STATUS OF THE SPECIES/CRITICAL HABITAT – piping plover (*Charadrius melodus*)

Legal Status – endangered and threatened

On January 10, 1986, the U.S. Fish and Wildlife Service (Service) listed the piping plover (*Charadrius melodus*) as endangered in the Great Lakes watershed and threatened elsewhere within its range, including migratory routes outside of the Great Lakes watershed and wintering grounds, under the Endangered Species Act of 1973, as amended (Act) (87 Stat. 884; 16 U.S.C. 1531 *et seq.*) (Service 1985). Piping plovers were listed principally because of habitat destruction and degradation, predation, and human disturbance. Critical habitat was designated for the Great Lakes breeding population, wintering piping plovers, and the Northern Great Plains breeding population on May 7, 2001, July 10, 2001, and September 11, 2002, respectively (Service 2001a,b; Service 2002).

Species/critical habitat description

Appearance/Morphology

The piping plover is a small (7 inches [in] long) shorebird with a wingspan of 15 in (Palmer 1967). Throughout the year, adults have sand-colored upper body parts, white undersides, and orange legs. During the breeding season, adults acquire a black forehead, a single black breast band, and an orange bill with a black tip. In general, males have brighter bands than females, and inland birds have more complete bands than east coast birds. Fledglings have flesh-colored legs and black bills and immature plumage is similar to adult non-breeding plumage. Juveniles acquire adult plumage in spring following the hatching year. The piping plover is similar to other ringed plovers in size and body shape; however, the very pale color of its upper parts, its orange legs, and the complete white band across the upper tail coverts are diagnostic characteristics.

Breeding populations

Three separate breeding populations have been identified, each with its own recovery criteria: the Northern Great Plains (threatened), the Great Lakes (endangered), and the Atlantic coast (threatened). The piping plover winters in coastal areas of the United States (U.S.) from North Carolina to Texas, along the coast of eastern Mexico, on Caribbean islands from Barbados to Cuba, and in the Bahamas (Haig and Elliott-Smith 2004). Because birds breeding populations overlap on their wintering grounds, most piping plover studies in the nonbreeding range report results without regard to breeding origin. Therefore, information summarized herein pertains to the species as a whole (*i.e.*, all three breeding populations), except where a particular breeding population is specified.

Critical Habitat

The Service designated critical habitat for the piping plover on three occasions. Two of these designations protected different breeding populations. Critical habitat for the Great Lakes and

Northern Great Plains breeding population was designated May 7, 2001 (Service 2001a) and September 11, 2002 (Service 2002), respectively. Piping plovers do not breed in Florida; therefore, critical habitat for breeding populations does not occur in Florida and will not be discussed further in this document.

The Service also designated critical habitat for wintering piping plovers on July 10, 2001 (Service 2001b). Wintering piping plovers may include individuals from the Great Lakes and Northern Great Plains breeding populations as well as birds that nest along the Atlantic coast. Designated wintering piping plover critical habitat originally included 142 areas (the rule states 137 units; this is in error) encompassing about 1,793 miles (mi) of mapped shoreline and 165,211 acres (ac) of mapped areas along the coasts of North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas. Since the designation of wintering critical habitat, 19 units (TX- 3,4,7-10, 14-19, 22, 23, 27,28, and 31-33) in Texas have been vacated and remanded back to the Service for reconsideration by Court order (Texas General Land Office v. U.S. Department of Interior, Case No. V-06-CV-00032). On May 19, 2009, the Service published a final rule designating 18 revised critical habitat units in Texas, totaling approximately 139,029 ac (Service 2009a). The Courts also vacated and remanded back to the Service for reconsideration, four units in North Carolina (Cape Hatteras Access Preservation Alliance v. U.S. Department of Interior, 344 F. Supp. 2d 108 [D.D.C. 2004]). The four critical habitat units vacated were NC-1, 2, 4, and 5, and all occurred within Cape Hatteras National Seashore. A revised designation for these four units was published on October 21, 2008 (Service 2008).

In accordance with section 3(5)(A)(i) and 4(b)(1)(A) of the Act and regulations at 50 CFR §424.12, critical habitat consists of the physical or biological features (PBFs) essential to the conservation of the species. These include, but are not limited to:

1. Space for individual and population growth and for normal behavior;
2. Food, water, air, light, minerals, or other nutritional or physiological requirements;
3. Cover or shelter;
4. Sites for breeding, reproduction, or rearing (or development) of offspring; and
5. Habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of a species.

For wintering piping plovers, PBFs are those habitat components that support foraging, roosting, and sheltering and the physical features necessary for maintaining the natural processes that support these habitat components. These areas typically include coastal areas that support intertidal beaches and flats and associated dune systems and flats above annual high tide (Service 2001a). The primary constituent elements (PCEs) of critical habitat are those PBFs that provide for a species' life-history processes and are essential to the conservation of the species. PCEs of wintering piping plover critical habitat include sand or mud flats (or both) with no or sparse emergent vegetation. Adjacent unvegetated or sparsely vegetated sand, mud, or algal flats above high tide are also important PCEs, especially for roosting piping plovers (Service 2001a). PCEs of the beach/dune ecosystem include surf-cast algae, natural wrack, sparsely vegetated back beach and salterns, spits, and over-wash areas. Over-wash areas are broad, unvegetated zones,

with little or no topographic relief, that are formed and maintained by the action of hurricanes, storm surge, or other extreme wave action. The units designated as critical habitat are those areas that had consistent use by piping plovers at the time of designation and that best meet the biological needs of the species. The Service anticipates that the amount of wintering habitat included in the designation is sufficient to support future recovered populations, and the existence of this habitat is essential to the conservation of the species. Additional information on each specific unit included in the designation can be found in the Service's final rule (Service 2001a).

Activities that affect PBFs include those that directly or indirectly alter, modify, or destroy the processes that are associated with the formation and movement of barrier islands, inlets, and other coastal landforms. Those processes include erosion, accretion, succession, and sea-level change. The integrity of the habitat components also depends upon daily tidal events and regular sediment transport processes, as well as episodic, high-magnitude storm events (Service 2001b).

Life History

Piping plovers live an average of 5 years, although studies have documented birds as old as 11 (Wilcox 1959) and 15 years. Breeding activity begins in mid-March when birds begin returning to their nesting areas (Coutu et al. 1990; Cross 1990; Goldin et al. 1990; MacIvor 1990; Hake 1993). The female can lay up to 4 eggs, which hatch approximately 25 days later. Chicks fledge in three to four weeks after hatching. Plovers are known to begin breeding as early as one year of age (MacIvor 1990; Haig 1992); however, the percentage of birds that breed in their first adult year is unknown. Piping plovers generally fledge only a single brood per season, but may re-nest several times if previous nests are lost.

Cryptic coloration is a primary defense mechanism for piping plovers. Nests, adults, and chicks all blend in with their typical beach surroundings. Piping plovers on wintering and migration grounds respond to intruders (pedestrian, avian, and mammalian) usually by squatting, running, and flying.

Migration

Plovers depart their breeding grounds for their wintering grounds from July through late August, but southward migration extends through November. Piping plovers spend up to 10 months of their life cycle on their migration and winter grounds, generally July 15 through as late as May 15. Piping plovers migrate through and winter in coastal areas of the U.S. from North Carolina to Texas and in portions of Mexico and the Caribbean. The pattern of both fall and spring counts at many Atlantic coast sites demonstrates that many piping plovers make intermediate stopovers lasting from a few days up to one month during their migrations (Noel et al. 2005; Stucker and Cuthbert 2006). Use of inland stopovers during migration is also documented (Pompei and Cuthbert 2004). The source breeding population of a given wintering individual cannot be determined in the field unless it has been banded or otherwise marked. Information from observation of color-banded piping plovers indicates that the winter ranges of the breeding populations overlap to a significant degree. See the **Status and distribution** section for

additional information pertaining to population distribution on the wintering grounds. While piping plover migration patterns and needs remain poorly understood and occupancy of a particular habitat may involve shorter periods relative to wintering, information about the energetics of avian migration indicates that this might be a particularly critical time in the species' life cycle.

Foraging (nonbreeding portion of annual cycle)

Behavioral observation of piping plovers on the wintering grounds suggests that they spend the majority of their time foraging (Nicholls and Baldassarre 1990a; Drake 1999a, 1999b). Feeding activities may occur during all hours of the day and night (Staine and Burger 1994; Zonick 1997), and at all stages in the tidal cycle (Goldin 1993; Hoopes 1993). Wintering plovers primarily feed on invertebrates such as polycheate marine worms, various crustaceans, fly larvae, beetles, and occasionally bivalve mollusks (Bent 1929; Nicholls 1989; Zonick and Ryan 1995). They peck these invertebrates on top of the soil or just beneath the surface. Plovers forage on moist substrate features such as intertidal portions of ocean beaches, over-wash areas, mudflats, sand flats, algal flats, shoals, wrack lines, sparse vegetation, shorelines of coastal ponds, lagoons, ephemeral pools and adjacent to salt marshes, as well as bay-side islands and beaches with abundant prey items (Gibbs 1986; Zivojnovich 1987; Nichols 1989; Nicholls and Baldassarre 1990a, 1990b; Coutu et al. 1990; Hoopes et al. 1992; Loegering 1992; Goldin 1993; Elias-Gerken 1994; Wilkinson and Spinks 1994; Zonick 1997; Service 2001a; Cohen et al. 2006). During piping plover surveys on the wintering grounds at St. Lucie Inlet, Martin County, Florida, Ecological Associates, Inc. observed that intertidal mudflats and/or shallow subtidal grass flats also appear to have greater value as foraging habitat than the unvegetated intertidal areas of a flood shoal (Ecological Associates 2009).

Roosting

Piping plovers roost in unvegetated or sparsely vegetated areas, which may have debris, detritus, or micro-topographic relief offering refuge to plovers from high winds and cold weather. Several studies identified that wrack (organic material including seaweed, seashells, driftwood, and other materials deposited on beaches by tidal action) is also an important component of roosting habitat for nonbreeding piping plovers (Drake 1999a, 1999b; Smith 2007; Lott et al. 2009; Maddock et al. 2009). Plovers will also roost on intertidal habitat, backshore coastline (defined as a zone of dry sand, shell, cobble and beach debris from the mean high water line up to the toe of the dune), over-wash and ephemeral pools (Smith 2007; Maddock et al. 2009), as well as sea grass debris (bay-shore wrack) (Drake 1999b).

Habitat

Wintering habitat

Wintering piping plovers prefer coastal habitat that include sand spits, islets (small islands), tidal flats, shoals (usually flood tidal deltas), and sandbars that are often associated with inlets (Harrington 2008). Sandy mud flats, ephemeral pools, and over-wash areas are also considered

primary foraging habitats. These substrate types have a richer infauna than the foreshore of high energy beaches and often attract large numbers of shorebirds (Cohen et al. 2006). Wintering plovers are dependent on a mosaic of habitat patches and move among these patches depending on local weather and tidal conditions (Nicholls and Baldassarre 1990a), but piping plovers have also been observed to exhibit wintering site fidelity. Drake (1999b) and Drake et al. (2001) estimated a mean home range size of 3,113 ac for 49 radio-marked piping plovers, with a mean core area of 717 ac and a mean linear distance moved between successive locations (averaged across seasons) of 2.1 mi. Similarly, Cohen at al. (2008a) found that seven radio-tagged piping plovers used a 4,967-ac area, and piping plover activity was concentrated in 12 areas totaling 544 ac. Noel and Chandler (2008) observed high fidelity of banded piping plovers along 0.62-mi up to 2.8-mi sections of beach.

Piping plovers have been observed utilizing bay shorelines, ocean-facing beaches, intertidal substrates, inlets, shorelines along the mouths of rivers, over-wash passes along major bay systems, and exposed sea grass beds and oyster reefs (Zonick 1997, 2000; Smith 2007; Harrington 2008; Cobb *in* Elliott-Smith et al. 2009; Lott et al. 2009; Maddock et al. 2009). The effects of dredged material deposition on piping plover habitat use also merit further study. Drake et al. (2001) concluded that conversion of southern Texas mainland bay-shore tidal flats to dredged material impoundments results in a net loss of habitat for wintering piping plovers because impoundments eventually convert to upland habitat not used by piping plovers. Zonick et al. (1998) reported that dredged material placement areas along the Intracoastal Waterway in Texas were rarely used by piping plovers, and noted concern that dredge islands block wind-driven water flows, which are critical to maintaining important shorebird habitats. By contrast, most of the sound islands used by foraging piping plovers at Oregon Inlet, North Carolina, were created by the Corps depositing dredged material in the subtidal bay bottom, with the most recent deposition ranging from 28 to less than 10 years prior to the study (Cohen et al. 2008a). Little work has been done to assess the effects (positive or negative) of using dredged material to create suitable shorebird habitat in other parts of the Gulf coast (*e.g.*, Louisiana, Mississippi).

Population Dynamics

Populations on all three portions of the breeding range have increased since listing. The Atlantic coast breeding population has increased an estimated 234 percent, from approximately 790 pairs in 1986 to 1,762 in 2011 (Service 2009b; Service 2012a). Likewise, the Great Lakes breeding population has increased from an estimated 12 pairs in 1984 to 58 nesting pairs in 2012, most of which nested in Michigan (Service 2009b; Service 2012b). The Northern Great Plains breeding population is the largest with an estimated 2,953 individuals in 1991 (1,981 in the U.S.) and an estimated 4,662 individuals in 2006 (2,959 in the U.S.) (Ferland and Haig 2002; Elliott-Smith et al. 2009). Note that pairs are not tracked in the Northern Great Plains as they are in the other two populations. A detailed status of each breeding population can be found in the Service's 2009 species status review and 2015 Northern Great Plains Recovery Plan; however, some information is provided here for clarity of overall population stability (Service 2009b; 2015a).

Atlantic coast population

Unlike prior years, none of the U.S. Atlantic states participated in the 2011 International Piping Plover Census (IPPC). The U.S. Atlantic breeding population is estimated annually from a survey conducted near the timeframe of the IPPC. That said, since its 1986 listing under the Act, the Atlantic coast population estimate (Service 2011a) has increased 234 percent by 2009, and the U.S. portion of the population has almost tripled. Even discounting apparent increases in New York, New Jersey, and North Carolina between 1986 and 1989, which likely were due in part to increased census effort (Service 1996), the population nearly doubled between 1989 and 2008. The largest population increase between 1989 and 2009 has occurred in New England (266 percent), followed by New York-New Jersey (70 percent). In the Southern (DE-MD-VA-NC) Recovery Unit, net growth between 1989 and 2009 was 52 percent, but almost all of this increase occurred in two years, 2003 to 2005. The Eastern Canada population fluctuated from year to year, with increases often quickly eroded in subsequent years; net growth between 1989 and 2009 was 8 percent. The overall population growth pattern was tempered by periodic rapid declines in the Southern and Eastern Canada Recovery Units. The Eastern Canada population decreased 21 percent in just 3 years (2002 to 2005), and the population in the southern half of the Southern Recovery Unit declined 68 percent in 7 years (1995 to 2001). The recent 64 percent decline in the Maine population from 2002 to 2008, following only a few years of decreased productivity, provides an example of the continuing risk of rapid and precipitous reversals in population growth.

Great Lakes population

The Recovery Plan (Service 2003) sets a population goal of at least 150 breeding pairs, for at least 5 consecutive years, with at least 100 breeding pairs in Michigan and 50 breeding pairs distributed among sites in other Great Lakes states. The Great Lakes piping plover population, which has been traditionally represented as the number of breeding pairs, has increased since the completion of the recovery plan in 2003 (Cuthbert and Roche 2007, 2006; Westbrock et al. 2005; Stucker and Cuthbert 2004; Stucker et al. 2003). A total of 98 piping plovers were observed in the U.S. Great Lakes during the 2011 IPPC which was 11 fewer birds than observed during the 2006 census (Elliott-Smith et al. 2015). Of the 2011 total, 8 were recorded in Wisconsin and the remainder in Michigan. Piping plovers were not observed in the other states (Illinois, Indiana, New York, and Pennsylvania).

The annual Great Lakes monitoring program reported a total of 50 breeding pairs in the U.S. portion of the Great Lakes (Elliott-Smith et al. 2015). The discrepancy in the number of piping plovers counted in 2011 may have been due to weather conditions during the census period or movement patterns of birds. Since the 2006 census, the Great Lakes population has continued to rise with a record 71 pairs recorded in 2009. During the last 2 years there have been declines and the causes thereof are currently being investigated.

Northern Great Plains Population

The IPPC, conducted every 5 years, estimates the number of piping plover adults and breeding pairs in the Northern Great Plains. None of the IPPC estimates of the number of pairs in the U.S. suggests that the Northern Great Plains population has yet satisfied the recovery criterion as stated in the Service's Recovery Plan (Service 1988) of 2,300 pairs (Table 1; Plissner and Haig 1997; Ferland and Haig 2002; Elliot-Smith et al. 2009). The 2011 IPPC count of 1,012 piping plovers in Prairie Canada is also short of the recovery goal of 2,500 adult piping plovers.

The IPPC indicates that the U.S. population decreased between 1991 and 1996, increased in 2001 and 2006, and then decreased in 2011. The decrease in 2011 could be real, or it may be an artifact of extreme flooding in the Prairie and Plains region during 2011, which would have rendered traditional habitat unsuitable. Some birds were observed using non-traditional habitat, such as flooded agricultural fields and gravel roads adjacent to traditional sites. It remains unknown what proportion of plovers use such sites, or other areas, during extreme wet and dry years.

While the IPPC provides an index to the piping plover population, the design does not always provide sufficient information to understand the population's dynamics. The 5-year time interval between IPPC efforts may be too long to allow managers to get a clear picture of what the short-term population trends are and to respond accordingly if needed. With only five data points over 20 years, it is impossible to determine if and to what extent the apparent downswing reflects a real population trend versus error(s) in the 2011 census count and/or a previous IPPC.

Summary

Various population viability analyses conducted for piping plovers indicate that small declines in adult and juvenile survival rates can cause substantial increases in extinction risk (Ryan et al. 1993; Melvin and Gibbs 1996; Plissner and Haig 2000; Wemmer et al. 2001; Larson et al. 2002; Amirault et al. 2005; Calvert et al. 2006; Brault 2007). This suggests that maximizing productivity on the breeding grounds does not ensure population increases. Efforts to partition survival within the annual cycle are beginning to receive more attention, but current information remains limited. Thus, survival during migration and on the wintering grounds remains an important concern for the stability of piping plover breeding populations.

Status and distribution

Nonbreeding (migrating and wintering) Range

Piping plovers spend up to 10 months of their life cycle on their migration and wintering grounds, generally July 15 through as late as May 15. Piping plover migration routes and habitats overlap breeding and wintering habitats, and, unless banded, migrants passing through a site usually are indistinguishable from breeding or wintering piping plovers. Review of published records of piping plover sightings throughout North America by Pompei and Cuthbert (2004) found more than 3,400 fall and spring stopover records at 1,196 sites. Published reports

indicated that piping plovers do not concentrate in large numbers at inland sites and that they seem to stop opportunistically. In most cases, reports of birds at inland sites were single individuals. In general, distance between stopover locations and duration of stopovers throughout the coastal migration range remains poorly understood.

Piping plovers migrate through and winter in coastal areas of the U.S. from North Carolina to Texas and in portions of Mexico and the Caribbean. Five range-wide, mid-winter (late January to early February) IPPC population surveys, conducted at 5-year intervals starting in 1991, are summarized in Table 2. Total numbers have fluctuated over time, with some areas experiencing increases and others decreases. About 89 percent of birds that are known to winter in the U.S. do so along the Gulf coast (Texas to Florida), while 8 percent winter along the Atlantic coast (North Carolina to Florida). Results from the 2011 IPPC indicated that the Bahamas are also an important wintering area for piping plovers

Wintering bird numbers may oscillate daily, monthly, seasonally, and from year to year at any given site. Difference or changes in wintering numbers may be attributed to several factors: 1) growth or decline of the particular breeding populations that concentrate their wintering distribution in a given area; 2) regional and local fluctuations; 3) time of year surveys are conducted; 4) local movements of birds between habitats; and 5) the number of surveyor visits to a site. Mid-winter (late January to early February) surveys may substantially underestimate the abundance of nonbreeding piping plovers using a site or region during other months. Local movements of nonbreeding piping plovers and the number of surveyor visits to the site may also affect abundance estimates. Preliminary analysis of detection rates by Maddock et al. (2009) found 87 percent detection during the mid-winter period on core sites surveyed three times a month during fall and spring and one time per month during winter, compared with 42 percent detection on sites surveyed three times per year (Cohen 2009). Regional and local fluctuations may reflect the quantity and quality of suitable foraging and roosting habitat, which vary over time in response to natural coastal formation processes as well as anthropogenic habitat changes (*e.g.*, inlet relocation, dredging of shoals and spits). Fluctuations may also represent effects of localized weather conditions (especially wind) during surveys or unequal survey coverage. Major opportunities to locate previously unidentified wintering sites are concentrated in the Caribbean and Mexico (see pertinent sections in Elliott-Smith et al. 2009, 2015). Further surveys and assessment of seasonally emergent habitats (*e.g.*, sea grass beds, mudflats, oyster reefs) within bays lying between the mainland and barrier islands in Texas are also needed. Consistent surveys on the Chandeleur Island chain in coastal Louisiana are needed as well.

Gratto-Trevor et al. (2009) found strong patterns (but no exclusive partitioning) in the winter distribution of uniquely banded piping plovers from four breeding populations. All eastern Canada and 94 percent of Great Lakes birds wintered from North Carolina to southwest Florida. However, eastern Canada birds were more heavily concentrated in North Carolina, and a larger proportion of Great Lakes piping plovers were found in South Carolina and Georgia. Northern Great Plains populations were primarily seen farther west and south, especially on the Texas Gulf coast. Although the great majority of Prairie Canada individuals were observed in Texas, particularly southern Texas, individuals from the U.S. Great Plains were more widely distributed on the Gulf coast from Florida to Texas.

The findings of Gratto-Trevor et al. (2009) provide evidence of differences in the wintering distribution of piping plovers from these four breeding areas. However, the distribution of birds by breeding origin during migration remains largely unknown. Other major information gaps include the wintering locations of the U.S. Atlantic coast breeding population and the breeding origin of piping plovers wintering on the Caribbean islands and in much of Mexico. Banded piping plovers from the Great Lakes, Northern Great Plains, and Eastern Canada breeding populations showed similar patterns of seasonal abundance at Little St. Simons Island, Georgia (Noel et al. 2007). However, the number of banded plovers originating from the latter two populations was relatively small at that study area.

Although movements and shifts by small numbers of piping plovers across the boundaries of the seven U.S. winter regions have been recorded, several of those shifts were associated with late summer or early spring migration periods (Gratto-Trevor et al. 2009). Overall, the piping plover exhibits a high degree of intra- and inter-annual wintering site fidelity (Nicholls and Baldassarre 1990a; Drake et al. 2001; Noel et al. 2005; Stucker and Cuthbert 2006). Local movements are more common, such as across inlets or islands, or between nearby islands, while larger movements tend to be associated with migration (Maddock 2008; Maddock et al. 2009).

Recovery criteria

<u>Northern Great Plains Population (Service 2015a)</u>

1. Demonstrate that the breeding population is viable and projected to remain viable into the foreseeable future, and ensure that the breeding population is distributed across the range so that a regional catastrophic event does not negatively impact the entire population.
2. Ensure that there is sufficient nesting and foraging habitat broadly distributed on the breeding grounds to support a stable population.
3. Ensure that there is sufficient habitat to support the population at recovery levels widely distributed on the coastal migration and wintering grounds.
4. Ensure that management commitments necessary for piping plovers' continued persistence are in place and functioning, and that they will continue to operate after the species is recovered.

<u>Great Lakes Population (Service 2003)</u>

1. At least 150 pairs (300 individuals), for at least 5 consecutive years, with at least 100 breeding pairs (200 individuals) in Michigan and 50 breeding pairs (100 individuals) distributed among sites in other Great Lakes states.
2. Five-year average fecundity within the range of 1.5-2.0 fledglings per pair, per year, across the breeding distribution, and 10-year population projections indicate the population is stable or continuing to grow above the recovery goal.
3. Protection and long-term maintenance of essential breeding and wintering habitat is ensured, sufficient in quantity, quality, and distribution to support the recovery goal of 150 pairs (300 individuals).
4. Genetic diversity within the population is deemed adequate for population persistence and can be maintained over the long-term.

5. Agreements and funding mechanisms are in place for long-term protection and management activities in essential breeding and wintering habitat.

Atlantic Coast Population (Service 1996)

1. Increase and maintain for 5 years a total of 2,000 breeding pairs, distributed among 4 recovery units.

Recovery Unit	Minimum Subpopulation
Atlantic (eastern) Canada	400 pairs
New England	625 pairs
New York-New Jersey	575 pairs
Southern (DE-MD-VA-NC)	400 pairs

2. Verify the adequacy of a 2,000 pair population of piping plovers to maintain heterozygosity and allelic diversity over the long term.
3. Achieve a 5-year average productivity of 1.5 fledged chicks per pair in each of the 4 recovery units described in criterion 1, based on data from sites that collectively support at least 90 percent of the recover unit's population.
4. Institute long-term agreements to assure protection and management sufficient to maintain the population targets and average productivity in each recovery unit.
5. Ensure long-term maintenance of wintering habitat, sufficient in quantity, quality, and distribution to maintain survival rates for a 2,000-pair population.

Threats to piping plovers/critical habitat

In the following sections, we provide an analysis of threats to piping plovers in their migration and wintering range. We have updated information obtained since the 1985 listing rule, the 1991 and 2009 status reviews, and the three breeding population recovery plans. Both previously identified and new threats are discussed. With minor exceptions, this analysis is focused on threats to piping plovers within the continental U.S. portion of their migration and wintering range. Threats in the Caribbean and Mexico remain largely unknown.

Climate change

Numerous studies have documented accelerating rise in sea levels worldwide (Douglas et al. 2001; Rahmstorf et al. 2007; Hopkinson et al. 2008; Pilkey and Young 2009; U.S. Climate Change Science Program [USCCSP] 2009; Vermeer and Rahmstorf 2009; Pilkey and Pilkey 2011). Predictions include a sea level rise of between 19.7 and 78.7 in above 1990 levels by the year 2100 (Rahmstorf et al. 2007; Pfeffer et al. 2008; Vermeer and Rahmstorf 2009; Grinsted et al. 2010; Jevrejeva et al. 2010) and potential conversion of as much as 33 percent of the world's coastal wetlands to open water by 2080 (Intergovernmental Panel on Climate Change [IPCC] 2007; USCCSP 2008). Potential effects of sea level rise on piping plover roosting and foraging habitats may vary regionally due to subsidence or uplift, the geological character of the coast and near-shore, and the influence of management measures such as beach nourishment, jetties, groins, and seawalls (Galbraith et al. 2002; USCCSP 2009; Gutierrez et al. 2011). Sea level rise

along the U.S. Gulf coast exceeded the global average by 5.1-5.9 in because coastal lands there are subsiding (U.S. Environmental Protection Agency [EPA] 2009).

Low elevations and proximity to the coast make all non-breeding piping plover foraging and roosting habitats vulnerable to the effects of rising sea level. Areas with small tidal ranges are the most vulnerable to loss of intertidal wetlands and flats (EPA 2009). Sea level rise was cited as a contributing factor in the 68 percent decline in tidal flats and algal mats in the Corpus Christi, Texas region (*i.e.*, Lamar Peninsula to Encinal Peninsula) between the 1950s and 2004 (Tremblay et al. 2008). Mapping by Titus and Richman (2001) showed that more than 80 percent of the lowest land along the Atlantic and Gulf coasts was in Louisiana, Florida, Texas, and North Carolina. Gutierrez et al. (2011) found that along the Atlantic coast, the central and southern Florida coast is the most likely Atlantic portion of the wintering and migration range to experience moderate to severe erosion with sea level rise.

Inundation of piping plover habitat by rising seas could lead to permanent loss of habitat if natural coastal dynamics are impeded by numerous structures or roads, especially if those shorelines are also armored with hardened structures (Brown and McLachlan 2002; Dugan and Hubbard 2006; Fish et al. 2008; Defeo et al. 2009). Without development or armoring, low undeveloped islands can migrate toward the mainland, pushed by the over-washing of sand eroding from the seaward side and being re-deposited in the bay (Scavia et al. 2002). Over-wash and sand migration are impeded on developed portions of islands. Instead, as sea-level increases, the ocean-facing beach erodes and the resulting sand is deposited offshore. The buildings and the sand dunes then prevent sand from washing back toward the lagoons, and the lagoon side becomes increasingly submerged during extreme high tides (Scavia et al. 2002), diminishing both barrier beach shorebird habitat and protection for mainland developments.

Modeling by Galbraith et al. (2002) for three sea level rise scenarios at five important U.S. shorebird staging and wintering sites predicted aggregate loss of 20-70 percent of current intertidal foraging habitat. The most severe losses were projected at sites where the coastline is unable to move inland due to steep topography or seawalls. Of five study sites, the model predicted the lowest loss of intertidal shorebird foraging habitat at Bolivar Flats, Texas (a designated piping plover critical habitat unit) by 2050 because the habitat at that site will be able to migrate inland in response to rising sea level. The potential for such barrier island migration with rising sea level is most likely in the 42 percent of plover's U.S. non-breeding range that is currently preserved from development (Rice 2012a). Although habitat losses in some areas are likely to be offset by gains in other locations, Galbraith et al. (2002) noted that time lags between these losses and the creation of replacement habitat elsewhere may have serious adverse effects on shorebird populations. Furthermore, even if piping plovers are able to move their wintering locations in response to accelerated habitat changes, there could be adverse effects on the birds' survival rates or subsequent productivity.

In summary, the magnitude of threats from sea level rise is closely linked to threats from shoreline development and artificial stabilization that modify and degrade habitat. These threats will be perpetuated in places where damaged structures are repaired or replaced, exacerbated where the height and strength of structures are increased, and increased at locations where

development and coastal stabilization is expanded. Sites that are able to adapt to sea level rise are likely to become more important to piping plovers as habitat at developed or stabilized sites degrades. Potential effects of storms, which could increase in frequency or intensity due to climate change, are discussed in a following section. If climate change increases the frequency or magnitude of extreme temperatures, piping plover survival rates may be affected. Other potential adverse and beneficial climate change-related effects (*e.g.*, changes in the composition or availability of prey, emergence of new diseases, fewer periods of severe cold weather) are poorly understood, but cannot be discounted.

Destruction, modification, or curtailment of its habitat or range (present or threatened)

The final rule stated that in addition to extensive breeding area problems, the loss and modification of wintering habitat was a significant threat to the piping plover (Service 1985). The three recovery plans state that shoreline development throughout the wintering range poses a threat to all populations of piping plovers (Service 1988, 1994, 1996, 2003). The plans further state that beach maintenance and nourishment, inlet dredging, and artificial structures, such as jetties and groins, could eliminate wintering areas and alter sedimentation patterns leading to the loss of nearby habitat. Priority 1 actions in the 1996 Atlantic Coast and 2003 Great Lakes Recovery Plans identify tasks to protect natural processes that maintain coastal ecosystems and quality wintering piping plover habitat and to protect wintering habitat from shoreline stabilization and navigation projects. The 1988 Northern Great Plains Recovery Plan states that, as winter habitat is identified, current and potential threats to each site should be determined.

The threats to piping plover habitat used during winter and migration were identified by the Service during its designation of critical habitat. The threats affecting most winter and migration areas include unregulated use of motorized vehicles, unregulated pedestrian recreation, inlet and shoreline stabilization projects, beach maintenance and nourishment, and pollution. Conservation efforts at some locations have likely resulted in the protection and/or enhancement of wintering habitat.

Important components of ecologically sound barrier beach management include perpetuation of natural dynamic coastal formation processes. Structural development along the shoreline or manipulation of natural inlets upsets the dynamic processes and results in habitat loss or degradation (Melvin et al. 1991). Throughout the range of migrating and wintering piping plovers, inlet and shoreline stabilization, inlet dredging, beach maintenance and nourishment activities, and seawall installations continue to constrain natural coastal processes. Dredging of inlets can affect spit formation adjacent to inlets and directly remove or affect ebb and flood tidal shoal formation. Jetties, which stabilize an island, cause island widening and subsequent growth of vegetation on inlet shores. Seawalls restrict natural island movement and exacerbate erosion. As discussed in more detail below, all these efforts result in loss of piping plover habitat. Construction of these projects during months when piping plovers are present also causes disturbance that disrupts the birds' foraging efficiency and hinders their ability to build fat reserves over the winter and in preparation for migration, as well as their recuperation from migratory flights.

Any assessment of threats to piping plovers from loss and degradation of habitat must recognize that up to 24 shorebird species migrate or winter along the Atlantic coast and almost 40 species of shorebirds are present during migration and wintering periods in the Gulf of Mexico region (Helmers 1992). Continual degradation and loss of habitats used by wintering and migrating shorebirds may cause an increase in intra-specific and inter-specific competition for remaining food supplies and roosting habitats. In Florida, for example, approximately 825 mi of coastline and parallel bayside flats (unspecified amount) were present prior to the advent of high human densities and beach stabilization projects. We estimate that only about 35 percent of the Florida coastline continues to support natural coastal formation processes, thereby concentrating foraging and roosting opportunities for all shorebird species and forcing some individuals into suboptimal habitats. Thus, intra- and inter-specific competition most likely exacerbates threats from habitat loss and degradation.

Development and construction

Development and associated construction threaten the piping plover in its migration and wintering range by degrading, fragmenting, and eliminating habitat. Constructing buildings and infrastructure adjacent to the beach can eliminate roosting and loafing habitat within the development's footprint and degrade adjacent habitat by replacing sparsely vegetated dunes or back-barrier beach areas with landscaping, pools, fences, etc. In addition, the development of bayside or estuarine shorelines, with finger canals and their associated bulkheads, docks, buildings, and landscaping, leads to direct loss and degradation of plover habitat. Finger canals can lead to water pollution, fish kills, loss of aquatic nurseries, saltwater intrusion of groundwater, disruption of surface flows, island breaching due to the funneling of storm surge, and a perpetual need for dredging and disposal of dredged material in order to keep the canals navigable for property owners (Morris et al. 1978; Bush et al. 1996). High-value plover habitat becomes fragmented as lots are developed or coastal roads are built between ocean-side and bayside habitats. Development activities can also include lowering or removing natural dunes to improve views or grade building lots, planting vegetation to stabilize dunes, and erecting sand fencing to establish or stabilize continuous dunes in developed areas. Such activities can further degrade, fragment, and eliminate sparsely vegetated and unvegetated habitats used by the piping plover and other wildlife. Development and construction of other infrastructure in close proximity to barrier beaches often creates economic and social incentives for subsequent shoreline stabilization projects, such as shoreline hardening and beach nourishment. Developed beaches are also highly vulnerable to further habitat loss because they cannot migrate in response to sea level rise.

Approximately 40 percent of the sandy beach shoreline in the migration and wintering range is already developed, and Rice (2012a) has identified over 900 mi (43 percent) of sandy beaches in the wintering range that are currently "preserved" through either public ownership, ownership by non-governmental conservation organizations, or conservation easements. These beaches may be subject to some erosion as they migrate in response to sea level rise or if sediment is removed from the coastal system, and they are vulnerable to recreational disturbance. However, the "preserved" shoreline areas are most likely to maintain the geomorphic characteristics of suitable piping plover habitat. The remaining 17 percent of shoreline habitat in the migration and

wintering range (that which is currently undeveloped, but not preserved) is susceptible to future loss to development and the resultant threats from shoreline stabilization activities. Nonetheless, the entire coastline regardless of whether it is developed or not is susceptible to sea level rise.

Disease

No instances of disease have been documented in piping plovers outside the breeding range. In the southeastern U.S., the cause of death of one piping plover received from Texas was emaciation (Acker 2009). Newstead (2012b) reported circumstantial evidence that red tide weakened piping plovers in the vicinity of Laguna Madre and Padre Island, Texas during the fall of 2011. Samples collected in Florida from two live piping plovers in 2006 both tested negative for avian influenza (Hines 2009). Based on information available to date, West Nile virus and avian influenza are a minor threat to piping plovers (Service 2009a). Neither the final listing rule nor the recovery plans state that disease is an issue for the species, and no plan assigns recovery actions to this threat factor.

Energy development

Various oil and gas exploration and development activities occur along the Gulf coast. Examples of conservation measures prescribed to avoid adverse effects on piping plovers and their habitats include conditions on driving on beaches and tidal flats, restrictions on discharging fresh water across unvegetated tidal flats, timing exploration activities during times when the plovers are not present, and use of directional drilling from adjacent upland areas (Service 2008b; Firmin 2012). With the implementation of appropriate conditions, threats to non-breeding piping plovers from land-based oil and gas extraction are currently very low.

Wind turbines are a potential future threat to piping plovers in their coastal migration and wintering range. Relatively small single turbines have been constructed along the beachfront in a few locations (*e.g.*, South Carolina; Caldwell 2012). Current risk to piping plovers from several wind farms located on the mainland north and west of several bays in southern Texas is deemed low during months of winter residency because the birds are not thought to traverse these areas in their daily movements (Newstead 2012a). To date, no piping plovers have been reported from post-construction carcass detection surveys at these sites (Clements 2012). However, Newstead (2012a) raised questions about collision risk during migration departure, as large numbers of piping plovers have been observed in areas of Laguna Madre east of the wind farms during the late winter. Furthermore, there is concern that, as sea level rises, the intertidal zone (and potential piping plover activity) may move closer to these sites.

In addition to uncertainty regarding the location and design (*e.g.*, number and height of turbines) of future wind turbines, the magnitude of potential threats is difficult to assess without better information about piping plover movements and behaviors. For wind projects situated on barrier beaches, bay shorelines, or within bays, relevant information includes the flight routes of piping plovers moving among foraging and roosting sites, flight altitude, and avoidance rates under varying weather and light conditions. For off-shore wind projects, piping plover migration routes and altitude, as well as avoidance rates will be key determinants of threats.

Exotic/invasive vegetation

An identified threat to piping plover habitat, not described in the listing rule or older recovery plans, is the spread of coastal invasive plants into suitable piping plover habitat. Like most invasive species, coastal exotic plants reproduce and spread quickly and exhibit dense growth habits, often outcompeting native plant species. If left uncontrolled, invasive plants cause a habitat shift from open or sparsely vegetated sand to dense vegetation, resulting in the loss or degradation of piping plover roosting habitat, which is especially important during high tides and migration periods. The propensity of these exotic species to spread, and their tenacity once established, make them a persistent threat, partially countered by increasing landowner awareness and willingness to undertake eradication activities.

Many invasive species are either currently affecting or have the potential to affect coastal beaches and thus plover habitat. Beach vitex (*Vitex rotundifolia*) is a woody vine introduced into the southeastern U.S. as a dune stabilization and ornamental plant which has spread to coastal communities throughout the southeastern U.S. from Virginia to Florida, and west to Texas (Westbrooks and Madsen 2006). Unquantified amounts of crowfoot grass (*Dactyloctenium aegyptium*) grow invasively along portions of the Florida coastline. It forms thick bunches or mats that may change the vegetative structure of coastal plant communities and alter shorebird habitat. The Australian pine (*Casuarina equisetifolia*) also changes the vegetative structure of the coastal community in south Florida and islands within the Bahamas. Shorebirds prefer foraging in open areas where they are able to see potential predators, and tall trees provide good perches for avian predators. Australian pines potentially impact shorebirds, including the piping plover, by reducing attractiveness of foraging habitat and/or increasing avian predation. Japanese sedge *(Carex kobomugi)*, which aggressively encroaches into sandy beach habitats (USDA 2013), was documented in Currituck County, North Carolina, in the mid-1970s and as recently as 2003 on Currituck National Wildlife Refuge (Gramling 2011), at two sites where migrating piping plovers have also been documented. Early detection and rapid response are key to controlling this and other invasive plants (Westbrooks 2011).

Defeo et al. (2009) cite biological invasions of both plants and animals as global threats to sandy beaches, with the potential to alter the food web, nutrient cycling and invertebrate assemblages. Although the extent of the threat is uncertain, this may be due to poor survey coverage more than an absence of invasions.

Groins

Groins pose an ongoing threat to piping plover beach habitat within the continental wintering range. Groins (structures made of concrete, rip rap, wood, or metal built perpendicular to the beach in order to trap sand) are typically found on developed beaches with severe erosion. Although groins can be individual structures, they are often clustered along the shoreline. Groins can act as barriers to long-shore sand transport and cause down-drift erosion (Hayes and Michel 2008), which prevents piping plover habitat creation by limiting sediment deposition and accretion. The resulting beach typically becomes scalloped in shape, thereby fragmenting plover

habitat over time. Groins and groin fields are found throughout the southeastern Atlantic and Gulf coasts, and although most were in place prior to the piping plover's 1986 listing under the Act, installation of new groins continues to occur, perpetuating the threat to migrating and wintering piping plovers. As sea level rises at an accelerating rate, the threat of habitat loss, fragmentation and degradation from groins and groin fields may increase as communities and beachfront property owners seek additional ways to protect infrastructure and property.

Human disturbance

Disturbance (*i.e.,* human and pet presence that alters bird behavior) disrupts piping plovers as well as other shorebird species. Intense human disturbance in shorebird winter habitat can be functionally equivalent to habitat loss if the disturbance prevents birds from using an area for a significant amount of time (Goss-Custard et al. 1996), which can lead to roost abandonment and local population declines (Burton et al. 1996). Pfister et al. (1992) implicated anthropogenic disturbance as a factor in the long-term decline of migrating shorebirds at staging areas. Disturbance can also cause shorebirds to spend less time roosting or foraging and more time in alert postures or fleeing from the disturbances (Johnson and Baldassarre 1988; Burger 1991, 1994; Elliott and Teas 1996; Lafferty 2001a, 2001b; Thomas et al. 2002), which limits the local abundance of piping plovers (Zonick and Ryan 1995; Zonick 2000). Shorebirds that are repeatedly flushed in response to disturbance expend energy on costly short flights (Nudds and Bryant 2000) and may not feed enough to support migration and/or subsequent breeding efforts (Puttick 1979; Lafferty 2001b). Elliott and Teas (1996) found a significant difference in actions between piping plovers encountering pedestrians and those not encountering pedestrians. Piping plovers encountering pedestrians spend proportionately more time in non-foraging behavior. This study suggests that interactions with pedestrians on beaches cause birds to shift their activities from calorie acquisition to calorie expenditure. In wintering and migration sites, human disturbance continues to decrease the amount of undisturbed habitat and appears to limit local piping plover abundance (Zonick and Ryan 1995).

Shorebirds are more likely to flush from the presence of dogs than people, and birds react to dogs from farther distances than people (Lafferty 2001a, 2001b; Thomas et al. 2002). Dogs off leash are more likely to flush piping plovers from farther distances than are dogs on leash; nonetheless, dogs both on and off leashes disturb piping plovers (Hoopes 1993). Pedestrians walking with dogs often go through flocks of foraging and roosting shorebirds, which may increase the likelihood that dogs would chase birds. Although the timing, frequency, and duration of human and dog presence throughout the wintering range are unknown, studies in Alabama and South Carolina suggest that most disturbances to piping plovers occur during periods of warmer weather, which coincides with piping plover migration (Johnson and Baldassarre 1988; Lott et al. 2009; Maddock et al. 2009).

Off-road vehicles (ORVs) can also significantly degrade piping plover habitat (Wheeler 1979) or disrupt the birds' normal behavior patterns (Zonick 2000). The 1996 Atlantic Coast Recovery Plan cites tire ruts crushing wrack into the sand, making it unavailable as cover or as foraging substrate (Goldin 1993; Hoopes 1993). The plan also notes that the magnitude of the threat from ORVs is significant, because ORVs extend impacts to remote stretches of beach where human

disturbance will otherwise be very slight. Godfrey et al. (1978, 1980) postulated that vehicular traffic along the beach may compact the substrate and kill marine invertebrates that are food for the piping plover. Zonick (2000) found that the density of ORVs negatively correlated with the abundance of roosting piping plovers on the ocean beach. Cohen et al. (2008a) found that piping plovers using ocean beach habitat were less likely to use the north side of the inlet where ORV use is allowed. Ninety-six percent of piping plover detections occurred on the south side of the inlet even though it was farther away from foraging sites (Cohen et al. 2008a). Although there is some variability among states, disturbance from human activities and pets poses a moderate to high and escalating threat to migrating and wintering piping plovers.

Based on surveys with land managers and biologists, knowledge of local site conditions, and other information, the Service has estimated the levels of eight types of disturbance at sites in the U.S. with wintering piping plovers (Service 2009b; Table 3). There are few areas used by wintering piping plovers that are devoid of human presence, and just under half have leashed and unleashed dog presence (Smith 2007; Lott et al. 2009). Data are not available on human disturbance at wintering sites in the Bahamas, other Caribbean countries, or Mexico.

Disturbance can be addressed by implementing recreational management techniques such as vehicle and pet restrictions and symbolic fencing (usually sign posts and string) of roosting and feeding habitats. In implementing conservation measures, managers need to consider a range of site-specific factors, including the extent and quality of roosting and feeding habitats and the types and intensity of recreational use patterns. In addition, educational materials such as informational signs or brochures can provide valuable information so that the public understands the need for conservation measures.

Inlet stabilization/relocation

Many navigable mainland or barrier island tidal inlets along the Atlantic and Gulf of Mexico coasts are stabilized with jetties, groins, seawalls, and/or adjacent industrial or residential development. Jetties are structures built perpendicular to the shoreline that extend through the entire near-shore zone and past the breaker zone to prevent or decrease sand deposition in the channel (Hayes and Michel 2008). Inlet stabilization with rock jetties and associated channel dredging for navigation alter the dynamics of long-shore sediment transport and affect the location and movement rate of barrier islands (Camfield and Holmes 1995), typically causing down-drift erosion. Sediment is then dredged and added back to the islands which are subsequently widened. Once the island becomes stabilized, vegetation encroaches on the bayside habitat, thereby diminishing and eventually destroying its value to piping plovers. Accelerated erosion may compound future habitat loss, depending on the degree of sea-level rise. Unstabilized inlets naturally migrate, re-forming important habitat components, whereas jetties often trap sand and cause significant erosion of the down-drift shoreline. These combined actions affect the availability of piping plover habitat (Cohen et al. 2008b). Rice (2012b) found that 40 percent (89 out of 221) of the inlets open in 2011 have been stabilized in some way, contributing to habitat loss and degradation throughout the wintering range. Accelerated erosion may compound future habitat loss, depending on the degree of sea level rise (Titus et al. 2009). Due to the complexity of impacts associated with projects such as jetties and groins, Harrington

(2008) noted the need for a better understanding of potential effects of inlet-related projects, such as jetties, on bird habitats.

Although the loss and/or degradation of piping plover habitat associated with the effects of tidal inlet relocation may persist for years, the effects are less permanent than the construction of hard structures. An inlet relocation project on Kiawah Island, South Carolina, degraded one of the most important piping plover habitats in the State by reducing the size and physical characteristics of an active foraging site, changing the composition of the benthic community, decreasing the tidal lag in an adjacent tidal lagoon, and decreasing the exposure time of the associated sand flats (Service and Town of Kiawah Island 2006). In 2006, pre-project piping plover numbers in the project area recorded during four surveys conducted at low tide averaged 13.5 piping plovers. This contrasts with a post-project average of 7.1 plovers during eight surveys (four in 2007 and four in 2008) conducted during the same months (Service and Town of Kiawah Island 2006), indicating that reduced habitat quality was one possible cause of the lower usage by plovers.

Macroinvertebrate prey base loss due to shoreline stabilization

Wintering and migrating piping plovers depend on the availability and abundance of macroinvertebrates as an important food item. Studies of invertebrate communities have found that communities are richer (greater total abundance and biomass) on protected (bay or lagoon) intertidal shorelines than on exposed ocean beach shorelines (McLachlan 1990; Cohen et al. 2006; Defeo and McLachlan 2011). Polychaete worms tend to have a more diverse community and be more abundant in more protected shoreline environments, and mollusks and crustaceans such as amphipods thrive in more exposed shoreline environments (McLachlan and Brown 2006). Polychaete worms comprise the majority of the shorebird diet (Kalejta 1992; Mercier and McNeil 1994; Tsipoura and Burger 1999; Verkuil et al. 2006); and of the piping plover diet in particular (Hoopes 1993; Nicholls 1989; Zonick and Ryan 1995).

The quality and quantity of the macroinvertebrate prey base is threatened by shoreline stabilization activities, including beaches that have received sand placement of various types. The addition of dredged sediment can temporarily affect the benthic fauna of intertidal systems. Invertebrates may be crushed or buried during project construction. Some benthic species can burrow through a thin layer (15-35 in for different species) of additional sediment since they are adapted to the turbulent environment of the intertidal zone; however, thicker layers (*i.e.*, >3.3 feet) of sediment are likely to smother the benthic fauna (Greene 2002). Numerous studies of such effects indicate that the recovery of benthic fauna after beach nourishment or sediment placement projects can take anywhere from 6 months to 2 years, and possibly longer in extreme cases (Thrush et al. 1996; Peterson et al. 2000; Zajac and Whitlatch 2003; Bishop et al. 2006; Peterson et al. 2006).

Invertebrate communities may also be affected by changes in the physical environment resulting from shoreline stabilization activities that alter the sediment composition or degree of exposure. Shoreline armoring with hard stabilization structures such as seawalls and revetments can alter the degree of exposure of the macroinvertebrate prey base by modifying the beach and intertidal

geomorphology, or topography. Seawalls typically result in the narrowing and steepening of the beach and intertidal slope in front of the structure, eventually leading to complete loss of the dry and intertidal beach as sea level continues to rise (Pilkey and Wright 1988; Hall and Pilkey 1991; Dugan and Hubbard 2006; Defeo et al. 2009; Kim et al. 2011). Sand placement projects bury the natural beach with new sediment, and grade the new beach and intertidal zone with heavy equipment to conform to a predetermined topographic profile, which can lead to compaction of the sediment (Nelson et al. 1987; Corps 2008; Defeo et al. 2009). If the material used in a sand placement project does not closely match the native material on the beach, the sediment incompatibility may result in modifications to the macroinvertebrate community structure, because several species are sensitive to grain size and composition (Rakocinski et al. 1996; Peterson et al. 2000, 2006; Peterson and Bishop 2005; Colosio et al. 2007; Defeo et al. 2009).

Delayed recovery of the benthic prey base or changes in their communities due to physical habitat changes may affect the quality of piping plover foraging habitat. The duration of the impact can adversely affect piping plovers because of their high site fidelity. Although recovery of invertebrate communities has been documented in many studies, sampling designs have typically been inadequate and have only been able to detect large-magnitude changes (Schoeman et al. 2000; Peterson and Bishop 2005). Therefore, uncertainty persists about the impacts of various projects to invertebrate communities and how these impacts affect shorebirds, particularly the piping plover. Rice (2009) identified several conservation measures that can avoid and minimize some of the known impacts.

Military actions

Twelve coastal military bases are located in the Southeast. To date, five bases have consulted with the Service under section 7 of the Act, on military activities on beaches and baysides that may affect piping plovers or their habitat. Overall, project avoidance and minimization actions currently reduce threats from military activities to wintering and migrating piping plovers to a minimal threat level. However, prior to removal of the piping plover from protection under the Act, Integrated Resource Management Plans or other agreements should clarify if and how a change in legal status would affect plover protections.

Oil spills and other contaminants

Contaminants have the potential to cause direct toxicity to individual birds or negatively affect their invertebrate prey base (Rattner and Ackerson 2008). Depending on the type and degree of contact, contaminants can have lethal and sub-lethal effects on birds, including behavioral impairment, deformities, and impaired reproduction (Rand and Petrocelli 1985; Gilbertson et al. 1991; Hoffman et al. 1996). Petroleum products are the contaminants of primary concern, as opportunities exist for petroleum to pollute intertidal habitats that provide foraging substrate. Impacts to piping plovers from oil spills have been documented throughout their life cycle (Chapman 1984; Service 1996; Burger 1997; Massachusetts Audubon 2003-2009; Amirault-Langlais et al. 2007; Amos 2009). However, lightly oiled piping plovers have survived and successfully reproduced (Chapman 1984; Amirault-Langlais et al. 2007; Amos 2009). To date, no plover mortality has been attributed to oil contamination outside the breeding grounds, but

latent effects would be difficult to prove. Chapman (1984) noted shifts in habitat use as piping plovers moved out of spill areas. This behavioral change was believed to be related to the demonstrated decline in benthic infauna (prey items) in the intertidal zone and may have decreased the direct impact to the species.

More subtle but cumulatively damaging sources of oil and other contaminants are leaking vessels located offshore or within the bays on the Atlantic and Gulf coasts, offshore oil rigs and undersea pipelines in the Gulf of Mexico, pipelines buried under the bay bottoms, and onshore facilities such as petroleum refineries and petrochemical plants. In Louisiana, about 2,500-3,000 oil spills are reported in the Gulf region each year, ranging in size from very small to thousands of barrels (Carver 2011). Chronic spills of oil from rigs and pipelines and natural seeps in the Gulf of Mexico generally involve small quantities of oil. The oil from these smaller leaks and seeps, if they occur far enough from land, will tend to wash ashore as tar balls. In cases such as this, the impact is limited to discrete areas of the beach, whereas oil slicks from larger spills coat longer stretches of the shoreline (Rice 2009). Federal and state land managers have protective provisions in place to secure and remove the oil, thus reducing the likelihood of contamination.

According to government estimates, the 2010 Deepwater Horizon Mississippi Canyon Well #252 (Deepwater Horizon) oil spill discharged more than 200 million gallons of oil into the Gulf of Mexico. Containment activities, recovery of oil-water mix, and controlled burning removed some oil, but additional impacts to natural resources may stem from the 1.84 million gallons of dispersant that were applied to the spill (U.S. Government 2010). Approximately 1,100 mi of shoreline was estimated to be oiled in the Gulf of Mexico. This included approximately 665 mi in Louisiana, 160 mi in Mississippi, 95 mi in Alabama, and 175 mi in Florida (Michel et al. 2013). These numbers do not address cumulative impacts or include shoreline that was cleaned earlier. The U.S. Coast Guard, the states, and responsible parties that form the Unified Command (with advice from federal and state natural resource agencies) initiated protective measures and clean-up efforts as provided in contingency plans for each state's coastline. The contingency plans identified sensitive habitats, including all ESA-listed species' habitats, which received a higher priority for response actions.

Efforts to prevent shoreline oiling and cleanup response activities can disturb piping plovers and their habitat. Although most piping plovers were on their breeding grounds in May, June, and early July when the Deepwater Horizon well was discharging oil, oil was still washing onto Gulf beaches when the plovers began arriving back on the Gulf in mid-July. Ninety percent of piping plovers detected during the prior 4 years of surveys in Louisiana were in the Deepwater Horizon oil spill impact zone, and Louisiana's Department of Wildlife and Fisheries reported significant disturbance to birds and their habitat from response activities. Wrack lines were removed, and sand washing equipment "cleansed" beaches (Seymour 2011). Potential long-term adverse effects stem from the construction of sand berms and closing of at least 32 inlets (Rice 2012b). Implementation of prescribed best management practices reduced, but did not negate, disturbance to plovers (and to other beach-dependent wildlife) from cleanup personnel, all-terrain vehicles, helicopters, and other equipment. Service and state biologists present during cleanup operations provided information about breeding, migrating, and wintering birds and their habitat protection needs. However, high staff turnover during the extended spill response period

necessitated continuous education and training of clean up personnel (Bimbi 2011). Limited clean-up operations were still ongoing throughout the spill area in November 2012 (Herod 2012). Results of a natural resources damage assessment study to assess injury to piping plovers are not yet available.

Pesticides and other contaminants

In 2000, mortality of large numbers of wading birds and shorebirds, including one piping plover, at Audubon's Rookery Bay Sanctuary on Marco Island, Florida, occurred following the county's aerial application of the organophosphate pesticide Fenthion for mosquito control purposes (Williams 2001). Fenthion, a known toxin to birds, was registered for use as an avicide by Bayer, a chemical manufacturer. Subsequent to a lawsuit being filed against the EPA in 2002, the manufacturer withdrew Fenthion from the market, and EPA declared all uses of the chemical were to end by November 30, 2004 (American Bird Conservancy 2007). All other counties in the U.S. now use less toxic chemicals for mosquito control. It is unknown whether pesticides are a threat for piping plovers wintering in the Bahamas, other Caribbean countries, or Mexico.

There has been limited opportunistic testing of piping plover eggs. Polychlorinated biphenol (PCB) concentrations in several composites of Great Lakes piping plover eggs tested in the 1990s had potential to cause reproductive harm. Analysis of prey available to piping plovers at representative Michigan breeding sites indicated that breeding areas along the upper Great Lakes region were not likely the major source of contaminants to this population (Service 2003). Relatively high levels of PCB, dichloro diphenyl dichloroethylene, and polybrominated diphenyl ether were detected in one of two clutches of Ontario piping plover eggs analyzed in 2009 (Cavalieri 2011). Results of opportunistic egg analyses to date from Atlantic coast piping plovers did not warrant follow-up investigation (Mierzykowski 2009, 2010, 2012). No recent testing has been conducted for contaminants in the Northern Great Plains piping plover population.

Predation

The impact of predation on migrating or wintering piping plovers remains essentially undocumented. Avian and mammalian predators are common throughout the species' wintering range. Predatory birds are relatively common during fall and spring migration, and it is possible that raptors occasionally take piping plovers (Drake et al. 2001). The 1996 Atlantic Coast Recovery Plan summarized evidence that human activities affect types, numbers, and activity patterns of some predators, thereby exacerbating natural predation on breeding piping plovers. It has been noted, however, that the behavioral response of crouching when in the presence of avian predators may minimize avian predation on piping plovers (Morrier and McNeil 1991; Drake 1999a; Drake et al. 2001).

Non-breeding piping plovers may reap some collateral benefits from predator management on their migration and wintering grounds conducted for the primary benefit of other species. Some predator control programs may provide limited protection to piping plovers, should the birds use the areas for roosting or foraging. The Service is not aware of any current predator control

programs targeting protection of coastal species in Georgia, Alabama, Mississippi, or Louisiana, but some predator control programs in North Carolina, South Carolina, Florida, and Texas may provide indirect benefits to plovers in wintering and migration habitat in those states.

Although the extent of predation to non-breeding piping plovers remains unknown, it remains a potential threat. Focused research to confirm impacts as well as to ascertain effectiveness of predator control programs may be warranted, especially in areas frequented by Great Lakes birds during migration and wintering months. At this time, however, we consider predator control on their wintering and migration grounds to be a low priority.

Sand mining/dredging

The dredging and mining of sediment from inlet complexes threatens the piping plover on its wintering grounds through habitat loss and degradation. The maintenance of navigation channels by dredging, especially deep shipping channels, can significantly alter the natural coastal processes on inlet shorelines of nearby barrier islands (Otvos 2006; Morton 2008; Otvos and Carter 2008; Beck and Wang 2009; Stockdon et al. 2010). Forty-four percent of the tidal inlets within the U.S. wintering range of the piping plover have been or continue to be dredged, primarily for navigational purposes (Service 2015a). The dredging of navigation channels or relocation of inlet channels for erosion-control purposes contributes to the cumulative effects of inlet habitat modification by removing or redistributing the local and regional sediment supply; the maintenance dredging of deep shipping channels can convert a natural inlet that normally bypasses sediment from one shoreline to the other into a sediment sink, where sediment no longer bypasses the inlet. Additionally, dredging can occur on an annual basis or every 2 to 3 years and the volume of sediment removed can be major, resulting in continual perturbations and modifications to inlet and adjacent shoreline habitat.

As sand sources for beach nourishment projects have become more limited, the mining of ebb tidal shoals for sediment has increased (Cialone and Stauble 1998). Exposed shoals and sandbars are valuable to piping plovers, as they tend to receive less human recreational use (because they are only accessible by boat) and therefore provide relatively less disturbed habitats for birds. Removing these sand sources can alter depth contours and change wave refraction as well as cause localized erosion (Hayes and Michel 2008). Ebb shoals are especially important because they act as “sand bridges” that connect beaches and islands by transporting sediment via longshore transport from one side (updrift) to the other (downdrift) side of an inlet. The mining of sediment from these shoals upsets the inlet system equilibrium and can lead to increased erosion of the adjacent inlet shorelines (Cialone and Stauble 1998). Rice (2012b) noted mining of material from inlet shoals for use as beach fill is not equivalent to the natural sediment bypassing that occurs at unmodified inlets for several reasons. Most notably for the massive volumes involved that are “transported” virtually instantaneously instead of gradually and continuously and for the placement of the material outside of the immediate inlet vicinity, where it would naturally bypass. The mining of inlet shoals can also remove massive amounts of sediment. Cialone and Stauble (1998) found that monitoring of the impacts of ebb shoal mining has been insufficient, and in one case the mining pit was only 66 percent recovered after 5 years.

They concluded that the larger the volume of sediment mined from the shoals, the larger the perturbation to the system and the longer the recovery period.

Information is limited on the effects to piping plover habitat due to the deposition of dredged material, and the available information is inconsistent. Studies have found instances where birds will and will not use islands created from dredged material throughout the wintering range. Research is needed to understand why piping plovers use some dredge material islands, but are not regularly found using others.

In summary, the removal of sediment from inlet complexes via dredging and sand mining for beach fill has modified nearly half of the tidal inlets within the continental wintering range of the piping plover, leading to habitat loss and degradation. Many of these inlet habitat modifications have become permanent, existing for over 100 years. The expansion of several harbors and ports to accommodate deeper draft ships poses an increasing threat as more sediment is removed from the inlet system, causing larger perturbations and longer recovery times. Sand removal or sediment starvation of shoals, sandbars and adjacent shoreline habitat has resulted in habitat loss and degradation, which may reduce the system's ability to maintain a full suite of inlet habitats as sea level continues to rise at an accelerating rate. Rice (2012b) noted that the adverse impacts of this threat to piping plovers may be mitigated by eliminating dredging and mining activities in inlet complexes with high habitat value, extending the interval between dredging cycles, discharging dredged material in near-shore downdrift waters so that it can accrete more naturally than when placed on the subaerial beach, and designing dredged material islands to mimic natural shoals and flats.

Sand placement projects

In the wake of episodic storm events, managers of lands under public, private, and county ownership often protect coastal structures using emergency storm berms which are frequently followed by beach nourishment or renourishment activities (nourishment projects are considered "soft" stabilization versus "hard" stabilization such as seawalls). Berm placement and beach nourishment deposit substantial amounts of sand along Gulf of Mexico and Atlantic beaches to protect local property in anticipation of preventing erosion and what otherwise would be considered natural processes of over-wash and island migration (Schmitt and Haines 2003). On unpopulated islands, the addition of sand and creation of marsh are sometimes used to counteract the loss of roosting and nesting habitat for shorebirds and wading birds as a result of erosional storm events.

Past and ongoing stabilization projects may fundamentally alter the naturally dynamic coastal processes that create and maintain beach strand and bayside habitats, including those habitat components that piping plovers rely upon. Although impacts may vary depending on a range of factors, stabilization projects may directly degrade or destroy piping plover roosting and foraging habitat in several ways. Front beach habitat may be used to construct an artificial berm that is densely planted in grass, which can directly reduce the availability of roosting habitat. Over time, if the beach narrows due to erosion, additional roosting habitat between the berm and the water can be lost. Berms can also prevent or reduce the natural over-wash that creates roosting

habitat by converting vegetated areas to open sand areas. The vegetation growth caused by impeding natural over-wash can also reduce the maintenance and creation of bayside intertidal feeding habitats. In addition, stabilization projects may indirectly encourage further development of coastal areas and increase the threat of disturbance.

The coastal ecosystem associated with coastal habitats along the Gulf of Mexico and Atlantic Ocean is threatened by the inability of the barrier islands to maintain geomorphologic functionality (Corps 2011). Consequently, most of the planned sediment placement projects are conducted as environmental restoration projects by various federal and state agencies because without the sediment many areas would erode below sea level since many coastal systems are starved for sediment sources. Agencies conducting coastal restoration projects aim to design projects that mimic the natural existing elevations of coastal habitats (*e.g.*, beach, dune, and marsh) in order to allow their projects to work within and be sustained by the natural ecosystem processes that maintain those coastal habitats. Due to the low elevation of barrier islands and coastal headlands, placement of additional sediment in those areas generally does not reach an elevation that would prevent the formation of over-wash areas or impede natural coastal processes, especially during storm events. Such careful design of these restoration projects allows daily tidal processes or storm events to re-work the sediments to reform the Gulf/Atlantic beach interface and create over-wash areas, sand flats, and mud flats on the bay-side of the islands, as well as sand spits on the ends of the islands; thus, the added sediment aids in sustaining the barrier island system.

Sediment placement also temporarily affects the benthic fauna found in intertidal systems by covering them with a layer of sediment. Some benthic species can burrow through a thin layer (varies from 15 to 35 in for different species) of additional sediment since they are adapted to the turbulent environment of the intertidal zone; however, thicker layers (*i.e.*, >3.3 feet) of sediment are likely to smother the benthic fauna (Greene 2002). Various studies of such effects indicate that the recovery of benthic fauna after beach renourishment or sediment placement can take anywhere from 6 months to 2 years (Rakocinski et al. 1996; Peterson et al. 2000; Peterson et al. 2006). Such delayed recovery of benthic prey species temporarily affects the quality of piping plover foraging habitat.

Seawalls and revetments

Seawalls and revetments are vertical hard structures built parallel to the beach in front of buildings, roads, and other facilities to protect them from erosion. However, these structures often accelerate erosion by causing scouring in front of and down-drift from the structure (Hayes and Michel 2008), which can eliminate intertidal foraging habitat and adjacent roosting habitat. Physical characteristics that determine microhabitats and biological communities can be altered after installation of a seawall or revetment, thereby depleting or changing the benthic community composition that serves as the prey base for piping plovers. At four California study sites, each comprised of an unarmored segment and a segment seaward of a seawall, Dugan and Hubbard (2006) found that armored segments had narrower intertidal zones, smaller standing crops of macrophyte wrack, and lower shorebird abundance and species richness. Geotubes (long

cylindrical bags made of high-strength permeable fabric and filled with sand) are softer alternatives, but act as barriers by preventing over-wash.

The repair of existing armoring structures and installation of new structures continues to degrade, destroy, and fragment beachfront plover habitat throughout its continental wintering range. As sea level rises at an accelerating rate, the threat of habitat loss, fragmentation and degradation from hard erosion-control structures is likely to increase as communities and property owners seek to protect their beachfront development. As coastal roads become threatened by rising sea level and increasing storm damage, additional lengths of beachfront habitat may be modified by riprap, revetments, and seawalls.

Severe cold weather

Several sources suggest the potential for adverse effects of severe winter cold on survival of piping plovers. The 1996 Atlantic Coast Recovery Plan mentioned high mortality of coastal birds and a drop from approximately 30-40, to 15 piping plovers following an intense 1989 snowstorm along the North Carolina coast (Fussell 1990). A preliminary analysis of survival rates for Great Lakes piping plovers found that the highest variability in survival occurred in spring and correlated positively with minimum daily temperature during the preceding winter (Roche 2010, 2012). Catlin (2012) reported that the average mass of 10 piping plovers captured in Georgia during unusually cold weather in December 2010, was 0.2 ounces less than the average for 9 birds captured in October of the same year.

Storm events

Storms are a component of the natural processes that form coastal habitats used by migrating and wintering piping plovers, and positive effects of storm-induced over-wash and vegetation removal have been noted in portions of the wintering range. For example, Gulf Islands National Seashore habitats in the National Park Service's Florida district benefited from increased over-wash events that created optimal habitat conditions during the 2004 and 2005 hurricane seasons, with biologists reporting piping plover use of these habitats within 6 months of the storms (Nicholas 2005). Hurricane Katrina (2005) over-washed the mainland beaches of Mississippi, creating many tidal flats where piping plovers were subsequently observed (Winstead 2008). Hurricane Katrina also created a new inlet and improved habitat conditions on some areas of Dauphin Island, Alabama (LeBlanc 2009). Conversely, localized storms, since Katrina, have induced habitat losses on Dauphin Island (LeBlanc 2009). Noel et al. (2005) suspected that changes in habitat caused by multiple hurricanes along the Georgia coastline altered the spatial distribution of piping plovers and may have contributed to mortality of three Great Lakes piping plovers wintering along the Georgia coastline. Following Hurricane Ike in 2008, Arvin (2009) reported decreased numbers of piping plovers at some heavily eroded Texas beaches in the center of the storm impact area, and increases in plover numbers at sites about 100 mi to the southwest. However, piping plovers were observed later in the season using tidal lagoons and pools that Ike created behind the eroded beaches (Arvin 2009).

The adverse effects on piping plovers attributed to storms are sometimes due to a combination of storms and other environmental changes or human use patterns. For example, four hurricanes between 2002 and 2005 are often cited in reference to rapid erosion of the Chandeleur Islands, a chain of low-lying islands in Louisiana where the 1991 IPPC tallied more than 350 piping plovers. Comparison of imagery taken 3 years before and several days after Hurricane Katrina found that the Chandeleur Islands lost 82 percent of their surface area (Sallenger et al. 2009), and a review of aerial photography prior to the 2006 IPPC suggested little piping plover habitat remained (Elliott-Smith et al. 2009). However, Sallenger et al. (2009) noted that habitat changes in the Chandeleur Islands stem not only from the effects of these storms, but rather from the combined effects of the storms, long-term (*i.e.*, greater than 1,000 years) diminishing sand supply, and sea-level rise relative to the land. Sallenger et al. (2009) went on to explain that although the marsh platform of the Chandeleur Islands continued to erode for 22 months post-Katrina, some sand was released from the marsh sediments which in turn created beaches, spits, and welded swash bars that advanced the shoreline seaward. Thus, although intense erosional forces have affected the Chandeleur Islands, they are still providing high quality shorebird habitat in the form of sand flats, spits, and beaches, until they are eroded below sea level. On January 18 and 19, 2011, piping plover surveys of the Chandeleur Islands were conducted by the piping plover NRDAR study team. Catlin et al. (2011) observed 194 piping plovers utilizing the Chandeleur Islands, and the birds were not distributed uniformly across the islands, but were clumped mostly in three locations. Because the survey was conducted within a two-day window, Catlin et al. (2011) believe that higher numbers of piping plovers are likely using the islands during spring and fall migration.

Other storm-induced adverse effects include post-storm acceleration of human activities such as beach nourishment, sand scraping, and berm and seawall construction. Such stabilization activities can result in the loss and degradation of feeding and resting habitats. Storms also can cause widespread deposition of debris along beaches. Removal of debris often requires large machinery, which can cause extensive disturbance and adversely affect habitat elements such as wrack.

Recent climate change studies indicate a trend toward increasing hurricane numbers and intensity (Emanuel 2005; Webster et al. 2005). When combined with predicted effects of sea-level rise, there may be increased cumulative impacts from future storms. Storms can create or enhance piping plover habitat while causing localized losses elsewhere in the wintering and migration range. Available information suggests that some birds may have resiliency to storms and move to unaffected areas without harm, while other reports suggest birds may perish from storm events. Significant concerns include disturbance to piping plovers and habitats during cleanup of debris along shorelines and post-storm acceleration of shoreline stabilization activities, which can cause persistent habitat degradation and loss.

Wrack removal and beach cleaning

Wrack on beaches and baysides provides important foraging and roosting habitat for piping plovers (Drake 1999a; Smith 2007; Lott et al. 2009; Maddock et al. 2009) and many other shorebirds on their winter, breeding, and migration grounds. Because shorebird numbers are

positively correlated with wrack cover and biomass of their invertebrate prey that feed on wrack (Tarr and Tarr 1987; Dugan et al. 2003; Hubbard and Dugan 2003), beach grooming has been shown to decrease bird abundance (Defeo et al. 2009).

There is increasing popularity along developed beaches in the Southeast, especially in Florida, for beach communities to carry out "beach cleaning" and "beach raking" actions. Beach cleaning occurs on private beaches, where piping plover use is not well documented, and on some municipal or county beaches that are used by piping plovers. Most wrack removal on state and federal lands is limited to post-storm cleanup and does not occur regularly.

Man-made beach cleaning and raking machines effectively remove seaweed, fish, glass, syringes, plastic, cans, cigarettes, shells, stone, wood, and virtually any unwanted debris (Barber Beach Cleaning Equipment 2009). These efforts remove accumulated wrack, topographic depressions, and sparse vegetation nodes used by roosting and foraging piping plovers. Removal of wrack also eliminates a beach's natural sand-trapping abilities, further destabilizing the beach. In addition, sand adhering to seaweed and trapped in the cracks and crevices of wrack is removed from the beach. Although the amount of sand lost due to single sweeping actions may be small, it adds up considerably over a period of years (Nordstrom et al. 2006; Neal et al. 2007). Beach cleaning or grooming can result in abnormally broad unvegetated zones that are inhospitable to dune formation or plant colonization, thereby enhancing the likelihood of erosion (Defeo et al. 2009).

We estimate that 240 of 825 mi (29 percent) of sandy beach shoreline in Florida are cleaned or raked on various schedules (*i.e.*, daily, weekly, monthly) (Florida Department of Environmental Protection 2008). Service biologists estimate that South Carolina mechanically cleans approximately 34 of its 187 shoreline mi (18 percent), and Texas mechanically cleans approximately 20 of its 367 shoreline mi (5.4 percent). In Louisiana, beach raking occurs on Grand Isle (the state's only inhabited island) along approximately 8 mi of shoreline, roughly 2 percent of the state's 397 sandy shoreline mi.

Tilling beaches to reduce soil compaction, as sometimes required by the Service for sea turtle protection after beach nourishment activities, also has similar impacts. Recently, the Service improved sea turtle protection provisions in Florida; these provisions now require tilling, when needed, to be above the primary wrack line, not within it.

Threats summary

A review of threats to piping plovers and their habitat in their migration and wintering range shows a continuing loss and degradation of habitat due to sand placement projects, inlet stabilization, sand mining, groins, seawalls and revetments, dredging of canal subdivisions, invasive vegetation, and wrack removal. This cumulative habitat loss is, by itself, a major threat to piping plovers, as well as the many other shorebird species competing with them for foraging resources and roosting habitats in their non-breeding range. In addition, artificial shoreline stabilization impedes the processes by which coastal habitats adapt to storms and accelerating sea level rise, thus setting the stage for compounding future losses. Furthermore, inadequate

management of increasing numbers of beach recreationists reduces the functional suitability of coastal migration and wintering habitat and increases pressure on piping plovers and other shorebirds depending upon a shrinking habitat base. Experience during the Deepwater Horizon oil spill illustrates how, in addition to the direct threat of contamination, spill response activities can result in short- and long-term effects on habitat and disturb piping plovers and other shorebirds. If climate change increases the frequency and magnitude of severe weather events, this may pose an additional threat. The best available information indicates that other threats are currently low, but vigilance is warranted, especially in light of the potential to exacerbate or compound effects of very significant threats from habitat loss and degradation and from increasing human disturbance.

Ongoing Conservation Efforts

Continued partnerships and long term planning among state and federal agencies, landowners, towns and beachgoers are vital to the plover's future. Conservation measures underway to protect the piping plover include recognition, research, protective management, requirements for federal protection, and prohibitions against certain practices.

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Table 1. The number of adult piping plovers and breeding pairs reported in the U.S. Northern Great Plains by the IPPC efforts (Plissner and Haig 1997; Ferland and Haig 2002; Elliot-Smith et al. 2009, 2015).

YEAR	ADULTS	PAIRS REPORTED BY THE CENSUS
1991	2,023	891
1996	1,599	586
2001	1,981	899
2006	2,959	1,213
2011	1,237	418

Table 2. Results of the 1991, 1996, 2001, and 2006, 2011 IPPCs of wintering birds (Haig et al. 2005; Elliott-Smith et al. 2009, 2015).

Location	1991	1996	2001	2006	2011
Virginia	Not surveyed	Not surveyed	Not surveyed	1	1
North Carolina	20	50	87	84	43
South Carolina	51	78	78	100	86
Georgia	37	124	111	212	63
Florida	551	375	416	454	306
-Atlantic	*70*	*31*	*111*	*133*	*223*
-Gulf	*481*	*344*	*305*	*321*	*83*
Alabama	12	31	30	29	38
Mississippi	59	27	18	78	88
Louisiana	750	398	511	226	**86**[1]
Texas	1,904	1,333	1,042	2,090	2,145
Puerto Rico	0	0	6	Not surveyed	2
U.S. Total	3,384	2,416	2,299	3,355	2,858
Mexico	27	16	Not surveyed	76	30
Bahamas	29	17	35	417	1,066
Cuba	11	66	55	89	19
Other Caribbean Islands	0	0	0	28	Not surveyed
GRAND TOTAL	**3,451**	**2,515**	**2,389**	**3,884**	**3,973**
Percent (%) of Total International Piping Plover Breeding Census	62.9	42.4	40.2	48.2	

[1]Data from Louisiana is incomplete due to the Deepwater Horizon oil spill.

Table 3. Percent of known piping plover winter and migration habitat locations, by state, where various types of anthropogenic disturbance have been reported.

	Percent by State							
Disturbance Type	AL	FL	GA	LA	MS	NC	SC	TX
Pedestrians	67	92	94	25	100	100	88	54
Dogs on leash	67	69	31	25	73	94	25	25
Dogs off leash	67	81	19	25	73	94	66	46
Bikes	0	19	63	25	0	0	28	19
All-terrain vehicle	0	35	0	25	0	17	25	30
Off-road vehicle	0	21	0	25	0	50	31	38
Boats	33	65	100	100	0	78	63	44
Kite surfing	0	10	0	0	0	33	0	0