(round(data.summary1[,5]*Rep),round((1-data.summary1[,5])*Rep))~ log(cr1Ipop), family=binomial)
LMPer111 = glm(cbind(round(data.summary1[,5]*Rep),round((1-data.summary1[,5])*Rep))~ (log(cr1Ipop)+ data.summary2[,6]), family=binomial)
LMPer112 = glm(cbind(round(data.summary1[,5]*Rep),round((1-data.summary1[,5])*Rep))~ data.summary1[,4], family=binomial)
LMPer113 = glm(cbind(round(data.summary1[,5]*Rep),round((1-data.summary1[,5])*Rep))~ log(r1Ipop)+data.summary4[,1], family=binomial)
LMPer114 = glm(cbind(round(data.summary1[,5]*Rep),round((1-data.summary1[,5])*Rep))~ log(r1Ipop)+data.summary4[,2], family=binomial)
LMPer115 = glm(cbind(round(data.summary1[,5]*Rep),round((1-data.summary1[,5])*Rep))~ log(r1Ipop)+data.summary4[,4], family=binomial)
LMPer116 = glm(cbind(round(data.summary1[,5]*Rep),round((1-data.summary1[,5])*Rep))~ log(r1Ipop)+data.summary4[,1] + data.summary4[,2] +data.summary4[,4], family=binomial)

#Linear models for region 2
LMPer21 = glm(cbind(round(data.summary1[,8]*Rep),round((1-data.summary1[,8])*Rep))~ r2Ipop, family=binomial)
LMPer22 = glm(cbind(round(data.summary1[,8]*Rep),round((1-data.summary1[,8])*Rep))~ data.summary1[,9], family=binomial)

LMPer23 = glm(cbind(round(data.summary1[,8]*Rep),round((1-data.summary1[,8])*Rep))~ r2Ipop + data.summary1[,9], family=binomial)
LMPer25 = glm(cbind(round(data.summary1[,8]*Rep),round((1-data.summary1[,8])*Rep))~ log(r2Ipop), family=binomial)
LMPer26 = glm(cbind(round(data.summary1[,8]*Rep),round((1-data.summary1[,8])*Rep))~ log(r2Ipop)+ data.summary1[,9], family=binomial)
LMPer27 = glm(cbind(round(data.summary1[,8]*Rep),round((1-data.summary1[,8])*Rep))~ cr2Ipop, family=binomial)
LMPer28 = glm(cbind(round(data.summary1[,8]*Rep),round((1-data.summary1[,8])*Rep))~ data.summary2[,9], family=binomial)
LMPer29 = glm(cbind(round(data.summary1[,8]*Rep),round((1-data.summary1[,8])*Rep))~ (cr2Ipop+ data.summary2[,9]), family=binomial)
LMPer210 = glm(cbind(round(data.summary1[,8]*Rep),round((1-data.summary1[,8])*Rep))~ log(cr2Ipop), family=binomial)
LMPer211 = glm(cbind(round(data.summary1[,8]*Rep),round((1-data.summary1[,8])*Rep))~ (log(cr2Ipop)+ data.summary2[,9]), family=binomial)

#Linear models for region 3
LMPer31 = glm(cbind(round(data.summary1[,11]*Rep),round((1-data.summary1[,11])*Rep))~ r3Ipop, family=binomial)
LMPer32 = glm(cbind(round(data.summary1[,11]*Rep),round((1-data.summary1[,11])*Rep))~ data.summary1[,12], family=binomial)
LMPer33 = glm(cbind(round(data.summary1[,11]*Rep),round((1-data.summary1[,11])*Rep))~ (r3Ipop + data.summary1[,12]), family=binomial)
LMPer35 = glm(cbind(round(data.summary1[,11]*Rep),round((1-data.summary1[,11])*Rep))~ log(r3Ipop), family=binomial)
LMPer36 = glm(cbind(round(data.summary1[,11]*Rep),round((1-data.summary1[,11])*Rep))~ log(r3Ipop)+ data.summary1[,12], family=binomial)
LMPer37 = glm(cbind(round(data.summary1[,11]*Rep),round((1-data.summary1[,11])*Rep))~ cr3Ipop, family=binomial)
LMPer38 = glm(cbind(round(data.summary1[,11]*Rep),round((1-data.summary1[,11])*Rep))~ data.summary2[,12], family=binomial)
LMPer39 = glm(cbind(round(data.summary1[,11]*Rep),round((1-data.summary1[,11])*Rep))~ (cr3Ipop + data.summary2[,12]), family=binomial)
LMPer310 = glm(cbind(round(data.summary1[,11]*Rep),round((1-data.summary1[,11])*Rep))~ log(cr3Ipop), family=binomial)
LMPer311 = glm(cbind(round(data.summary1[,11]*Rep),round((1-data.summary1[,11])*Rep))~ (log(cr3Ipop)+ data.summary2[,12]), family=binomial)

```
#Linear models for region 4
LMPer41 = glm(cbind(round(data.summary1[,14]*Rep),round((1-data.summary1[,14])*Rep))~ r4Ipop, family=binomial)
LMPer42 = glm(cbind(round(data.summary1[,14]*Rep),round((1-data.summary1[,14])*Rep))~ data.summary1[,15], family=binomial)
LMPer43 = glm(cbind(round(data.summary1[,14]*Rep),round((1-data.summary1[,14])*Rep))~ (r4Ipop + data.summary1[,15]),
family=binomial)
LMPer45 = glm(cbind(round(data.summary1[,14]*Rep),round((1-data.summary1[,14])*Rep))~ log(r4Ipop), family=binomial)
LMPer46 = glm(cbind(round(data.summary1[,14]*Rep),round((1-data.summary1[,14])*Rep))~ (log(r4Ipop)+ data.summary1[,15]),
family=binomial)
LMPer47 = glm(cbind(round(data.summary1[,14]*Rep),round((1-data.summary1[,14])*Rep))~ cr4Ipop, family=binomial)
LMPer48 = glm(cbind(round(data.summary1[,14]*Rep),round((1-data.summary1[,14])*Rep))~ data.summary2[,15], family=binomial)
LMPer49 = glm(cbind(round(data.summary1[,14]*Rep),round((1-data.summary1[,14])*Rep))~ (cr4Ipop+ data.summary2[,15]),
family=binomial)
LMPer410 = glm(cbind(round(data.summary1[,14]*Rep),round((1-data.summary1[,14])*Rep))~ log(cr4Ipop), family=binomial)
LMPer411 = glm(cbind(round(data.summary1[,14]*Rep),round((1-data.summary1[,14])*Rep))~ (log(cr4Ipop)+ data.summary2[,15]),
family=binomial)

#GLM Modeling output.
AIC(LMNFS,LMNFS2,LMNFS3,LMNFS4,LMPet1,LMPet2,LMPet3,LMPet4,LMPet5,LMPet6,LMPet42)
AIC(LMPet7,LMPet8,LMPet9,LMPet10,LMPet11,LMPet14)

AIC(LMPer11,LMPer12,LMPer13,LMPer15,LMPer16,LMPer14,lm1,LMPer113,LMPer114,LMPer115,LMPer116)
AIC(LMPer17,LMPer18,LMPer19,LMPer110,LMPer111)

AIC(LMPer21,LMPer22,LMPer23,LMPer25,LMPer26,lm2)
AIC(LMPer27,LMPer28,LMPer29,LMPer210,LMPer211)

AIC(LMPer31,LMPer32,LMPer33,LMPer35,LMPer36,lm3)
```

```
AIC(LMPer37,LMPer38,LMPer39,LMPer310,LMPer311)

AIC(LMPer41,LMPer42,LMPer43,LMPer45,LMPer46,lm4)
AIC(LMPer47,LMPer48,LMPer49,LMPer410,LMPer411)


summary(LMPet6)
summary(LMPet11)
summary(LMNFS)
summary(LMPer111)
summary(LMPer211)
summary(LMPer311)
summary(LMPer411)
```

Appendix 3B
Monitoring Recommendations

Bird Monitoring

Piping plovers have been monitored throughout much of the U.S. Northern Great Plains (NGP) range since the mid-1980's, with more consistent and widespread monitoring conducted in large portions of the range starting in the mid-1990's. This long-term dataset has proved invaluable for various purposes, including understanding local trends in the population, specific site use, and reproductive success. Recovery Criterion 1 stipulates that the probability of the population going extinct within the next 50 years must be < 0.05. Although extinction probability is not directly measurable, it can be estimated with the NGP population model (McGowan *et al.* 2014), given information on survival, fecundity, and movement rates for each of the three (four if Prairie Canada is included) regions identified below.

1. Southern Rivers -Missouri River system from Fort Randall Dam, South Dakota to Ponca, Nebraska, the Niobrara River, the Loup River system and the Platte River system
2. Northern Rivers -Missouri River system from Fort Peck Lake, Montana to Pierre, South Dakota
3. U.S. Alkaline Lakes

In addition, Recovery Criterion 1a calls for a stable to increasing population trend in each of the three U.S. regions, and Criterion 1b requires that ≥ 15% of the NGP population occur in each of the three regions. Ideally monitoring would be similar in Prairie Canada, although we recognize that managers face different challenges in Canada, and therefore we defer to the Canadian Recovery Plan for their recovery goals (Goossen *et al.* 2002).

The above considerations lead to the minimum requirements of a range-wide bird monitoring program. For the Service to evaluate whether Recovery Criterion 1 has been met, information must be available on 1) vital rates for use in assessing probability of extinction, 2) population trend within each region, and 3) distribution of plovers among the three regions.

We acknowledge that monitoring of annual survival and movement among regions is beyond the capability of individual management entities (programs). We further recognize how logistically difficult, invasive, and expensive it is to obtain such information. We expect that collection of new data on these parameters will be infrequent, at best, and will generally be left for researchers. When such research studies are underway (as they are now), we strongly encourage programs to cooperate with researchers engaged in mark/resight studies (e.g., by resighting marked birds) that can provide critical information needed to estimate extinction probability.

Monitoring has historically been implemented separately in each management area by programs with varying amounts of resources, and approaches to monitoring have varied. For example, some programs performed an annual adult count, while others counted the number of nests in an area and considered that to be an index to the number of adults present. Either method may be useful for tracking local population trend, but data clearly cannot be pooled without additional information about how the various metrics relate to the actual number of breeding adults. Even when the same metric is used, under- or over-counting can be substantial and can vary from area to area (Shaffer *et al.* 2013). For this reason, existing data from the various monitoring programs, although useful for local purposes, generally cannot be combined to provide reliable information on regional population trend or distribution of birds among regions.

The Recovery Team believes development of a range-wide monitoring plan that overcomes the above limitations to be a high priority need and recommends that funding be sought to develop such a plan in the near future. The Team recognizes that each program faces a unique set of challenges in terms of habitat, bird density, logistics, and human dimensions that makes a one-size-fits-all approach to monitoring impractical. The Team recommends that the monitoring plan be flexible enough to accommodate program limitations in a way that assures results can be combined to give meaningful assessments of regional and range-wide trends and of plover distribution among regions. Development of a monitoring plan would best be accomplished by an individual or small team of wildlife-survey professionals working closely with personnel from individual programs who can articulate monitoring constraints unique to their particular area.

We encourage the use of probability-based sampling to reduce the number of places where data must be collected while preserving the ability to make inference about the larger area. For example, the USGS generated estimates of population size on Lake Sakakawea based on a probability sample of 40 shoreline and island segments. The estimates for any given year were imprecise because of the limited sample size. Despite that variability, it appears possible to estimate 10–year trends in population size and population growth rate with much greater precision.

The Team notes that not only is this a critical time for developing a monitoring program, it is also an opportune time because several banding and resighting studies are underway. Samples of banded birds provide a unique opportunity to learn about issues of double-counting, non-detection, and movement, and they provide a means to generate independent estimates of population size that can be compared with estimates derived from the monitoring program.

Although it is our hope and desire that the new monitoring program, once developed, can be fully implemented without the need for additional resources, we are committed to the idea that results from each region must effectively meet the minimum monitoring requirements laid out above.

<u>Habitat Monitoring</u>

Recovery Criterion 2 sets forth minimum habitat requirements for each region. The Recovery Team encourages the development and integration of remote-sensing-based habitat inventory methods that can be applied periodically across the entire Northern Great Plains breeding range. These methodologies have been developed and applied to parts of the Missouri River system (Anteau *et al.* 2014, Strong 2012) but additional work is needed to refine and extend the techniques to include other parts of the range. The Team recognizes that image acquisition and processing costs may preclude annual assessment of habitat availability but emphasizes that monitoring must occur frequently and regularly enough to determine whether habitat goals are being met on average 3 out of 4 years.

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