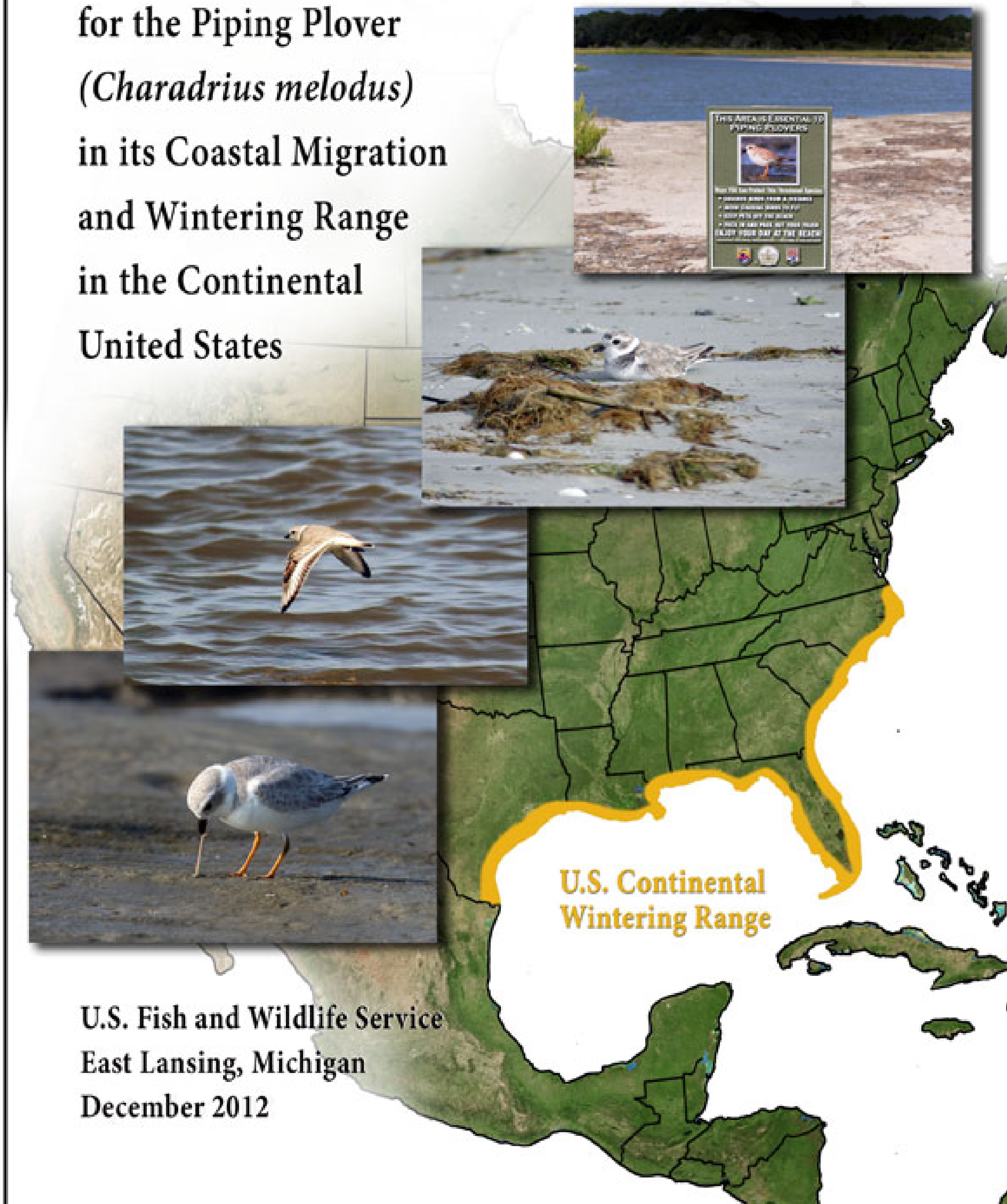
Comprehensive Conservation Strategy for the Piping Plover *(Charadrius melodus)* in its Coastal Migration and Wintering Range in the Continental United States



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PURPOSE AND GEOGRAPHIC SCOPE OF THIS STRATEGY

This Comprehensive Conservation Strategy (CCS) synthesizes conservation needs across the shared coastal migration and wintering ranges of the federally listed Great Lakes (endangered), Atlantic Coast (threatened), and Northern Great Plains (threatened) piping plover (*Charadrius melodus*) populations. The U.S. Fish and Wildlife Service's 2009 5-Year Review recommended development of the CCS to enhance collaboration among recovery partners and address widespread habitat loss and degradation, increasing human disturbance, and other threats in the piping plover's coastal migration and wintering range. The 2010 Deepwater Horizon oil spill further increased concerns regarding piping plover conservation in the nonbreeding portion of the range. This CCS provides a unified summary of the biology, habitat, and threats to nonbreeding piping plovers. It also identifies the planning, coordination, protection, and research actions needed to reduce threats to nonbreeding piping plovers and their habitat. The CCS is intended to serve as an integrated resource for biologists, land managers, regulators, and others seeking to conserve nonbreeding piping plovers.

The primary geographic focus of this CCS is the U.S. coastal nonbreeding range of the piping plover from North Carolina to Texas. While we recognize that piping plover protection in Mexico and the Caribbean is very important, this document only provides cursory information about the non-U.S. wintering range. Piping plover conservation actions in other countries are strongly encouraged, and parallel planning documents may be warranted. Current information indicates that piping plovers do not concentrate in large numbers or make extended stopovers at inland migration sites outside of their breeding range. Conservation planning for inland migration habitats, currently considered a lower priority, can be re-evaluated if existing or foreseeable threats during inland migration are identified.

RELATIONSHIP OF THIS STRATEGY TO RECOVERY PLANS

Implementation of actions described in this CCS will support attainment of relevant reclassification and delisting criteria contained in approved USFWS piping plover recovery plans (USFWS 1988b, 1996, 2003). The pertinent recovery plan tasks are listed in the introduction to each recommended action in this strategy. Information summarized in this document may also inform improvement of criteria in future recovery plan revisions, including the revised recovery plan for the Northern Great Plains population (in progress in 2012). Likewise, experience with implementation of actions associated with the CCS may guide updated estimates of time and cost to achieve reclassification or delisting in the future.

ACKNOWLEDGMENTS

Hundreds of biologists from all levels of government, non-governmental organizations, and academic institutions, as well as unaffiliated individuals have provided important information reflected in this conservation strategy. Although they are too many to name individually, we cannot overstate the value of their generous contributions. We also recognize the collective on-going efforts to conserve piping plovers throughout their range.

* * *

DISCLAIMER: This document describes actions to address threats and conservation needs for piping plovers. It does not obligate any party to undertake specific actions and may not represent the views or the official positions or approval of any individuals or agencies involved in piping plover recovery.

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PART I: INTRODUCTION

The piping plover is a small shorebird that breeds in three geographic regions of North America. These demographically independent populations are confirmed to be of two separate subspecies (AOU 1945, 1957[1]; Miller et al. 2010). Piping plovers that breed on the Atlantic Coast of the United States (U.S.) and Canada belong to the subspecies *Charadrius melodus melodus*. The second subspecies, *C. m. circumcinctus*, comprises two populations. One population breeds on the Northern Great Plains[2] of the U.S. and Canada, while the other breeds in the Great Lakes watershed (USFWS 2009d). The shared wintering range of the three populations extends along the U.S. Atlantic and Gulf Coasts from North Carolina to Texas and into Mexico, the Bahamas, and West Indies (Elliott-Smith and Haig 2004, Elliott-Smith et al. 2009).

In January 1986, the piping plover was listed under the provisions of the U.S. Endangered Species Act (ESA) as endangered in the Great Lakes watershed of both the U.S. and Canada, and as threatened in the remainder of its range (USFWS 1985). All piping plovers are classified as threatened on their shared migration and wintering range outside the watershed of the Great Lakes. However, U.S. Fish and Wildlife Service (USFWS) biological opinions prepared under section 7 of the ESA acknowledge that activities affecting wintering and migrating plovers differentially influence the survival and recovery of the three breeding populations. Furthermore, the 2009 5-Year Review found that the best available scientific information supports recognition of three separate entities consistent with the ESA definition of "species," with *C. m. melodus* breeding on the Atlantic Coast and two distinct population segments (DPSs), Great Lakes and Northern Great Plains, within *C. m. circumcinctus* (see Figure 1) (USFWS 2009d).

In Canada, the Canadian Committee on the Status of Endangered Wildlife currently recognizes *C. m. melodus* and *C. m. circumcinctus* as separate taxa and designates each subspecies as "Endangered" (Department of Justice Canada 2002). This supersedes 1978 and 1985 designations assigned to the entire Canadian population of piping plovers (COSEWIC 2001). Canadian recovery strategies for both subspecies recognize the importance of conserving migration and wintering habitat (Environment Canada 2006, 2012). Canadian piping plover breeding sites identified as critical habitat receive legal protections under the Species at Risk Act (Environment Canada 2007, 2012).

In 2001, critical habitat was designated for the breeding population in the U.S. Great Lakes region (USFWS 2001a), while a separate rule determined critical habitat for the U.S. portion of the Northern Great Plains breeding population in 2002 (USFWS 2002a). No critical habitat has been proposed or

[1] The 1957 checklist provides the American Ornithologists' Union's most recent treatment of subspecies.

[2] USFWS documents use "Northern Great Plains" in reference to the piping plover population that breeds from Alberta, Canada to Colorado in the U.S. (Figure 1), but Canadian documents and some scientific literature refer to *C. m. circumcinctus* in that country as the "Prairie Canada population." "U.S. Northern Great Plains" is used as appropriate to denote just the portion of the population breeding south of the international boundary.

designated for the Atlantic Coast breeding population, but the needs of all three breeding populations were considered in the 2001 critical habitat designation for wintering piping plovers (USFWS 2001b) and in subsequent re-designations (USFWS 2008g, 2009e).

Figure 1. Distribution and range[3] of *C. m. melodus*, Great Lakes distinct population segment (DPS) of *C. m. circumcinctus*, and Northern Great Plains DPS of *C. m. circumcinctus* as delineated in the USFWS 2009 5-Year Review (base map from Elliott-Smith and Haig 2004, used by permission of Birds of North America Online).

Critical habitat for wintering piping plovers currently comprises 141 units totaling 256,513 acres along the coasts of North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas. The original designation included 142 areas (the rule erroneously states 137 units) encompassing approximately 1,798 miles of mapped shoreline and 165,211 acres of mapped areas (USFWS 2001b). A revised designation for four North Carolina units was published in 2008 (USFWS 2008g). Eighteen revised Texas critical habitat units were designated in 2009, replacing 19 units that were vacated and remanded by a 2006 court order (USFWS 2009e). Designated areas include habitats that support roosting, foraging, and sheltering activities of piping plovers.

[3] Conceptual presentation of subspecies and DPS ranges are not intended to convey precise boundaries.

The USFWS has approved recovery plans for the three breeding populations: the threatened Atlantic Coast population (USFWS 1988a, USFWS 1996), the endangered Great Lakes population (USFWS 1988b, USFWS 2003), and the threatened Northern Great Plains population, which is addressed in a combined plan with the Great Lakes population[4] (USFWS 1988b). A separate revised Northern Great Plains recovery plan is under development in 2012. All the plans recognize that survival and recovery of piping plovers are dependent on the continued availability of sufficient habitat in their coastal migration and wintering range, where the species spends more than two-thirds of its annual cycle. Progress towards recovery, attained primarily through intensive protections designed to increase productivity on the breeding grounds, would quickly be diminished or reversed by even small decreases in survival rates or fecundity due to stress experienced during migration and wintering periods (Roche et al. 2010). Accordingly, the recovery plans provide recovery criteria to address threats in the nonbreeding portion of the species' range. Relevant criteria are described below.

- Criterion 3 of the 2003 Great Lakes recovery plan, which is required for reclassification of the Great Lakes breeding population from endangered to threatened listing status, is to ensure protection and long-term maintenance of essential breeding habitat in the Great Lakes region and wintering habitat, sufficient in quantity, quality, and distribution to support the recovery goal of 150 pairs. Delisting, as described in Criterion 5, will additionally require that agreements and funding mechanisms are in place to ensure long-term protection and management in essential breeding and wintering habitat (and to prevent reversal of the population increases). Essential wintering habitat is defined as all areas where Great Lakes banded piping plovers have been reported in the winter (USFWS 2003).

- Recovery Criterion 5 of the 1996 Atlantic Coast recovery plan requires long-term maintenance of wintering habitat, sufficient in quantity, quality, and distribution to maintain survival rates for a 2,000-pair Atlantic Coast breeding population (USFWS 1996).

- Criterion B of the 1988 Northern Great Plains recovery plan states that essential breeding and wintering habitat will be protected (USFWS 1988b).

Information pertaining to the life history, status, and threats to piping plovers in their breeding range is provided in the recovery plans and in the 2009 5-Year Review (USFWS 1988b, 1996, 2003, 2009d).

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[4] Because the sections of this plan that pertain to the Great Lakes population have been superseded by the 2003 recovery plan, the 1988 plan is generally referred to as the Northern Great Plains Piping Plover Recovery Plan, a convention that we follow in this document.

BIOLOGY, ECOLOGY, AND HABITAT PREFERENCES OF NONBREEDING PIPING PLOVERS

Description

The piping plover, named for its melodic call, is a small North American shorebird approximately 17 centimeters (7 inches) long with a wingspan of about 38 cm (15 in) and weighing 40-65 grams (1.4-2.3 oz) (Palmer 1967, Elliot-Smith and Haig 2004). Adult piping plovers can arrive on wintering grounds with partial breeding plumage remaining (a single black breastband, which is often incomplete, and a black bar across the forehead). During the late summer or early autumn, the birds lose the black bands, the legs fade from orange to pale yellow, and the bill turns from orange and black to mostly black (see Figure 2). Most adults begin their molt into breeding plumage before northward migration and complete the molt before arrival on their breeding sites. Piping plover subspecies are considered phenotypically indistinguishable, although slight clinal breeding plumage variations between populations have been noted (Elliot-Smith and Haig 2004).

Figure 2. Adult breeding plumage (left) and nonbreeding plumage (right).

Temporal and Spatial Distribution

Piping plovers spend up to 10 months of their annual cycle on their migration and winter grounds, typically from 15 July through 15 May (Elliott-Smith and Haig 2004, Noel et al. 2007, Stucker et al. 2010). Southward migration from the breeding grounds primarily occurs from July to September, with the majority of birds initiating migration by the end of August (USFWS 1996, USFWS 2003). However, the New Jersey Division of Fish and Wildlife documented sustained presence of low numbers of piping plovers at several sites through October 2011 (C. Davis, New Jersey Division of Fish and Wildlife, pers. comm. 2012). Piping plovers depart the wintering grounds as early as mid-February and as late as mid-May, with peak migration in March (Haig 1992). In their analysis of 10 years of band sightings, Stucker et al. (2010) found that wintering adult males and females from the Great Lakes population exhibit latitudinal segregation. Female plovers arrived on the winter grounds before males and returned later to breeding sites. Second year birds arrived latest on the breeding grounds, rarely appearing on the breeding grounds before the third week of May (Stucker et al. 2010).

Routes of migration and habitat use overlap breeding and wintering habitats and, unless the birds are banded, migrants passing through a site are indistinguishable from breeding or wintering piping plovers. Coastal migration stopovers of plovers banded in the Great Lakes region have been documented in New Jersey, Maryland, Virginia, North Carolina, South Carolina and Georgia (Stucker et al. 2010). Migrating birds from eastern Canada have been observed in Massachusetts, New Jersey, New York, and North Carolina (Amirault et al. 2005). Piping plovers banded in the Bahamas have been sighted during migration in nine Atlantic Coast states and provinces between Florida and Nova Scotia (C. Gratto-Trevor, Environment Canada, pers. comm. 2012a). In general, the distance between stopover locations and the duration of stopovers throughout the coastal migration range remain poorly understood.

International Piping Plover Winter Censuses, which began in 1991, have been conducted during mid-winter at five-year intervals across the species' range (see Table 1; results of 2011 census not yet available). Total numbers have fluctuated over time, with some areas increasing while other areas showed declines. Regional and local fluctuations may reflect changes in the quantity and quality of suitable foraging and roosting habitat, which vary in response to natural coastal formation processes as well as anthropogenic habitat changes (e.g., inlet relocation, dredging of shoals and spits). See, for example, discussions of survey number changes in Mississippi, Louisiana, and Texas in Elliott-Smith et al. (2009). Fluctuations may also reflect localized weather conditions during surveys or different survey coverage; for example, changes in wind-driven tides can cause large rapid shifts in the distribution of piping plovers on the Texas Laguna Madre (Zonick 2000). In another example, Cobb (*in* Elliott-Smith et al. 2009) notes that use of airboats during the 1991 and 2006 censuses facilitated greater coverage in central Texas than in 1996 and 2001, when airboats were not used and counts were lower. Changes in wintering numbers within a given area may also be influenced by growth or decline in particular breeding populations.

Increased survey effort in the Bahamas since approximately 2006 resulted in dramatic increases in wintering population estimates. More than 1,000 birds were counted in the Bahamas during the 2011 International Piping Plover Winter Census (E. Elliott-Smith, U.S. Geological Survey, pers. comm. 2012a), compared to 417 birds in 2006 and 35 birds in 2001. Additional habitat in the Bahamas remains to be surveyed, as do many other sites in the Caribbean. Piping Plovers have been reported from Nicaragua, St. Vincent and the Grenadines, Turks and Caicos Islands, and St. Croix (L. Schibley, Manomet Center for Conservation Science, pers. comm. 2011, and C. Lombard, USFWS, pers. comm. 2010), but follow-up is needed to determine where and in what numbers piping plovers were seen and if the sites are used regularly.

Table 1. Results of the 1991, 1996, 2001, and 2006 international piping plover winter censuses (Haig et al. 2005, Elliott-Smith et al. 2009) and preliminary 2011 results (Elliott-Smith pers. comm. 2012b).

Location	Number of piping plovers				
	1991	**1996**	**2001**	**2006**	**2011 (preliminary)**
Virginia	ns[a]	ns	ns	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*	*83*
-Gulf	*481*	*344*	*305*	*321*	*223*
Alabama	12	31	30	29	38
Mississippi	59	27	18	78	88
Louisiana	750	398	511	226	86
Texas	1,904	1,333	1,042	2,090	2,145
Puerto Rico	0	0	6	ns	2
U.S. Total	**3,384**	**2,416**	**2,299**	**3,355**	**2,858**
Mexico	27	16	ns	76	30
Bahamas	29	17	35	417	1066
Cuba	11	66	55	89	19
Other Caribbean Islands	0	0	0	28	2
GRAND TOTAL	**3,451**	**2,515**	**2,389**	**3,884**	**3,975**

[a] ns = not surveyed

Survey timing and intensity affect abundance estimates and the ability to detect local movements of nonbreeding piping plovers. Mid-winter surveys (such as the International Census) may substantially underestimate the number of nonbreeding piping plovers using a site or region during other months. Along the central Texas Gulf Coast, Pinkston (2004) observed much heavier use of ocean-facing beaches between early September and mid-October (approximately 16 birds per mile) than during the period from December to March (approximately two birds per mile). Zdravkovic and Durkin (2011) reported a similar pattern in southern Texas. In late September, 2007, 104 piping plovers were counted at the south end of Ocracoke Island, North Carolina (NPS 2007), where none were seen during the 2006 International Piping Plover Winter Census (Elliott-Smith et al. 2009). Differences among fall, winter, and spring counts in South Carolina were less pronounced, but large inter-year fluctuations (e.g., 108 piping plovers in spring 2007 versus 174 piping plovers in spring 2008) were observed (Maddock et al. 2009). Noel et al. (2007) observed up to 100 piping plovers during peak migration and only about 40 overwintering at Little St. Simons Island, Georgia in 2003-2005. Monthly counts at Phipps Preserve in Franklin County, Florida ranged from a mid-winter low of four piping plovers in December 2006 to peak counts of 47 in October 2006 and March 2007 (Smith 2007). Zdravkovic and Durkin (2011) attributed substantially higher counts during surveys in the Lower Laguna Madre, Texas in 2010 compared with the 2006 International Census (881 plovers versus 459 plovers) to more complete survey coverage.

Abundance estimates for nonbreeding piping plovers may also be affected by the number of surveyor visits to the site. A preliminary analysis found 87% detection during the mid-winter period at South Carolina sites surveyed three times a month during fall and spring and one time per month during winter, compared with 42% detection at sites surveyed only three times per year (J. Cohen, Virginia Tech, pers. comm. 2009, review of data by Maddock et al. 2009).

Gratto-Trevor et al. (2012) found distinct patterns (but no exclusive partitioning) in winter distribution of banded piping plovers from four breeding areas (Figure 3). Resightings of more than 700 uniquely marked birds from 2001 to 2008 were used to analyze winter distributions along the Atlantic and Gulf Coasts. Plovers from eastern Canada and most Great Lakes birds wintered from North Carolina to Southwest Florida. However, eastern Canada birds were more heavily concentrated in North Carolina, while a larger proportion of Great Lakes piping plovers were found in South Carolina, Georgia, and Florida. This pattern is consistent with analysis of band sightings of Great Lakes plovers from 1995-2005 by Stucker et al. (2010). Gratto-Trevor et al. (2012) also found that Northern Great Plains populations were primarily seen farther west and south, especially on the Texas Gulf Coast. The majority of birds from the Canadian Prairie were observed in Texas (particularly southern Texas), while individuals from the U.S. Great Plains were more widely distributed on the Gulf Coast from Texas to Florida. Seventy-nine percent of 57 piping plovers banded in the Bahamas in 2010 have been reported breeding on the Atlantic Coast, and none have been resighted at interior locations (preliminary results, Gratto-Trevor pers. comm. 2012a). However, consistent with patterns observed in other parts of the wintering range, a few banded individuals from the Great Lakes and Northern Great Plains populations have been observed in the Bahamas (Gratto-Trevor pers. comm. 2012b, D. Catlin, Virginia Polytechnic Institute, pers. comm. 2012a). Collectively, these studies demonstrate an intermediate level of connectivity between breeding and wintering areas. Specific breeding populations will be disproportionately affected by habitat and threats occurring where they are most concentrated in the winter.

Survival

Population viability analyses (PVAs) conducted for piping plovers (Ryan et al. 1993, Melvin and Gibbs 1996, Plissner and Haig 2000, Wemmer et al. 2001, Larson et al. 2002, Calvert et al. 2006, Brault 2007, McGowan and Ryan 2009) all demonstrate the sensitivity of extinction risk in response to small declines in adult and/or juvenile survival rates. These results further emphasize the importance of nonbreeding habitat to species recovery (Roche et al. 2010). Poor overwintering and stopover habitat has been shown to have a negative effect on survival of other shorebird species, which contributed to breeding population declines (Gill et al. 2001, Baker et al. 2004, Morrison and Hobson 2004).

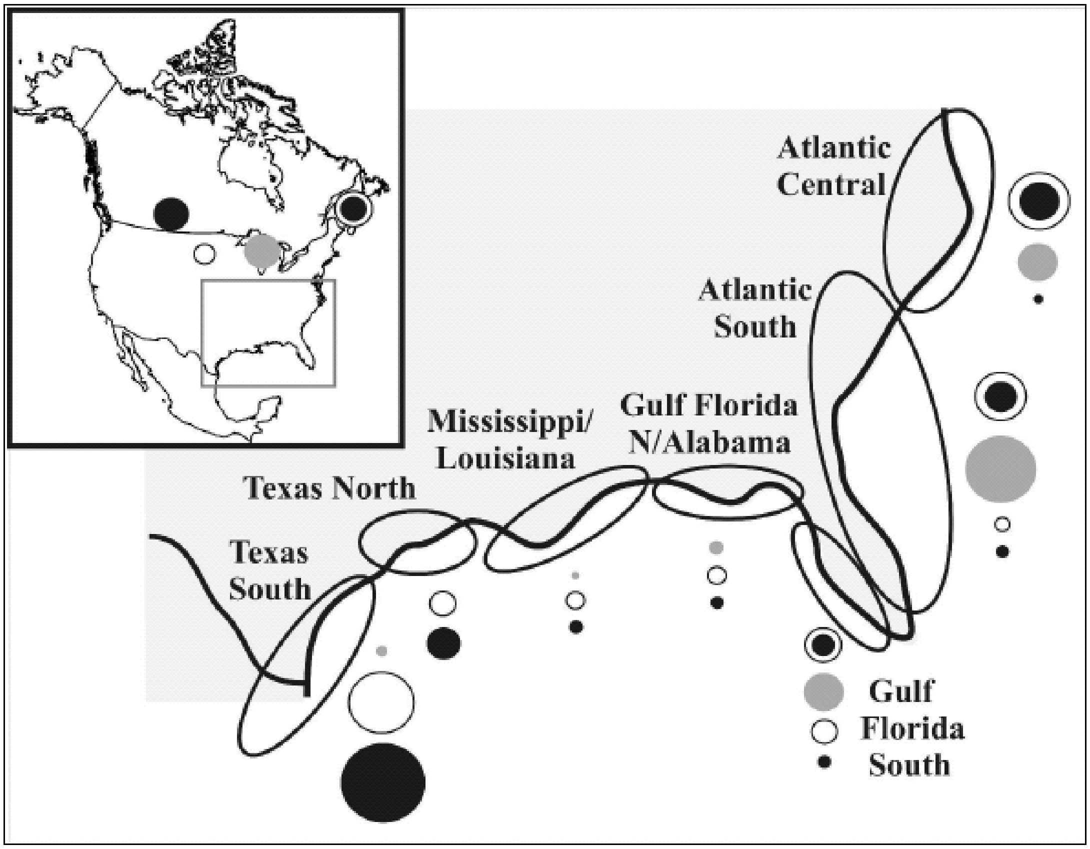

Figure 3. The winter distribution in the continental U.S. of piping plovers from four breeding locations (inset), including eastern Canada (white circle with central black dot), Great Lakes (gray circle), U. S. Northern Great Plains (white circle), and Prairie Canada (black circle). The wintering range is expanded to the right, divided into different wintering regions. The size of the adjacent circles relative to the others represents the percentage of individuals from a specific breeding area reported in that wintering region (from Gratto-Trevor et al. 2012; reproduced by permission).

There is limited information specific to survival rates during the nonbreeding portion of the annual cycle. Drake et al. (2001) observed no mortality among 49 radio-marked piping plovers (total of 2,704 transmitter-days) in Texas in the 1990s. Cohen et al. (2008) also reported no mortality among a small sample (n=7) of radio-marked piping plovers at Oregon Inlet, North Carolina in 2005-2006. Analysis of resighting data for 87 banded piping plovers observed in South Carolina during 2006-2007 and 2007-

2008 found 100% survival from December to April[5] (J. Cohen, pers. comm. 2009). At Little St. Simons Island, Georgia, Noel et al. (2007) inferred two winter mortalities among 21 banded (but not radio-tagged) overwintering piping plovers in 2003-2004, and nine mortalities among 19 overwintering birds during the winter of 2004-2005. In a study of 150 after-hatch-year Great Lakes piping plovers, LeDee (2008) found higher apparent survival[6] rates during breeding and southward migration than during winter and northward migration.

Analysis of piping plover mark-recapture data by Roche et al. (2010) found that after-hatch-year apparent survival declined in four of their seven study populations. They found evidence of correlated year-to-year fluctuations in annual survival among populations wintering primarily along the southeastern U.S. Atlantic Coast, as well as indications that shared overwintering or stopover sites may influence annual variation in survival among geographically disparate breeding populations. Additional mark-resighting analysis of color-banded individuals across piping plover breeding populations has the potential to shed light on threats that may affect survival in the migration and wintering range, and also to further elucidate survival within the annual cycle (Cohen 2009, Roche et al. 2010).

Habitat Use

Wintering piping plovers utilize a mosaic of habitat patches and move among these patches in response to local weather and tidal conditions (Nicholls and Baldassarre 1990a, Nicholls and Baldassarre 1990b, Drake et al. 2001, Cohen et al. 2008). Preferred coastal habitats include sand spits, small islands, tidal flats, shoals (usually flood tidal deltas), and sandbars that are often associated with inlets (Nicholls and Baldassarre 1990b, Harrington 2008, Addison 2012). Sandy mud flats, ephemeral pools, seasonally emergent seagrass beds, mud/sand flats with scattered oysters, and overwash fans are considered primary foraging habitats (Nicholls and Baldassarre 1990b, Cohen et al. 2008). A South Carolina study strongly links plover habitat use to the abundance of key invertebrate taxa (SCDNR 2011). Plovers vary their use of ocean beaches and bay shorelines and flats in Texas depending on season and in response to weather conditions (Zdravkovic and Durkin 2011, Zonick 2000).

Studies in North Carolina, South Carolina, Texas, and Florida complement earlier investigations of the habitat use patterns (Zivojnovich and Baldassarre 1987, Johnson and Baldassarre 1988, Nicholls and Baldassarre 1990a and 1990b, Fussell 1990, Drake et. al. 2001). Nonbreeding piping plovers in North Carolina primarily used sound (bay or bayshore) beaches and sound islands for foraging. On ocean beaches they exhibited roosting, preening, and alert behaviors (Cohen et al. 2008). The probability of piping plovers being present on the sound islands increased as exposure of the intertidal areas increased

[5] However, two of those birds were seen in the first winter and resighted in the second fall, but were not seen during the second winter (Maddock et al. 2009).

[6] "Apparent survival" does not account for permanent emigration. If marked individuals leave a survey site, apparent survival rates will be lower than true survival. If a survey area is sufficiently large, such that emigration out of the site is unlikely, apparent survival will approach true survival.

(Cohen et al. 2008). Maddock et al. (2009) also observed shifts in roosting habitats and behaviors during high-tide periods in South Carolina. Similar patterns in Gulf Coast studies confirm high plover numbers on Gulf beaches during migration (July-October) and when wind conditions inundate bayside flats (Zdravkovic and Durkin 2011, Pinkston 2004, Zonick 2000).

Several studies identified wrack (organic material including seaweed, seashells, driftwood, and other materials deposited on beaches by tidal action) as an important component of roosting habitat for nonbreeding piping plovers[7]. Lott et al. (2009b) found that more than 90% of roosting piping plovers in southwest Florida were roosting in old wrack. In South Carolina, 45% of roosting piping plovers were in old wrack, and 18% were in fresh wrack (Maddock et al. 2009). Thirty percent of roosting piping plovers in northwest Florida were observed in wrack substrates (Smith 2007). In Texas, seagrass debris (bayshore wrack) was found to be an important feature of piping plover roost sites (Drake 1999a).

Intertidal areas provide key foraging habitats. Exposed intertidal areas were the dominant foraging substrate, both in South Carolina (accounting for 94% of observed foraging piping plovers; Maddock et al. 2009) and in northwest Florida (96% of foraging observations; Smith 2007). In southwest Florida, Lott et al. (2009b) found approximately 75% of foraging piping plovers on intertidal substrates with bay beaches (bay shorelines as opposed to ocean-facing beaches) as the most common landform used by foraging piping plovers. In northwest Florida, however, Smith (2007) reported that landform use by foraging piping plovers was almost equally divided between Gulf (ocean-facing) and bay beaches. Zonick (2000) found dietary differences across the range of piping plovers in Texas, with plovers along the northern Texas coast feeding predominantly on polychaetes while those observed further south largely fed on insects and other arthropods.

Atlantic and Gulf Coast studies highlighted the importance of inlets for nonbreeding piping plovers. Almost 90% of observations of roosting piping plovers at ten coastal sites in southwest Florida were on inlet shorelines (Lott et al. 2009b). In an evaluation of 361 International Shorebird Survey sites from North Carolina to Florida (Harrington 2008), piping plovers were among seven shorebird species found more often than expected ($p = 0.0004$; Wilcoxon Scores test) at inlet versus non-inlet locations. Wintering plovers on the Atlantic Coast prefer wide beaches in the vicinity of inlets (Nicholls and Baldassarre 1990b, Wilkinson and Spinks 1994). At inlets, foraging plovers are associated with moist substrate features such as intertidal flats, algal flats, and ephemeral pools (Nicholls and Baldassarre 1990b, Wilkinson and Spinks 1994, Dinsmore et al. 1998, Addison 2012).

In South Carolina, multivariate analyses showed that many of the taxa responsible for the temporal changes in composition of the invertebrate community at occupied foraging sites were also responsible for the changes associated with site abandonment by piping plovers (SCDNR 2011). This suggests that

[7] Wrack also contains invertebrate organisms consumed by piping plovers and other shorebirds.

taxa changes in the diets of migratory and overwintering piping plovers were occurring both within individual foraging sites (leading to subsequent site-abandonment) and within the larger Kiawah Island/Bird Key system, potentially contributing to declines in the overwintering population. The study further suggests that larger, errant polychaetes such as the families Nereididae, Glyceridae, and Oenonidae may be particularly important to piping plover overwintering in this region. Consequently, habitat changes, whether natural or anthropogenic in origin, that affect polychaete densities may also affect overwintering populations of the piping plover (SCDNR 2011).

Geographic analysis of piping plover distribution on the upper Texas coast noted major concentration areas in washover passes (low, sparsely vegetated barrier island habitats created and maintained by temporary, storm-driven water channels) and at the mouths of rivers feeding into major bay systems (Arvin 2008). Earlier studies in Texas indicated the importance of washover passes or fans which were commonly used by piping plovers during periods of high bayshore tides and during the spring migration period (Zonick 1997, Zonick 2000). Surveys of the Lower Laguna Madre in Texas found piping plovers using both Gulf beach and bayside areas during the fall 2009 migratory period. These include Gulf beaches, inlet shorelines, bay shorelines of barrier islands, shorelines of islands in the bay (natural and dredged-material), mainland bay shorelines, tidal flats and other habitats such as isolated "pools" of evaporating water also associated with bay habitats. A clear shift from Gulf beaches to bay habitats occurred during the wintering period, as well as during certain wind and weather conditions (Zdravkovic and Durkin 2011). Piping plovers have also been observed in high numbers on seasonally emergent seagrass beds and oyster-studded mud flats in several central Texas coastal bays (Cobb *in* Elliott-Smith et al. 2009).

Winter Site Fidelity

Piping plovers exhibit a high degree of intra- and inter-annual fidelity to wintering areas, which often encompass several relatively nearby sites (Drake et al. 2001, Noel and Chandler 2008, Stucker et al. 2010). Gratto-Trevor et al. (2012) found little movement between or among regions (as defined in Figure 3), and reported that 97% of the birds they surveyed remained in the same region, often at the same beach. Only six of 259 banded piping plovers were observed more than once per winter moving across boundaries of seven U.S. regions. Of 216 birds observed in multiple years, only eight changed regions between years, and several of these shifts were associated with late summer or early spring migration periods (Gratto-Trevor et al. 2012). Although many sites on the northern Gulf Coast of Texas and in Louisiana were affected by hurricanes after the 2008 fall migration, none of the 17 birds known to have wintered in these areas before the hurricane and resighted afterward moved from their original areas (Gratto-Trevor et al. 2012).

The areas used by wintering piping plovers often comprise habitats on both sides of an inlet, nearby sandbars or shoals, and ocean and bayside shorelines. In South Carolina, Maddock et al. (2009)

documented many movements back and forth across inlets by color-banded piping plovers, as well as occasional movements of up to 18 km by approximately 10% of the banded population. Similarly, eight banded piping plovers that were observed in two locations during the 2006-2007 surveys in Louisiana and Texas were all in close proximity to their original location, such as on the bay and ocean side of the same island or on adjoining islands (Maddock 2008).

The mean-average home-range size for 49 radio-marked piping plovers in southern Texas in 1997-1998 was 12.6 km^2; the mean core area was 2.9 km^2; and the mean linear distance moved between successive locations, averaged across seasons, was 3.3 km (Drake et al. 2001). Seven radio-tagged piping plovers used a 20.1 km^2 area at Oregon Inlet, North Carolina, in 2005-2006, and piping plover activity was found to be concentrated in 12 areas totaling 2.2 km^2 that were located on both sides of the inlet (Cohen et al. 2008). Noel and Chandler (2008) also observed high site fidelity of banded piping plovers to 1-4.5 km sections of beach on Little St. Simons Island, Georgia.

Intra- and Inter-specific Interactions

Piping plovers are often found in association with other shorebird species during the nonbreeding season, as many shorebird species utilize the southern Atlantic and Gulf Coasts for migration and wintering (Nicholls and Baldassarre 1990b, Eubanks 1992, Helmers 1992). Migrating and wintering piping plovers often roost close to conspecifics, as well as in multi-species flocks (Nicholls and Baldassarre 1990b, Zonick and Ryan 1993, Elliott and Teas 1996, Drake 1999a). During foraging, however, territorial and agonistic interactions with other piping plovers and with similar-sized plover species, including semipalmated and snowy plovers, are relatively common (Johnson and Baldassarre 1988, Zonick and Ryan 1993, Elliott and Teas 1996, Drake 1999a). Burger et al. (2007) observed competition for foraging space among shorebird species foraging in Delaware Bay, especially between shorebirds and larger gulls. Intra- and inter-specific competition for foraging habitat may be increased by continuing habitat loss and degradation, as well as by disturbance due to human recreation, forcing some piping plovers to forage or roost in suboptimal habitats and thereby affecting their energetic budgets. Shorebirds require extensive fat reserves to complete migrations. Birds with less than maximum fat reserves are expected to show reduced survival rates (Brown et al. 2001).

KEY THREATS TO PIPING PLOVERS IN THEIR COASTAL MIGRATION AND WINTERING RANGE

This section summarizes information on current and projected threats to piping plovers in their coastal migration and wintering range. Recommended actions to address each threat are provided in Part III, Conservation Strategy (see pages 51-87).

LOSS, MODIFICATION, AND DEGRADATION OF HABITAT

The wide, flat, sparsely vegetated barrier beaches, spits, sandbars, and bayside flats preferred by piping plovers in the U.S. are formed and maintained by natural forces and are thus susceptible to degradation caused by development and shoreline stabilization efforts. As described below, barrier island and beachfront development, inlet and shoreline stabilization, inlet dredging, beach maintenance and nourishment activities, seawall installations, and mechanical beach grooming continue to alter natural coastal processes throughout the range of migrating and wintering piping plovers. Dredging of inlets can affect spit formation adjacent to inlets, as well as ebb and flood tidal shoal formation. Jetties stabilize inlets and cause island widening and subsequent vegetation growth on the updrift inlet shores; they also cause island narrowing and/or erosion on the downdrift inlet shores. Seawalls and revetments restrict natural island movement and exacerbate erosion. Although dredge and fill projects that place sand on beaches and dunes may restore lost or degraded habitat in some areas, in other areas these projects may degrade habitat quality by altering the natural sediment composition, depressing the invertebrate prey base, hindering habitat migration with sea level rise, and replacing the natural habitats of the dune-beach-nearshore system with artificial geomorphology. Construction of any of these projects during months when piping plovers are present also causes disturbance that disrupts the birds' foraging and roosting behaviors. These threats are exacerbated by accelerating sea level rise, which increases erosion and habitat loss where existing development and hardened stabilization structures prevent the natural migration of the beach and/or barrier island. Although threats from sea level rise are discussed on pages 29-31, its specific synergistic effects on threats from coastal development and artificial coastal stabilization are also described in the pertinent subsections, below.

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, bayside development can replace foraging habitat with finger canals, bulkheads, docks and lawns. High-value plover habitat becomes fragmented as lots are developed or coastal roads are built between oceanside and bayside habitats. Development activities can 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; these 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.

At present, there are approximately 2,119 miles of sandy beaches within the U.S. continental wintering range of the piping plover (Table 2). Approximately 40% (856 miles) of these sandy beaches are developed, with mainland Mississippi (80%), Florida (57%), Alabama (55%), South Carolina (51%), and North Carolina (49%) comprising the most developed coasts, and Mississippi barrier islands (0%), Louisiana (6%), Texas (14%) and Georgia (17%) the least developed (Appendix 1c). As discussed further below (see pages 29-31), developed beaches are highly vulnerable to further habitat loss because they cannot migrate in response to sea level rise.

Several studies highlight concerns about adverse effects of development and coastline stabilization on the quantity and quality of habitat for migrating and wintering piping plovers and other shorebirds. For example, Zdravkovic and Durkin (2011) observed fewer plovers on the developed portions of the Laguna and Gulf beach sides of South Padre Island than on undeveloped portions during both migratory and wintering surveys. Drake et al. (2001) observed that radio-tagged piping plovers overwintering along the southern Laguna Madre of Texas seldom used tidal flats adjacent to developed areas (five of 1,371 relocations of radio-marked individuals), suggesting that development and associated anthropogenic disturbances influence piping plover habitat use. Detections of piping plovers during repeated surveys of the upper Texas coast in 2008 were low in areas with significant beach development (Arvin 2008).

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 are channels cut into a barrier island or peninsula from the soundside to increase the number of waterfront residential lots. 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).

Rice (2012b) has identified over 900 miles (43%) of sandy beaches in the wintering range that are currently “preserved” through public ownership, ownership by non-governmental conservation organizations, or conservation easements (Table 2). 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, they are the areas most likely to maintain the geomorphic characteristics of suitable piping plover habitat.

Table 2. The lengths and percentages of sandy oceanfront beach in each state that are developed, undeveloped, and preserved as of December 2011 (Appendix 1c).

State	Approximate Shoreline Beach Length (miles)	Approximate Miles of Beach Developed (percent of total shoreline length)	Approximate Miles of Beach Undeveloped (percent of total shoreline length)[a]	Approximate Miles of Beach Preserved (percent of total shoreline length)[b]
North Carolina	326	159 (49%)	167 (51%)	178.7 (55%)
South Carolina	182	93 (51%)	89 (49%)	84 (46%)
Georgia	90	15 (17%)	75 (83%)	68.6 (76%)
Florida	809	459 (57%)	351 (43%)	297.5 (37%)
-Atlantic	*372*	*236 (63%)*	*136 (37%)*	*132.4 (36%)*
-Gulf	*437*	*223 (51%)*	*215 (49%)*	*168.0. (38%)*
Alabama	46	25 (55%)	21 (45%)	11.2 (24%)
Mississippi barrier island coast	27	0 (0%)	27 (100%)	27 (100%)
Mississippi mainland coast	51[c]	41 (80%)	10 (20%)	12.6 (25%)
Louisiana	218	13 (6%)	205 (94%)	66.3 (30%)
Texas	370	51 (14%)	319 (86%)	152.7 (41%)
TOTAL	**2,119**	**856 (40%)**	**1,264 (60%)**	**901.5 (43%)**

[a] Beaches classified as "undeveloped" occasionally include a few scattered structures.
[b] Preserved beaches include public ownership, ownership by non-governmental conservation organizations, and conservation easements. The miles of shoreline that have been preserved generally overlap with the miles of undeveloped beach but may also include some areas (e.g., in North Carolina) that have been developed with recreational facilities or by private inholdings.
[c] The mainland Mississippi coast along Mississippi Sound includes 51.3 miles of sandy beach as of 2010-2011, out of approximately 80.7 total shoreline miles (the remaining portion is non-sandy, either marsh or armored coastline with no sand). See Appendix 1c for details.

In summary, approximately 40% of the sandy beach shoreline in the migration and wintering range is already developed, while 43% are largely preserved. This means, however, that the remaining 17% of shoreline habitat (that which is currently undeveloped but not preserved) is susceptible to future loss to development and the attendant threats from shoreline stabilization activities and sea level rise[8].

Dredging and Sand Mining

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 such as those in Alabama and Mississippi, can significantly alter the natural coastal processes on inlet shorelines of nearby barrier islands, as described by Otvos (2006), Morton (2008), Otvos and Carter (2008), Beck and Wang (2009), and Stockdon et al. (2010). Cialone and Stauble (1998) describe the impacts of mining ebb shoals within inlets as a source of beach fill material at eight locations and provide a recommended monitoring protocol for future mining events; Dabees and Kraus (2008) also describe the impacts of ebb shoal mining in southwest Florida.

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 (Table 3). States where more than two-thirds of inlets have been dredged include Alabama (three of four), Mississippi (four of six), North Carolina (16 of 20), and Texas (13 of 18), and 16 of 21 along the Florida Atlantic coast. 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.

Among the dredged inlets identified in Rice (2012a), dredging efforts began as early as the 1800s and continue to the present, generating long-term and even permanent effects on inlet habitat; at least 11 inlets were first dredged in the 19^{th} century, with the Cape Fear River (North Carolina) being dredged as early as 1826 and Mobile Pass (Alabama) in 1857. Dredging can occur on an annual basis or every two to three years, resulting in continual perturbations and modifications to inlet and adjacent shoreline habitat. The volumes of sediment removed can be major, with 2.2 million cubic yards (mcy) of sediment removed on average every 1.9 years from the Galveston Bay Entrance (Texas) and 3.6 mcy of sediment removed from Sabine Pass (Texas) on average every 1.4 years (USACE 1992).

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[8] See chapters 1 and 2 in Titus (2011) for a detailed discussion of the relationship between shoreline development and sea level rise.

Table 3. The number of open tidal inlets, inlet modifications, and artificially closed inlets in each state as of December 2011 (Appendix 1b).

State	Existing Inlets							Artificially closed
	Number of Inlets	Total Number of Modified Inlets	Habitat Modification Type					
			structures[a]	dredged	relocated	mined	artificially opened	
North Carolina	20	17 (85%)	7	16	3	4	2	11
South Carolina	47	21 (45%)	17	11	2	3	0	1
Georgia	23	6 (26%)	5	3	0	1	0	0
Florida *-Atlantic*	21	19 (90%)	19	16	0	3	10	0
Florida *-Gulf*	48	24 (50%)	20	22	0	6	7	1
Alabama	4	4 (100%)	4	3	0	0	0	2
Mississippi	6	4 (67%)	0	4	0	0	0	0
Louisiana	34	10 (29%)	7	9	1	2	0	46
Texas	18	14 (78%)	10	13	2	1	11	3
TOTAL	221	119 (54%)	89 (40%)	97 (44%)	8 (4%)	20 (9%)	30 (14%)	64 (N/A)

[a] Structures include jetties, terminal groins, groin fields, rock or sandbag revetments, seawalls, and offshore breakwaters.

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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). This is a problem because exposed ebb and flood tidal shoals and sandbars are prime roosting and foraging habitats for piping plovers. In general, such areas are only accessible by boat; and as a result, they tend to receive less human recreational use than nearby mainland beaches. Rice (2012a) found that the ebb shoal complexes of at least 20 inlets within the wintering range of the piping plover have been mined for beach fill. 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 (2012a) noted that this 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 remove massive amounts of sediment, with 1.98 mcy mined for beach fill from Longboat Pass (Florida) in 1998, 1.7 mcy from Shallotte Inlet (North Carolina) in 2001 and 1.6 mcy from Redfish Pass (Florida) in 1988 (Cialone and Stauble 1998, USACE 2004). 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% recovered after five years; they conclude 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 of the deposition of dredged material, and the available information is inconsistent. Drake et al. (2001) concluded that the conversion of bayshore tidal flats of southern Texas mainland to dredged material impoundments results in a net loss of habitat for wintering piping plovers because such impoundments eventually convert to upland habitat. Zonick et al. (1998) reported that dredged material placement areas along the Gulf Intracoastal Waterway in Texas were rarely used by piping plovers, and noted concern that dredge islands block the wind-driven water flows that are critical to maintaining important shorebird habitats. Although Zdravkovic and Durkin (2011) found 200 piping plovers on the Mansfield Channel dredge material islands during a survey in late 2009, none were counted there in early 2011. By contrast, most of the sound islands where Cohen et al. (2008) found foraging piping plovers at Oregon Inlet, North Carolina were created by the U.S. Army Corps of Engineers from dredged material. Another example is Pelican Island, in Corpus Christi Bay, Texas, where dredged material is consistently used by piping plovers (R. Cobb, USFWS, pers. comm. 2012a). Research is needed to understand why piping plovers use some dredge material islands, but are not regularly found using many 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; maintenance dredging conducted annually or every few years may prevent full recovery of the inlet system. 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 (2012a) noted that the adverse impacts of this threat to piping plovers may be mitigated, however, by eliminating dredging and mining activities in inlet complexes with high habitat value, extending the interval between dredging cycles, discharging dredged material in nearshore 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.

Inlet Stabilization and Relocation

Many navigable tidal inlets along the Atlantic and Gulf coasts are stabilized with hard structures. A description of the different types of stabilization structures typically constructed at or adjacent to inlets – jetties, terminal groins, groins, seawalls, breakwaters and revetments – can be found in Appendix 1a as well in the *Manual for Coastal Hazard Mitigation* (Herrington 2003, available online) and in *Living by the Rules of the Sea* (Bush et al. 1996).

The adverse direct and indirect impacts of hard stabilization structures at inlets and inlet relocations can be significant. The impacts of jetties on inlet and adjacent shoreline habitat have been described by Cleary and Marden (1999), Bush et al. (1996, 2001, 2004), Wamsley and Kraus (2005), USFWS (2009a), Thomas et al. (2011), and many others. The relocation of inlets or the creation of new inlets often leads to immediate widening of the new inlet and loss of adjacent habitat, among other impacts, as described by Mason and Sorenson (1971), Masterson et al. (1973), USACE (1992), Cleary and Marden (1999), Cleary and Fitzgerald (2003), Erickson et al. (2003), Kraus et al. (2003), Wamsley and Kraus (2005) and Kraus (2007).

Rice (Appendix 1b) found that, as of 2011, an estimated 54% of 221 mainland or barrier island tidal inlets in the U.S continental wintering range of the piping plover had been modified by some form of hardened structure, dredging, relocation, mining, or artificial opening or closure (Table 3). On the Atlantic Coast, 43% of the inlets have been stabilized with hard structures, whereas 37% were stabilized on the Gulf Coast. The Atlantic coast of Florida has 17 stabilized inlets adjacent to each other, extending between the St. John's River in Duval County and Norris Cut in Miami-Dade County, a distance of 341 miles. A shorebird would have to fly nearly 344 miles between unstabilized inlets along this stretch of coast.

The state with the highest proportion of natural, unmodified inlets is Georgia (74%). The highest number of adjacent unmodified, natural inlets is the 15 inlets found in Georgia between Little Tybee Slough at Little Tybee Island Nature Preserve and the entrance to Altamaha Sound at the south end of Wolf Island National Wildlife Refuge, a distance of approximately 54 miles. Another relatively long stretch of adjacent unstabilized inlets is in Louisiana, where 17 inlets between a complex of breaches on the West Belle Pass barrier headland (in Lafourche Parish) and Beach Prong (near the western boundary of the state Rockefeller Wildlife Refuge) have no stabilization structures; one of these inlets (the Freshwater Bayou Canal), however, is dredged (Appendix 1b).

Unstabilized inlets naturally migrate, reforming important habitat components over time, particularly during a period of rising sea level. Inlet stabilization with rock jetties and revetments alters the dynamics of longshore sediment transport and the natural movement and formation of inlet habitats such as shoals, unvegetated spits and flats. Once a barrier island becomes “stabilized” with hard structures at inlets, natural overwash and beach dynamics are restricted, allowing encroachment of new vegetation on the bayside that replaces the unvegetated (open) foraging and roosting habitats that plovers prefer. Rice (2012a) found that 40% (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.

Relocation of tidal inlets also can cause loss and/or degradation of piping plover habitat. Although less permanent than construction of hard structures, the effects of inlet relocation can persist for years. For example, December-January surveys documented a continuing decline in wintering plover numbers from 20 birds pre-project (2005-2006) to three birds during the 2009 - 2011 seasons (SCDNR 2011). Subsequent decline in the wintering population on Kiawah is strongly correlated with the decline in polychaete worm densities, suggesting that plovers emigrated to other sites as foraging opportunities in these habitats became less profitable (SCDNR 2011). At least eight inlets in the migration and wintering range have been relocated; a new inlet was cut and the old inlet was closed with fill. In other cases, inlets have been relocated without the old channels being artificially filled (Table 3 and Appendix 1b).

The artificial opening and closing of inlets typically creates very different habitats from those found at inlets that open or close naturally (Rice 2012a). Rice (2012a) found that 30 inlets have been artificially created within the migration and wintering range of the piping plover, including 10 of the 21 inlets along the eastern Florida coast (Table 3). These artificially created inlets tend to need hard structures to remain open or stable, with 20 of the 30 (67%) of them having hard structures at present. An even higher number of inlets (64) have been artificially closed, the majority in Louisiana (Table 3). One inlet in Texas was closed as part of the Ixtoc oil spill response efforts in 1979 and 32 were closed as part of Deepwater Horizon oil spill response efforts in 2010-2011. Of the latter, 29 were in Louisiana, two in Alabama and one in Florida. To date only one of these inlets, West (Little Lagoon) Pass in Gulf Shores, Alabama, has been reopened, and the rest remain closed with no plans to reopen any of those identified by Rice (2012a). Most other artificial inlet closures in Louisiana are part of barrier island restoration projects, because much of that state’s barrier islands are disintegrating (Otvos 2006, Morton 2008, Otvos and Carter 2008). Inlets closed during coastal restoration projects in Louisiana are purposefully designed to approximate low, wide naturally closed inlets and to allow overwash in the future. By contrast, most artificially closed inlets have higher elevations and tend to have a constructed berm and dune system. Overwash may occur periodically at a naturally closed inlet but is prevented at an artificially closed inlet by the constructed dune ridge, hard structures, or sandbags (Rice 2012a).

The construction of jetties, groins, seawalls and revetments at inlets leads to habitat loss and both direct and indirect impacts to adjacent shorelines. Rice (2012a) found that these structures result in long-term effects, with at least 13 inlets across six of the eight states having hard structures initially constructed in the 19th century. The cumulative effects are ongoing and increasing in intensity, with hard structures built as recently as 2011 and others proposed for 2012. With sea level rising and global climate change altering storm dynamics, pressure to modify the remaining half of sandy tidal inlets in the range is likely to increase, notwithstanding that this would be counterproductive to the climate change adaptation strategies recommended by the USFWS (2010d), CCSP (2009), Williams and Gutierrez (2009), Pilkey and Young (2009), and many others.

Groins

Groins pose an ongoing threat to piping plover beach habitat within the continental wintering range. Groins are hard structures built perpendicular to the shoreline (sometimes in a T-shape), designed to trap sediment traveling in the littoral drift and to slow erosion on a particular stretch of beach or near an inlet. “Leaky” groins, also known as permeable or porous groins, are low-crested structures built like typical groins but which allow some fraction of the littoral drift or longshore sediment transport to pass through the groin. They have been used as terminal groins near inlets or to hold beach fill in place for longer durations. Although groins can be individual structures, they are often clustered along the shoreline in “groin fields.” Because they intentionally act as barriers to longshore sand transport, groins cause downdrift erosion, which degrades and fragments sandy beach habitat for the piping plover and other wildlife. 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 are present at 28 of 221 sandy tidal inlets (Appendix 1b). Leaky terminal groins have been installed at the south end of Amelia Island, Florida, the west end of Tybee Island, Georgia, and the north end of Hilton Head Island, South Carolina. Permeable or leaky groins have also been constructed on the beaches of Longboat Key and Naples, Florida, and terminal groins were approved in 2011 for use in up to four inlet locations in North Carolina (reversing a nearly 30-year prohibition on hard stabilization structures in that state).

Although most groins were in place before the piping plover’s 1986 ESA listing, new groins continue to be installed, perpetuating the threat to migrating and wintering piping plovers. Two groins were built in South Carolina between 2006 and 2010, bringing the statewide total to 165 oceanfront groins (SC DHEC 2010). Eleven new groins were built in Florida between 2000 and 2009. The East Pass Navigation Project in Okaloosa County, Florida (USFWS 2009a) illustrates the negative impacts to plover habitat that can be associated with groins, which are often built as one component of a much larger shoreline or inlet stabilization project. The East Pass Navigation Project includes two converging jetties, one with a groin at the end, with dredged material placed on either side to stabilize the jetties; minimal piping plover foraging habitat remains due to changed inlet morphology. 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.

Seawalls and Revetments

Seawalls and revetments are hard vertical structures built parallel to the beach in front of buildings, roads, and other facilities[9]. Although they are intended to protect human infrastructure from erosion, these armoring structures often accelerate erosion by causing scouring both in front of and downdrift from the structure, which can eliminate intertidal plover foraging 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 composition of benthic communities that serve as the prey base for piping plovers (see *Loss of Macroinvertebrate Prey Base due to Shoreline Stabilization*, on page 25-27). Dugan and Hubbard (2006) found in a California study that intertidal zones were narrower and fewer in the presence of armoring, armored beaches had significantly less macrophyte wrack, and shorebirds responded with significantly lower abundance (more than three times lower) and species richness (2.3 times lower) than on adjacent unarmored beaches. As sea level rises, seawalls will prevent the coastline from moving inland, causing loss of intertidal foraging habitat (Galbraith et al. 2002, Defeo et al. 2009). Geotubes (long cylindrical bags made of high-strength permeable fabric and filled with sand) are less permanent alternatives, but they prevent overwash and thus the natural production of sparsely vegetated habitat.

Rice (2012b, Appendix 1c) found that at least 230 miles of beach habitat has been armored with hard erosion-control structures[10]. Data were not available for all areas, so this number is a minimum estimate of the length of habitat that has been directly modified by armoring. Out of 221 inlets surveyed, 89 were stabilized with some form of hard structure, of which 24 had revetments or seawalls along their shorelines (Appendix 1c). The Texas coast is armored with nearly 37 miles of seawalls, bulkheads and revetments, the mainland Mississippi coast has over 45 miles of armoring, the Florida Atlantic coast has at least 58 miles, and the Florida Gulf coast over 59 miles (Rice 2012b). Shoreline armoring has modified plover beachfront habitat in all states, but Alabama (4.7 miles), Georgia (10.5 miles) and Louisiana (15.9 miles) have the fewest miles of armored beaches.

Although North Carolina has prohibited the use of hard erosion-control structures or armoring since 1985[11] the "temporary" installation of sandbag revetments is allowed. As a result the precise length of armored sandy beaches in North Carolina is unknown, but at least 350 sandbag revetments have been

[9] See page 19 for references describing these stabilization structures.
[10] Although Rice (2012b) included jetties and groins in this inventory, structures that are perpendicular to the shoreline comprised a very small proportion of the armored shoreline; seawalls and revetments predominated.
[11] In 2011 North Carolina made a further exception for authorization of up to four terminal groins.

constructed (Rice 2012b). South Carolina also limits the installation of some types of new armoring but already has 24 miles (27% of the developed shoreline or 13% of the entire shoreline) armored with some form of shore-parallel erosion-control structure (SC DHEC 2010).

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.

Sand Placement Projects

Sand placement projects threaten the piping plover and its habitat by altering the natural, dynamic coastal processes that create and maintain beach strand and bayside habitats, including the habitat components that piping plovers rely upon. Although specific impacts vary depending on a range of factors, so-called “soft stabilization” projects may directly degrade or destroy roosting and foraging habitat in several ways. Beach habitat may be converted to an artificial berm that is densely planted in grass, which can in turn 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 overwash that creates and maintains sparsely vegetated roosting habitats. The growth of vegetation resulting from impeding the natural overwash can also reduce the availability of bayside intertidal feeding habitats.

Overwash is an essential process, necessary to maintain the integrity of many barrier islands and to create new habitat (Donnelly et al. 2006). In a study on the Outer Banks of North Carolina, Smith et al. (2008) found that human “modifications to the barrier island, such as construction of barrier dune ridges, planting of stabilizing vegetation, and urban development, can curtail or even eliminate the natural, self-sustaining processes of overwash and inlet dynamics.” They also found that such modifications led to island narrowing from both oceanside and bayside erosion. Lott (2009) found a strong negative correlation between ocean shoreline sand placement projects and the presence of piping and snowy plovers in the Panhandle and southwest Gulf Coast regions of Florida[12].

Sand placement projects threaten migration and wintering habitat of the piping plover in every state throughout the range (Rice 2012b, Table 4). At least 684.8 miles (32%) of sandy beach habitat in the continental wintering range of the piping plover have received artificial sand placement via dredge disposal activities, beach nourishment or restoration, dune restoration, emergency berms, inlet bypassing,

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[12] Lott (2009) noted that sand placement projects may directly degrade plover habitat, but they may also correlate with high human density, where disturbance is higher.

inlet closure and relocation, and road reconstruction projects. In most areas, sand placement projects are in developed areas or adjacent to shoreline or inlet hard stabilization structures in order to address erosion, reduce storm damages, or ameliorate sediment deficits caused by inlet dredging and stabilization activities.

The beaches along the mainland coast of Mississippi are the most modified by sand placement activities with at least 85% affected (Table 4). Of the oceanfront beaches, the Atlantic coast of Florida has had the highest proportion (at least 51%) of beaches modified by sand placement activities. Approximately 47% of Florida's sandy beach coastline has received sand placement of some type, with many areas receiving fill multiple times from dredge disposal, emergency berms, beach nourishment, dune restoration and other modifications (Rice 2012b).

In Louisiana, the sustainability of the coastal ecosystem is threatened by the inability of the barrier islands to maintain geomorphologic functionality. The state's coastal systems are starved for sediment sources (USACE 2010). Consequently, most of the planned sediment placement projects in Louisiana are conducted as environmental restoration projects by various federal and state agencies because without the sediment many areas would erode below sea level. Several Louisiana Coastal Wetland Planning, Protection, and Restoration Act projects have been constructed on portions of undeveloped islands within the Terrebonne Basin to restore and maintain the diverse functions of those barrier island habitats (USFWS 2010a). Altogether over 60 miles of sandy beaches have been modified with sand placement projects in Louisiana, both through restoration projects and in response to the Deepwater Horizon oil spill (Rice 2012b).

Table 4. Approximate shoreline miles of sandy beach that have been modified by sand placement activities for each state in the U.S. continental wintering range of the piping plover as of December 2011. These totals are minimum numbers, given missing data for some areas (Appendix 1c).

State	Known Approximate Miles of Beach Receiving Sand	Proportion of Modified Sandy Beach Shoreline
North Carolina	91.3	28%
South Carolina	67.6	37%
Georgia	5.5	6%
Florida Atlantic coast	189.7	51%
Florida Gulf coast	189.9	43%
Alabama	7.5	16%
Mississippi barrier island coast	1.1	4%
Mississippi mainland coast	43.5	85%
Louisiana	60.4	28%
Texas	28.3	8%
TOTAL	**684.8+**	**32%**

Both the number and the size of sand projects along the Atlantic and Gulf coasts are increasing (Trembanis et al. 1998), and these projects are increasingly being chosen as a means to combat sea level rise and related beach erosion problems (Klein et al. 2001). Lott et al. (2009a) documented an increasing trend in sand placement events in Florida (Figure 4). In northwest Florida, the USFWS consulted on first-time sand placement projects along 46 miles of shoreline in 2007-2008. Much of this work was authorized on public lands (Gulf Islands National Seashore [USFWS 2007a], portions of St. Joseph State Park [USFWS 2007b], and at Eglin Air Force Base [USFWS 2008a]). Throughout the plover migration and wintering range, the number of sand placement events has increased every decade for which records are available, with at least 710 occurring between 1939 and 2007, and more than 75% occurring since 1980 (PSDS 2011). The cumulative volume of sand placed on East Coast beaches has risen exponentially since the 1920s (Trembanis et al. 1998). As a result, sand placement projects increasingly pose threats to plover habitat. As of 2011, at least 32% (~ 685 miles) of the sandy beaches in the continental wintering range have had one or more sand placement projects.

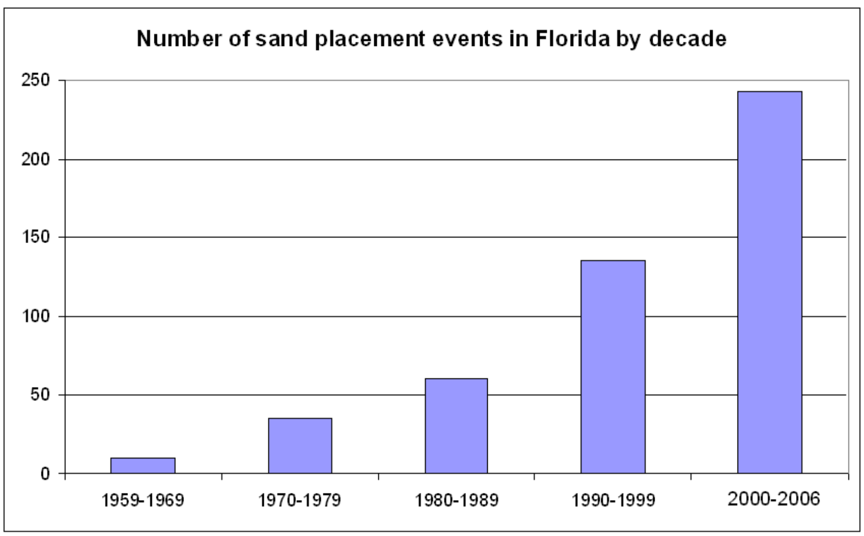

Figure 4. Number of sand placement events per decade in Florida between 1959-1999, and 2000-2006 (from Lott et al. 2009a).

Loss of Macroinvertebrate Prey Base 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 1996).

The quality and quantity of the macroinvertebrate prey base is threatened by shoreline stabilization activities, including the approximately 685 miles of 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. Although some benthic species can burrow through a thin layer of additional sediment (38-89 cm for different species), thicker layers (i.e., >1 meter) are likely to smother these sensitive benthic organisms (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 six months to two 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. For example, SCDNR (2011) found the decline in piping plovers to be strongly correlated with a decline in polychaete densities on the east end of Kiawah Island, South Carolina, following an inlet relocation project in 2006. Similar results were documented on Bird Key, South Carolina, in 2006 when rapid habitat changes occurred within the sheltered lagoon habitat following dredge disposal activities, and piping plovers shifted to more exposed areas. Their diet also appeared to have shifted to haustoriid amphipods, based on analysis of fecal samples containing pieces of *Neohaustorius schmitzi*, *Lepidactylus dytiscus*, and *Acanthohaustorius* sp., which were also found during the invertebrate sampling in both locations (SCDNR 2011).

Shoreline armoring with hard stabilization structures such as seawalls and revetments can also 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 up to millions of cubic yards of new sediment, and grade the new beach and intertidal zone with heavy equipment to conform to a predetermined topographic profile. This can lead to compaction of the sediment (Nelson et al. 1987, USACE 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, Appendix 1a) has identified several conservation measures that can avoid and minimize some of the known impacts.

Invasive Vegetation

The spread of invasive plants into suitable wintering piping plover habitat is a relatively recently identified threat (USFWS 2009d). Such plants tend to reproduce and spread quickly and to exhibit dense growth habits, often outcompeting native plants. Uncontrolled invasive plants can shift habitat 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 invasive species to spread, and their tenacity once established, make them a persistent threat that is only 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). Hundreds of beach vitex occurrences and targeted eradication efforts in North and South Carolina and a small number of known locations in Georgia and Florida are discussed in the 5-Year Review (USFWS 2009d). Crowfootgrass (*Dactyloctenium aegyptium*), which grows invasively along portions of the Florida coastline, forms thick bunches or mats that can change the vegetative structure of coastal plant communities and thus alter shorebird habitat (USFWS 2009d, Florida Exotic Pest Plant Council 2009). Australian pine (*Casuarina equisetifolia*) affects piping plovers and other shorebirds by encroaching on foraging and roosting habitat (Stibolt 2011); it may also provide perches for avian predators. Japanese sedge *(Carex kobomugi),* which aggressively encroaches into sand beach habitats (USDA plant profile website), was documented in Currituck County, North Carolina, in the mid-1970s and as recently as 2003 on Currituck National Wildlife Refuge (J. Gramling, Department of Biology, The Citadel, pers. comm. 2011), at two sites where migrating piping plovers have also been documented. Early detection and rapid response are the keys to controlling this and other invasive plants (R. Westbrooks, U.S. Geological Survey, pers. comm. 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.

Wrack Removal and Beach Cleaning

Wrack on beaches and baysides provides important foraging and roosting habitat for piping plovers (Drake 1999a, Smith 2007, Maddock et al. 2009, Lott et al. 2009b; see also discussion of piping plover use of wrack substrates on page 10 in *Habitat Use*) and for many other shorebirds. Because shorebird numbers are positively correlated both with wrack cover and the biomass of their invertebrate prey that feed on wrack (Tarr and Tarr 1987, Hubbard and Dugan 2003, Dugan et al. 2003), beach grooming has been shown to decrease bird numbers (Defeo et al. 2009).

It is increasingly common for beach-front communities to carry out "beach cleaning" and "beach raking" activities. Beach cleaning is conducted on private beaches, where piping plover use is not well documented, and on some municipal or county beaches used by piping plovers. Most wrack removal on state and federal lands is limited to post-storm cleanup and does not occur regularly. Wrack removal and beach raking both occur on the Gulf beach side of the developed portion of South Padre Island in the Lower Laguna Madre in Texas, where plovers have been documented during both the migratory and wintering periods (Zdravkovic and Durkin 2011). Wrack removal and other forms of beach cleaning have been the subject of formal consultations between the U.S. Army Corps of Engineers, municipalities, and USFWS in Neuces County, Texas (USFWS 2008e, 2009c).

Although beach cleaning and raking machines effectively remove human-made debris, these efforts also remove accumulated wrack, topographic depressions, emergent foredunes and hummocks, and sparse vegetation nodes used by roosting and foraging piping plovers (Nordstrom 2000, Dugan and Hubbard 2010). Removal of wrack also reduces or eliminates natural sand-trapping, further destabilizing the beach. Cathcart and Melby (2009) found that beach grooming and raking beaches "fluffs the sand" whereas heavy equipment compacts the sand below the top layer; the fluffed sand is then more vulnerable to erosion by storm water runoff and wind. These authors found that beach raking and grooming practices on mainland Mississippi beaches "exacerbate the erosion process and shorten the time interval between renourishment projects" (Cathcart and Melby 2009). Furthermore, the sand adhering to seaweed and trapped in the cracks and crevices of wrack also is lost to the beach when the wrack is removed. Although the amount of sand lost during a single sweeping activity may be small, over a period of years this loss could be significant (Neal et al. 2007).

Tilling beaches to reduce soil compaction, which is sometimes required by the USFWS for sea turtle protection after beach nourishment activities, has similar impacts to those described above. In northwest Florida, tilling on public lands is currently conducted only if the land manager determines that it is necessary. Where tilling is needed, adverse effects are reduced by Florida USFWS sea turtle protection provisions that require tilling to be above the primary wrack line, rather than within it.

As of 2009, the Florida Department of Environmental Protection's Beaches and Coastal Management Systems section had issued 117 permits allowing multiple entities to conduct beach raking or cleaning operations. The Florida Department of Environmental Protection estimated that 240 of 825 miles (29%) of sandy beach shoreline in Florida are cleaned or raked on varied schedules, i.e., daily, weekly, monthly (L. Teich, Florida DEP, pers. comm. 2009). Beach cleaning along 45 miles of coastline in Nueces, Kleberg, and Cameron Counties in Texas was addressed in five USFWS biological opinions completed between 2008 and 2012 (Cobb pers. comm. 2012c).

Dugan and Hubbard (2010), studying beach grooming activities on the beaches and dunes of southern California, concluded that "beach grooming has contributed to widespread conversion of coastal strand ecosystems to unvegetated sand" by removing wrack cover, increasing the transport of windblown sediment, lowering the seed bank and the survival and reproduction of native plants, and decreasing native plant abundance and richness. They argue that conserving beach ecosystems by reducing beach grooming and raking activities "could help retain sediment, promote the formation of dunes, and maintain biodiversity, wildlife, and human use in the face of rising sea level (Dugan and Hubbard 2010)."

ACCELERATING SEA LEVEL RISE AND OTHER CLIMATE CHANGE IMPACTS

Accelerating sea level rise poses a threat to piping plovers during the migration and wintering portions of their life cycle. As noted in the previous section, threats from sea level rise are tightly intertwined with artificial coastal stabilization activities that modify and degrade habitat. Potential effects of storms, which could increase in frequency or intensity due to climate change, are discussed starting on page 31. If climate change increases the frequency or magnitude of extreme temperatures (see discussion of *Severe Cold Weather*, page 33), 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.

Numerous studies have documented accelerating rise in sea levels worldwide (Rahmstorf et al. 2007, Douglas et al. 2001 as cited in Hopkinson et al. 2008, CCSP 2009, Pilkey and Young 2009, Vermeer and Rahmstorf 2009, Pilkey and Pilkey 2011). Predictions include a sea level rise of between 50 and 200 cm above 1990 levels by the year 2100 (Rahmstorf 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% of the world's coastal wetlands to open water by 2080 (IPCC 2007, CCSP 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 nearshore, and the influence of management measures such as beach nourishment, jetties, groins, and seawalls (CCSP 2009, Galbraith et al. 2002, Gutierrez et al. 2011). Sea level rise along the U.S. Gulf Coast exceeded the global average by 13-15 cm because coastal lands there are subsiding (EPA 2009). The rate of sea level rise in Louisiana is particularly high (Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority 1998). Sediment compaction and oil and gas extraction compound tectonic subsidence along the Gulf of Mexico coastline (Penland and Ramsey 1990, Morton et al. 2003, Hopkinson et al. 2008).

Low elevations and proximity to the coast make all nonbreeding 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% 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% 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, especially if those shorelines are armored with hardened structures (Brown and McLachlan 2002, Dugan and Hubbard 2006, Fish et al. 2008, Defeo et al. 2009). Overwash and sand migration are impeded on the developed portions of sandy ocean beaches (Smith et al. 2008) that comprise 40% of the U.S. nonbreeding range (Rice 2012b). As the sea level rises, the ocean-facing beaches erode and attempt to migrate inland. Buildings and artificial sand dunes then prevent sand from washing back toward the lagoons (i.e., bayside), and the lagoon side becomes increasingly submerged during extreme high tides (Scavia et al. 2002). Barrier beach shorebird habitat and natural features that protect mainland developments are both diminished as a result.

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% 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% of plover's U.S. nonbreeding range that is currently preserved from development (Rice 2012b). 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 (see pages 13-23). 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.

WEATHER EVENTS

Storm Events

Storms are an integral part of the natural processes that form coastal habitats used by migrating and wintering piping plovers, and positive effects of storm-induced overwash and vegetation removal have been noted in portions of the wintering range. For example, biologists reported piping plover use of newly created habitats at Gulf Islands National Seashore in Florida within six months of overwash events that occurred during the 2004 and 2005 hurricane seasons (M. Nicholas, Gulf Islands National Seashore, pers. comm. 2005). Hurricane Katrina created a new inlet and improved habitat conditions on some areas of Dauphin Island, Alabama, but subsequent localized storms contributed to habitat loss there (D. LeBlanc, USFWS, pers. comm. 2009) and the inlet was subsequently closed with a rock dike as part of Deepwater Horizon oil spill response efforts (Rice 2012a). 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 miles to the southwest. Piping plovers were observed later in the season using tidal lagoons and pools that Hurricane Ike created behind the eroded beaches (Arvin 2009).

Adverse effects attributed to storms alone are sometimes actually 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 International Piping Plover Winter Census (Haig and Plissner 1992) tallied more than 350 birds. Comparison of imagery taken three years before and again several days after Hurricane Katrina found that the Chandeleur Islands had lost 82% of their combined surface area (Sallenger 2010). A review of aerial photographs taken before the 2006 Census suggested that 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, and more than a thousand years of diminishing sand supply and sea level rise. Although the Chandeleur Islands marsh platform 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. Despite the effects of intense erosion, the Chandeleur Islands are still providing high quality shorebird habitat in the form of sand flats, spits, and beaches used by substantial numbers of piping plovers (Catlin et al. 2011), a scenario that could continue if restoration efforts[13] are sustainable and successful from a shorebird perspective (USACE 2010).

Storm-induced adverse effects include post-storm acceleration of human activities such as beach nourishment, sand scraping, closure of new inlets, and berm and seawall construction. As discussed on pages 19-27, such stabilization activities can result in the loss and degradation of feeding and resting habitats. Land managers sometimes face public pressure after big storm events to plant vegetation, install sandfences, and bulldoze artificial "dunes." For example, national wildlife refuge managers sometimes receive pressure from local communities to "restore" the beach and dunes following blow-outs from storm surges that create the overwash foraging habitat preferred by plovers (C. Hunter, USFWS, pers. comm. 2011a). At least 64 inlets have been artificially closed, the vast majority of them shortly after opening in storm events[14] (see Table 3). Storms also can cause widespread deposition of debris along beaches. Subsequent removal of this debris often requires large machinery that in turn can cause extensive disturbance and adversely affect habitat elements such as wrack. Challenges associated with management of public use can grow when storms increase access (e.g., merger of Pelican Island with Dauphin Island in Alabama following a 2007 storm (Gibson et. al. 2009, D. LeBlanc pers. comm. 2009)).

Some available information indicates that birds may be resilient, even during major storms, and move to unaffected areas without harm. Other reports suggest that birds may perish in or following storm events. Noel and Chandler (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 the winter mortality of three individuals. Wilkinson and Spinks (1994) suggested that low plover numbers in South Carolina in January 1990 could have been partially influenced by effects on habitat from Hurricane Hugo the previous fall, while Johnson and Baldassarre (1988) found a redistribution of piping plovers in Alabama following Hurricane Elena in 1985.

Climate change studies indicate a trend toward increasing numbers and intensity of hurricane events (Emanuel 2005, Webster et al. 2005). Combined with the predicted effects of sea level rise, this trend indicates potential for increased cumulative impact of future storms on habitat. Major storms can create or enhance piping plover habitat while causing localized losses elsewhere in the wintering and migration range.

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[13] The State of Louisiana built a sand berm along the northern end of the Chandeleur Island chain during the Deepwater Horizon oil spill response effort, restoring a sand supply to seven miles of the chain and closing approximately 11 inlets (Rice 2012b).
[14] See discussion of differences between naturally and artificially closed inlets, page 20.

Severe Cold Weather

Several sources suggest the potential for adverse effects of severe winter cold on survival of piping plovers. The Atlantic Coast piping plover 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 (weighted mean based on proportion of the population wintering near five weather stations) during the preceding winter (E. Roche, Univ. of Tulsa, pers. comm. 2010 and 2012). Catlin (pers. comm. 2012b) reported that the average mass of ten piping plovers captured in Georgia during unusually cold weather in December 2010 was 5.7 grams (g) less than the average for nine birds captured in October of the same year (46.6 g and 52.4 g, respectively; $p = 0.003$).

DISTURBANCE FROM RECREATION ACTIVITIES

Increasing human disturbance is a major threat to piping plovers in their coastal migration and wintering range (USFWS 2009d). Intense human disturbance in shorebird winter habitat can be functionally equivalent to habitat loss if the disturbance prevents birds from using an area (Goss-Custard et al. 1996). Nicholls and Baldassarre (1990a) found less people and off-road vehicles at sites where nonbreeding piping plovers were present than at sites without piping plovers. Pfister et al. (1992) implicate anthropogenic disturbance as a factor in the long-term decline of migrating shorebirds at staging areas. Disturbance can cause shorebirds to spend less time roosting or foraging and more time in alert postures or fleeing from the disturbances (Burger 1991, 1994; Elliott and Teas 1996; Lafferty 2001a, 2001b; Thomas et al. 2003). Shorebirds that are repeatedly flushed in response to disturbance expend energy on costly short flights (Nudds and Bryant 2000).

Shorebirds are more likely to flush from the presence of dogs than people, and breeding and nonbreeding shorebirds react to dogs from farther distances than people (Lafferty 2001a, 2001b; Lord et al. 2001, Thomas et al. 2003). Hoopes (1993) found that dogs flush breeding piping plovers from further distances than people and that both the distance the plovers move and the duration of their response is greater. Foraging shorebirds at a migratory stopover on Delaware Bay, New Jersey responded most strongly to dogs compared with other disturbances; shorebirds often failed to return within ten minutes after the dog left the beach (Burger et al. 2007). Dogs off-leash were disproportionate sources of disturbance in several studies (Thomas et al. 2003, Lafferty 2001b), but leashed dogs also disturbed shorebirds. Pedestrians walking with dogs often go through flocks of foraging and roosting shorebirds; some even encourage their dogs to chase birds.

Off-road vehicles can disrupt piping plover's normal behavior patterns. The density of off-road vehicles negatively correlated with abundance of piping plovers on the ocean beach in Texas (Zonick 2000). Cohen et al. (2008) found that radio-tagged wintering piping plovers using ocean beach habitat at Oregon Inlet in North Carolina were far less likely to use the north side of the inlet where off-road vehicle use was allowed. Ninety-six percent of piping plover detections occurred on the south side of the inlet even though it was more than four times farther away from foraging sites, prompting a recommendation that controlled management experiments be conducted to determine if recreational disturbance drives roost site selection (Cohen et al. 2008). Zdravkovic and Durkin (2011) stated that Laguna Madre Gulf beaches are considered part of the Texas state highway system and are severely impacted by unrestricted public recreational off-road vehicle use.

In a study of migrating shorebirds in Maryland, Forgues (2010) found that shorebird abundance declined with increased off-road vehicle frequency, as did the number and size of roosts. Migrants spent less time foraging in the presence of vehicles. In a before-after control-impact experiment, densities of three focal species were significantly reduced after a vehicle closure was lifted, while densities outside the closure zone exhibited little change; densities of two other species also decreased more in the area where the closure was removed, but the difference was not significant (Forgues 2010). In North Carolina, a before-after control-impact experiment using the undisturbed plots as the controls found that vehicle disturbance decreased abundance of shorebirds and altered their habitat use during fall migration (Tarr 2008).

Recreational activities, especially off-road vehicles, may degrade piping plover habitat. Tires that crush wrack into the sand render it unavailable as a roosting habitat or foraging substrate (Goldin 1993, Hoopes 1993). At four study beaches in New York and Massachusetts, Kluft and Ginsberg (2009) found that abundance of invertebrates in pitfall trap samples and abundance of wrack was higher on vehicle-free beaches, although invertebrate abundance in wrack clumps and cores taken below them did not show consistent differences between areas open and closed to vehicles. Off-road vehicles significantly lessened densities of invertebrates on intertidal flats on the Cape Cod National Seashore in Massachusetts (Wheeler 1979). In eastern Australia, off-road vehicles use has been documented as a significant cause of invertebrate mortality on beaches (Schlacher et al. 2008a, 2008b). Results of Schlacher and Thompson (2012) in eastern Australia also suggest that channeling major pedestrian access points away from key shorebird habitat may enhance protection of their prey base.

Various local and regional examples also illustrate threats from recreation. On a 12-kilometer stretch of Mustang Island in Texas, Foster et al. (2009) observed a 25% decline in piping plover abundance and a simultaneous five-fold increase in human use over a 29-year study period, 1979 – 2007. This trend was marginally significant, but declines in two other plover species were significant; declining shorebird abundance was attributed to a combination of human disturbance and overall declines in shorebird populations (Foster et al. 2009). In South Carolina, almost half of sites with five or more piping plovers had ten or more people present during surveys conducted in 2007-2008 and more than 60% allow dogs

(Maddock and Bimbi unpubl. data). Zdravkovic and Durkin (2011) noted disturbance to piping plovers in Texas from kite-boarding, windsurfing, and horseback riding.

LeDee et al. (2010a) surveyed land managers of designated critical habitat sites across seven southern states and documented the extent of beach access and recreation. All but four of the 43 reporting sites owned or managed by federal, state, and local governmental agencies or by non-governmental organizations allowed public beach access year-round (88% of the sites). At the sites allowing public access, 62% of site managers reported more than 10,000 visitors during September-March, and 31% reported more than 100,000 visitors in this period. However, more than 80% of the sites allowing public access did not allow vehicles on the beach and half did not allow dogs during the winter season.

OIL SPILLS AND OTHER CONTAMINANTS

Piping plovers may accumulate contaminants from point and non-point sources at migratory and wintering sites. 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). Notwithstanding documented cases of lightly oiled piping plovers that have survived and successfully reproduced (Amirault-Langlais et al. 2007, A. Amos, University of Texas Marine Science Institute, pers. comm. 2009, 2012), contaminants have both the potential to cause direct toxicity to individual birds and to negatively impact their invertebrate prey base (Chapman 1984, Rattner and Ackerson 2008). Piping plovers' extensive use of the intertidal zone puts them in constant contact with coastal habitats likely to be contaminated by water-borne spills. Negative impacts can also occur during rehabilitation of oiled birds. Frink et al. (1996) describe how standard treatment protocols were modified to reflect the extreme susceptibility of piping plovers to handling and other stressors.

Oil Spills

Following the Ixtoc spill, which began on June 3, 1979 off the coast of Mexico, approximately 350 metric tons of oil accumulated on South Texas barrier beaches, resulting in a 79% decrease in the total number of infaunal organisms on contaminated portions of the beach (Kindinger 1981, Tunnell et al. 1982). Chapman (1984) collected pre- and post-spill data on the abundance, distribution, and habitat use of shorebirds on the beaches in the affected area and saw declines in the numbers of birds as well as shifts in the habitats used. Shorebirds avoided the intertidal area of the beach, occupying the backshore or moving to estuarine habitats when most of the beach was coated. Chapman surmised that the decline in infauna probably contributed to the observed shifts in habitats used. His observations indicated that all the shorebirds, including piping plovers, avoided the contaminated sediments and concentrated in oil-free areas. Amos, however, reported that piping plovers ranked second to sanderlings in the numbers of oiled birds he observed on the beach, although there was no recorded mortality of plovers due to oil (Amos pers. comm. 2009, 2012). Oiled birds were seen for a year or more following the initial spill, likely due to continued washing in of sunken tar; but there were only occasional subsequent observations of oiled or tarred plovers (Amos pers. comm. 2009).

According to government estimates, the 2010 Deepwater Horizon Mississippi Canyon Well #252 oil spill discharged more than 200 million gallons of oil into the Gulf of Mexico (U.S. Government 2010). 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). At the end of July 2010, approximately 625 miles of Gulf of Mexico shoreline was oiled. This included approximately 360 miles in Louisiana, 105 miles in Mississippi, 66 miles in Alabama, and 94 miles in Florida (U.S. Government 2010). 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 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 four 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 (M. Seymour, Louisiana Natural Heritage Program, pers. comm. 2011). Potential long-term adverse effects stem from the construction of sand berms and closing of at least 32 inlets (Appendix 1b). 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. USFWS 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 (M. Bimbi, USFWS, pers. comm. 2011). Limited clean-up operations were still on-going throughout the spill area in November 2012 (H. Herod, USFWS, pers. comm. 2012). Results of a natural resources damage assessment study to assess injury to piping plovers (Fraser et al. 2010) are not yet available.

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 (L. Carver, Louisiana Department of Wildlife and Fisheries, pers. comm. 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 (K. Rice, USFWS, pers. comm. 2009). In late July and early August 2009, for example, oil suspected to have originated from an offshore oil rig in Mexican waters was observed on plumage or legs of 14 piping plovers in south Texas (Cobb pers. comm. 2012b).

Pesticides and Other Contaminants

A piping plover was found among dead shorebirds discovered on a sandbar near Marco Island, Florida following the county's aerial application of the organophosphate pesticide Fenthion for mosquito control in 1997 (Pittman 2001, Williams 2001). Subsequent to further investigations of bird mortalities associated with pesticide applications and to a lawsuit being filed against the Environmental Protection Agency in 2002, the manufacturer withdrew Fenthion from the market, and Environmental Protection Agency banned all use after November 30, 2004 (American Bird Conservancy 2007).

Absent identification of contaminated substrates or observation of direct mortality of shorebirds on a site used by migrating and wintering piping plovers, detection of contaminants threats is most likely to occur through analysis of unhatched eggs. Contaminants in eggs can originate from any point in the bird's annual cycle, and considerable effort may be required to ascertain where in the annual cycle exposure occurred (see, for example, Dickerson et al. 2011 characterizing contaminant exposure of mountain plovers).

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 (D. Best, USFWS, pers. comm. 1999 in USFWS 2003). Relatively high levels of PCB, dichloro diphenyl dichloroethylene (DDE), and polybrominated diphenyl ether (PBDE) were detected in one of two clutches of Ontario piping plover eggs analyzed in 2009 (V. Cavalieri, USFWS, pers. comm. 2011). Results of opportunistic egg analyses to date from Atlantic Coast piping plovers did not warrant follow-up investigation (Mierzykowski 2009, 2010, 2012; S. Mierzykowski, USFWS pers. comm. 2012). No recent testing has been conducted for contaminants in the Northern Great Plains piping plover population.

ENERGY DEVELOPMENT

Land-based Oil and Gas Exploration and 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 (USFWS 2008f; B. Firmin, USFWS, pers. comm. 2012). With the implementation of appropriate conditions, threats to nonbreeding piping plovers from land-based oil and gas extraction are currently very low.

Wind Turbines

Wind turbines are a potential future threat to piping plovers in their coastal migration and wintering range[15]. Relatively small single turbines have been constructed along the beachfront in at least a few locations (e.g., South Carolina; M. Caldwell, USFWS, pers. comm. 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 believed to traverse these areas in their daily movements (D. Newstead, Coastal Bend Bays and Estuaries Program, pers. comm. 2012a). To date, no piping plovers have been reported from post-construction carcass detection surveys at these sites (P. Clements, USFWS, pers. comm. 2012). However, Newstead (pers. comm. 2012a) has raised questions about collision risk during migration departure, as large numbers of piping plovers have been observed in areas of the 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. Several off-shore wind farm proposals in South Carolina are in various stages of early scoping (Caldwell pers. comm. 2012). A permit application was filed in 2011 for 500 turbines in three areas off the coast of south Texas (USACE 2011), but it is unknown whether piping plovers transit these areas.

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.

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[15] Piping plovers are under consideration for inclusion in a habitat conservation plan addressing wind energy development that overlaps the piping plover's interior migration routes (USFWS 2011b).

PREDATION

The extent of predation on migrating or wintering piping plovers remains largely unknown and is difficult to document. Avian and mammalian predators are common throughout the species' wintering range. Human activities affect the types, numbers, and activity patterns of some predators, thereby exacerbating natural predation on breeding piping plovers (USFWS 1996). One incident involving a cat observed stalking piping plovers was reported in Texas (NY Times 2007). It has been estimated that free-roaming cats kill over one billion birds every year in the U.S., representing one of the largest single sources of human-influenced mortality for small native wildlife (Gill 1995, Sax and Gaines 2008).

Predatory birds, including peregrine falcons, merlin, and harriers, are present in the nonbreeding range. Newstead (pers. comm. 2012b) reported two cases of suspected avian depredation of piping plovers in a Texas telemetry study, but he also noted that red tide may have compromised the health of these 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). Drake (1999a) theorized that this piping plover behavior enhances concealment associated with roosting in depressions and debris in Texas.

Nonbreeding piping plovers may reap some collateral benefits from predator management conducted for the primary benefit of other species. Florida Keys Refuges National Wildlife Refuge (USFWS 2011a), for example, released a draft integrated predator management plan that targets predators, including cats, for the benefit of native fauna and flora. Other predator control programs are ongoing in North Carolina, South Carolina, Florida, and Texas beach ecosystems (USFWS 2009d).

Although the extent of predation to nonbreeding piping plovers is unknown, it remains a potential threat. At this time, however, the USFWS considers predator control and related research on wintering and migration grounds to be a low priority[16] (see Action 5 on page 74).

MILITARY OPERATIONS

Five of the eleven coastal military bases located in the U.S. continental range of nonbreeding piping plovers have consulted with the USFWS about potential effects of military activities on plovers and their habitat (USFWS 2009d, USFWS 2010a). Formal consultation under section 7 of the ESA with Camp Lejeune, North Carolina in 2002 provided for year-round piping plover surveys, but restrictions on activities on Onslow Beach only pertain to the plover breeding season (J. Hammond, USFWS, pers. comm. 2012). Informal consultations with three Florida bases (Naval Station Mayport, Eglin Air Force

[16] However, the threat of predation should be distinguished from the threat of disturbance to roosting and feeding piping plovers posed by dogs off leash.

Base, Tyndall Air Force Base) addressed training activities that included beach exercises and occasional use of motorized equipment on beaches and bayside habitats. Eglin Air Force Base conducts twice-monthly surveys for piping plovers, and habitats consistently used by piping plovers are posted with avoidance requirements to minimize direct disturbance from troop activities. Operations at Tyndall Air Force Base and Naval Station Mayport were determined to occur outside optimal piping plover habitats. A 2001 consultation with the Navy for one-time training operations on Peveto Beach in Louisiana concluded informally (USFWS 2010a). Current threats to wintering and migrating piping plovers posed by military activities appear minimal.

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 (C. Acker, U.S. Geological Survey, pers. comm. 2009). Newstead (pers. comm. 2012b) reported circumstantial evidence that red tide weakened piping plovers in the vicinity of the 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 (M. Hines, U.S. Geological Survey, pers. comm. 2009). The 2009 5-Year Review concluded that West Nile virus and avian influenza remain minor threats to piping plovers on their wintering and migration grounds.

SUMMARY AND SYNTHESIS OF THREATS

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, of major threat to piping plovers, as well as the many other shorebird species competing with them for foraging resources and roosting habitats in their nonbreeding range. However, artificial shoreline stabilization also 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.

CURRENT CONSERVATION EFFORTS

Conservation efforts on behalf of piping plovers in their nonbreeding range have increased since the species listing and further accelerated since the early 2000s. Diverse conservation tools are selectively used to address protection needs across federal, state, municipal, and private land ownership. This overview of existing regulatory mechanisms and ongoing conservation is supplemented by examples described in other sections of this document.

International Treaties

International treaties confer responsibility on the U.S., as well as other signatories, to conserve international migratory bird resources. The migratory bird conventions between the U.S. and Canada (1916) and Mexico (1936), the Ramsar Convention, and the Western Hemisphere (or Pan American) Convention pertain to conservation of piping plovers. Implementation occurs through a variety of mechanisms, including the Canada/Mexico/U.S. Trilateral Committee for Wildlife and Ecosystem Conservation and Management. The Specially Protected Areas and Wildlife Protocol of the Cartagena Convention offers another potential framework for coordinated piping plover conservation efforts in the Caribbean.

Federal Regulatory Protections

Key protections are afforded to piping plovers under the ESA, the Migratory Bird Treaty Act, and the Coastal Barrier Resources Act. Recommendations regarding application of regulatory tools to conservation of nonbreeding piping plovers are provided under Action 6 (see pages 75-79).

Section 7 of the ESA (16 U.S.C. 1536) directs all federal agencies to use their authorities to further the conservation of listed species. Section 7 also requires that these agencies consult with the USFWS before authorizing, funding, or carrying out activities that may affect listed species. Examples of federal activities that may affect piping plovers, thereby triggering section 7 consultations, include federal inlet dredging projects; permits for coastal stabilization structures, beach nourishment, wetland developments, and placement of wind turbines; and funding of post-storm beach restoration projects. Section 7 consultations facilitate incorporation of conservation measures that reduce adverse effects on nonbreeding piping plovers (see Action 6.1.1).

Section 9 of the ESA (16 U.S.C. 1538) prohibits any person subject to the jurisdiction of the U.S. from taking (i.e., harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting) listed wildlife species. It is also unlawful to attempt such acts, to solicit another person to commit such acts, or cause such acts to be committed. Regulations implementing the ESA (50 CFR 17.3) further define "harm" to include significant habitat modifications or degradation that results in the killing or injury of wildlife by significantly impairing essential behavioral patterns such as breeding, feeding, or sheltering. "Harass" means an intentional or negligent act or omission that creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering.

Section 10 of the ESA (16 U.S.C. 1539) and related regulations provide for permits that may authorize activities prohibited under Section 9, either for scientific purposes or to enhance the propagation or survival of a listed species. Section 10 also allows permits to be issued for take that is "incidental to, and not the purpose of, carrying out an otherwise lawful activity" if the USFWS determines that certain conditions have been met. Section 10(a)(2)(A) of the ESA requires an applicant for an incidental take permit to submit a conservation plan (commonly termed a habitat conservation plan or HCP) that specifies the likely impacts and the measures the applicant will undertake to minimize and mitigate such impacts. For example, the 2005 amendment to the Volusia County, Florida Habitat Conservation Plan added piping plovers as a covered species (Ecological Associates, Inc. 2011). As a result, recreational driving is prohibited along approximately 20 miles of beach, including inlet beaches north and south of Ponce de Leon Inlet. Other conservation measures include piping plover monitoring on county beaches, education, and outreach.

Piping plovers are also protected under the Migratory Bird Treaty Act of 1918 (16 U.S.C. 703-712). Prohibited acts include pursuing, hunting, shooting, wounding, killing, trapping, capturing, collecting, or attempting such conduct.

The Coastal Barrier Resources Act (CBRA) of 1982 (16 U.S.C. 3501 et seq.), as amended by the Coastal Barrier Improvement Act of 1990, provides certain protections to designated units of the Coastal Barrier Resources System (CBRS), including sites where piping plovers overwinter on the Atlantic and Gulf coastlines. The CBRS is a collection of specific, undeveloped (or sparsely developed) units of land and associated aquatic environments that serve as barriers protecting the Atlantic and Gulf coastlines. Three important goals of CBRA are to minimize loss of human life by discouraging development in high-risk areas, to reduce wasteful expenditures of federal resources, and to protect the natural resources associated with coastal barriers. The USFWS is responsible for issuing concurrence to federal agencies that propose spending federal funds within the CBRS (see Action 6.2).

The CBRS currently includes 585 units, which comprise almost 1.3 million acres. Review of a stratified random sample of 91 units by the Government Accountability Office in 2007 found that 84 percent remained undeveloped (i.e., no new structures had been built), 13 percent had experienced minimal development, and three percent had undergone significant development (i.e., more than 100 structures per unit). Overall, however, CBRS units in the southern part of the U.S. had experienced more development than units in the northern part of the country (Government Accountability Office 2007). The coastal barrier legislation is not intended to prevent or regulate development in these high-risk areas. It only directs that federal funds not be spent to subsidize developments. According to federal and local officials, CBRA played little role in the extent of development within the CBRS units reviewed by the Government Accountability Office in 2007.

Federal Lands

Important coastal migration and wintering piping plover habitats are located on lands managed by the USFWS's National Wildlife Refuge System, the National Park Service, and the Department of Defense. These agencies implement legal authorities (in addition to the ESA) that facilitate conservation of piping plovers and their habitats. Examples of protection and management activities benefiting piping plovers on federal lands are included in Part III of this document (see, for example, Actions 2.1 and 6.3).

The National Wildlife Refuge System Improvement Act of 1997 (16 U.S.C. 668dd) establishes wildlife conservation, coupled with the purpose(s) for which each refuge was established, as the principal management direction on that refuge. The statute also requires preparation of a comprehensive conservation plan for each refuge, and it prescribes the process for determining the compatibility of public uses on refuges. Habitat at 15 national wildlife refuges was included in the critical habitat designations for wintering piping plovers (USFWS 2001b, 2008g, 2009e).

Five national seashores also provide important protection for piping plovers and their habitat in North Carolina, Georgia, Florida, Mississippi, and Texas. The National Park Service Organic Act (16 U.S.C. 1) prohibits impairment of Park resources and values unless a particular law explicitly directs otherwise. National Park Service lands are managed according to requisite general management plans, often with additional specific plans for managing public uses or natural resources of particular concern.

The U.S. Department of Defense is responsible under the Sikes Act (16 U.S.C. 670) for carrying out programs and implementing management strategies to conserve and protect biological resources on its lands. Under the 1997 amendments to the Sikes Act, Department of Defense installations develop and implement mutually agreed upon integrated natural resource management plans through voluntary cooperative agreements with the USFWS and the respective state fish and wildlife agencies. Eleven coastal military bases are located in the piping plover's U.S. continental coastal migration and wintering range.

Executive Order 11644, Use of Off-Road Vehicles on the Public Lands and Executive Order 11989, Off-Road Vehicles on Public Lands pertain to lands under custody of the Secretaries of Agriculture, Defense, and Interior (except for Native American Tribal lands). Executive Order 11644 requires administrative designation of areas and trails where off-road vehicles may be permitted. Executive Order 11989 states that "... the respective agency head shall, whenever he determines that the use of off-road vehicles will cause or is causing considerable adverse effects on the soil, vegetation, *wildlife, wildlife habitat* ... immediately close such areas or trails to the type of off-road vehicles causing such effects, until such time as he determines that such effects have been eliminated and that measures have been implemented to prevent future recurrence" (emphasis added).

State Protections

Most states within the U.S. continental coastal migration and wintering range include the piping plover on lists of species protected under state law (see Table 5).

The Wildlife Conservation and Restoration Program and State Wildlife Grants (both administered by the USFWS) require state wildlife agencies to develop comprehensive wildlife conservation strategies, also known as state wildlife action plans. Congressional direction asked states to assess the health of a full array of wildlife, with particular attention to the wildlife species that have low or declining populations and are indicative of the diversity and health of state wildlife, typically termed "species of greatest conservation need." The 2005 North Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas state wildlife action plans all identified piping plovers as species of greatest conservation need.

Table 5. The piping plover's status and legal protection under state laws.

State	Status of the piping plover	State law
North Carolina	threatened	15A NCAC 10I .0100 Endangered and Threatened Species
South Carolina	none	
Georgia	threatened	Endangered Wildlife Act of 1973 (O.C.G.A. 27-3-130)
Florida	federally designated threatened (confers State protections)	Florida Administrative Code Rules 68A-27.003 Designation of Endangered Species; Prohibitions Florida Endangered and Threatened Species Act, Sections 372.072, 372.0725 of Title 28
Alabama	protected	220-2-.92 Nongame Species Regulation
Mississippi	endangered	Nongame and Endangered Species Conservation Act of 1974 (MS ST §§ 49-5-101 – 119)
Louisiana	threatened/ endangered	Louisiana Revised Statutes, Title 56, Chapter 8, Part IV, Threatened and Endangered Species Conservation Louisiana RS (Revised Statutes) 56:1901, RS 56:1903, RS 56:1904
Texas	threatened	Texas Parks and Wildlife Code, Chapters 67 and 68; and Title 31 of Texas Administrative Code, Sections 65.171 - 65.176

State parks, wildlife management areas, and other lands furnish important habitat and protection for migrating and wintering piping plovers, including 23 percent of the 2001 critical habitat designation for wintering piping plovers[17] (USFWS 2001b). Management protecting piping plovers has been implemented at various state parks; for example, the Texas Parks and Wildlife Department has installed bollards and cables to prevent vehicles from accessing piping plover habitat areas, requires leashing of pets, and does not mechanically rake beaches (K. Keyes, Texas Parks and Wildlife Department, pers. comm. 2011, A. Sipocz, Texas Parks and Wildlife Department, pers. comm. 2011). Managers of several state parks and protected islands in South Carolina post important piping plover areas and restrict access by people and dogs. Although enforcement is limited, pets are not permitted on beaches in Florida State Parks (Florida State Parks 2012).

Non-regulatory Activities

Numerous agencies, organizations, academic institutions, and unaffiliated individuals play key non-regulatory roles in the conservation of piping plovers in their migration and wintering range by conducting surveys, advocating and monitoring protective management, and providing research results.

The USFWS inter-regional piping plover team consists of six biologists from the five regions spanning the piping plover's U.S. range. Established in 2002, the team includes three biologists from the wintering range (two from the Southeast Region and one from the Southwest Region), as well as three biologists from the breeding range (Northeast, Midwest, and Mountain-Prairie Regions). Team efforts include coordination with USFWS field offices and other programs across the range, review of actions with rangewide implications (e.g., banding), development of the 2009 5-Year Review, and sponsorship of workshops in the nonbreeding range.

Non-governmental organizations carry out conservation efforts beneficial to wintering piping plovers, and several academic institutions have conducted scientific studies on wintering piping plovers. Dedicated unaffiliated individuals are also important partners (Appendix 3).

National and regional conservation initiatives with broader missions for shorebirds or birds in general are also valuable current or potential partners:

- The Atlantic Coast Joint Venture and its South Atlantic Migratory Bird Initiative integrates the efforts of the four major migratory bird planning initiatives (North American Waterfowl Management Plan, U.S. Shorebird Conservation Plan, North American Waterbird Conservation Plan, and Partners in Flight).

[17] Redesignation of 18 Texas critical habitat units in 2009 substantially increased the proportion of critical habitat in that State that is classified as state-owned. However, this is primarily attributable to a change in mapping methods that included intertidal areas in the 2009 land ownership estimates, whereas intertidal lands had been excluded from the estimation of critical habitat acreage and ownership in 2001. The 2009 ownership estimates for the 2009 Texas redesignation, therefore, are not comparable to the estimates for the other states or for Texas critical habitat units designated in 2001 (F. Weaver, USFWS, pers. comm. 2012).

- The National Audubon Society, the U.S. partner for BirdLife International's Important Bird Area program, has designated many state-level Important Bird Areas for piping plovers.

- Partners in Flight's North American Landbird Conservation Plan (Rich et al. 2004) and Southeast Working Group incorporate the entire continental U.S. portion of the piping plover's nonbreeding range. They comprise domestic subdivisions of an international partnership (see page 47).

- The Southeastern Coastal Plains – Caribbean Region Report of the U.S. Shorebird Conservation Plan articulates the needs and goals of shorebird conservation efforts in this region (USFWS 2002b).

- Development of an Atlantic Flyway Shorebird Business Plan is a collaborative effort initiated by federal, state, and non-governmental biologists in 2011. Conservation activities will target 15 focal species, including piping plovers (Winn et al. 2012). Although efforts to date have primarily involved U.S. and Canadian organizations, engagement of Caribbean and South American partners is anticipated (S. Johnston, USFWS, pers. comm. 2012).

Conservation Efforts Outside the Continental United States

Although conservation efforts in other countries are not the primary focus of this document, the following summary of conservation actions in other countries provides international context. Protection of piping plovers and their habitats in Mexico and the Caribbean is extremely important to piping plover recovery.

Protections for piping plovers in Mexico include the 2005 designation of 1.5 million acres of the Laguna Madre de Tamaulipas region in Mexico as a Federal Natural Protected Area. Land-use alterations to piping plover habitats within this area are subject to review under a federal permitting process that encourages avoidance and minimization of impacts, but they are not precluded (USFWS 2009d). Ongoing conservation efforts that may benefit piping plovers in Tamaulipas include trash removal on beaches, control of feral animals, environmental education, and organization of volunteer groups (A. Banda, State Government of Tamaulipas, pers. comm. 2012; J. Pena, Gladys Porter Zoo, pers. comm. 2012).

The Bahamas National Trust maintains the lead responsibility for piping plover conservation in the Bahamas and has worked to identify and conserve piping plover sites since the early 2000s. Other Bahamian partners include the Friends of the Environment in Abaco and the Andros Conservancy and Trust (P. Moore and L. Gape, Bahamas National Trust, pers. comm. 2012). Canadian and U.S. government agencies and non-governmental organizations have also participated in expanding surveys in the Bahamas. Designation of global-level Important Bird Areas at Grand Bahama Southern Shore, the

Joulter Cays, Kemp Cay to Pigeon Cay (in the Berry Islands), Stafford Creek to Andros Town (on North Andros) and Driggs Hill to Mars Bay (on South Andros) provide recognition for key habitats used by large numbers of piping plovers and other shorebirds (BirdLife International 2012). Educational activities and outreach to local communities are underway, as are experimental projects to restore habitat through removal of invasive non-native vegetation (A. Hecht, USFWS, pers. obs. 2012).

Surveys in Cuba are conducted as part of the International Piping Plover Census and through other efforts (Blanco 2012, Elliott-Smith et al. 2009, Blanco 2006). Piping plover numbers contributed to designation criteria for three Cuban Important Bird Areas (Wege pers. comm. 2012). Surveys in other Caribbean countries are also carried out by the International Piping Plover Census.

Other international collaborations for shorebirds and birds in general include the following (most of which have informational websites):

- The Western Hemisphere Shorebird Reserve Network is a voluntary, non-regulatory coalition of private and public organizations in nine countries across the Americas aiming to identify and conserve shorebird species and their habitats through a network of key sites.

- The International Shorebird Survey is a global effort to gather information on shorebirds and the wetlands they use. A new initiative called the Program for Regional and International Shorebird Monitoring coordinates and expands existing shorebird survey efforts, including the International Shorebird Survey, the Western Shorebird Survey and the Canadian Maritimes Shorebird Survey.

- The Caribbean Waterbird Census is a regional monitoring program of the Society for the Conservation and Study of Caribbean Birds.

- The North American Bird Conservation Initiative is a coalition of government agencies, private organizations, and bird initiatives working to ensure the long-term health of North America's native bird populations.

- Partners in Flight strives to coordinate and increase bird conservation resources among public and private organizations in the Western Hemisphere.

PART II: PRINCIPLES FOR CONSERVATION OF PIPING PLOVERS IN THEIR NONBREEDING RANGE

The information summarized in Part I regarding the biology, habitat use, and status of wintering and migrating piping plovers supports the following principles pertinent to their conservation in the nonbreeding range:

1. **Piping plovers from all three populations overlap on the coastal nonbreeding range, but there are marked areas of concentration for each population.** Observations of piping plovers from all three populations span the coast from North Carolina to Mexico and into the Bahamas. There is no exclusive partitioning of the wintering range; however, there are very strong patterns in the distribution of the breeding populations in their coastal nonbreeding range. Piping plovers from the Atlantic Coast are most prevalent during migration and winter along the southern Atlantic Coast and in the Bahamas. The majority of reported Great Lakes individuals winter in South Carolina, Georgia, and Florida. Piping plovers breeding on the Northern Great Plains predominate in coastal Mississippi, Louisiana, and Texas. Wintering ranges of all three breeding populations overlap most markedly on the Gulf Coast of Florida. Assessments of existing circumstances, trends, or potential changes that may affect piping plovers in their nonbreeding range should recognize any disproportionate effects on a single breeding population, while not discounting the potential impacts on all three populations.

2. **Piping plovers demonstrate high intra- and inter-annual fidelity to their wintering sites.** Resightings of marked piping plovers consistently confirm their fidelity to wintering sites, thereby reinforcing the importance of maintaining robust habitats distributed across the species' range.

3. **Piping plovers depend on a mosaic of habitats within their wintering home ranges.** Nonbreeding piping plovers use a mosaic of habitats to meet their foraging and roosting needs and to shelter themselves from harsh weather. Habitat availability and quality may shift with changes in lunar or wind-driven tides, weather, and other environmental factors. Conservation efforts should recognize the specialized function of many habitats and the value of particular areas to piping plovers in the region.

4. **Importance of a site to migrating and wintering piping plovers may vary within and between years.** Some sites support far greater numbers of piping plovers during migration than during the winter. Some sites may be more important for fall migration than spring migration, or vice versa. Understanding temporal variability in piping plover use of a site is key to accurate appraisal of habitat values, as well as seasonal variability in management needs (e.g., managing disturbance from recreational activities). Multiple surveys conducted across several migration and wintering seasons are required to assess the importance of a site to piping plovers and to identify appropriate

conservation needs and actions. Because coastal piping plover habitats are fundamentally dynamic, it is also important to reassess coastal lands following significant changes such as those resulting from major storms.

5. **Conservation activities and threats in the coastal nonbreeding range strongly affect attainment of recovery goals.** Piping plover populations are inherently vulnerable to even small declines in their most sensitive vital rates, i.e., survival of adults and fledged juveniles. Progress towards recovery, attained primarily through intensive protections designed to increase productivity on the breeding grounds, would be quickly diminished or reversed by even small sustained decreases in survival rates or fecundity due to stress experienced during migration and wintering. Reduction or management of threats across the nonbreeding range is essential to piping plover survival and recovery.

Although protection of piping plovers and their coastal migration and wintering habitat will require a significant long-term commitment, the benefits go beyond survival of this one species. Sites that are important to wintering piping plovers consistently support high numbers of a diverse group of other shorebirds. Protection of piping plovers and their habitat responds to the stated purposes of the Endangered Species Act of 1973, as amended (Section 2(b)), by "provid[ing] a means whereby the ecosystems on which endangered species and threatened species depend may be conserved."

PART III: CONSERVATION STRATEGY – RECOMMENDATIONS FOR ADDRESSING THREATS AND RECOVERY NEEDS

This conservation strategy addresses the key threats to nonbreeding piping plovers and their coastal migration and wintering habitat. It also supports recovery by addressing conservation needs such as monitoring and research. These aims should be implemented in accordance with the principles in Part II and accomplished through: (1) reducing threats from habitat loss and degradation; (2) reducing threats from human-caused disturbance; (3) providing more effective monitoring of both piping plover status and ongoing management efforts; (4) addressing threats from contaminants; (5) assessing and addressing threats from predation; (6) improving application of existing regulatory tools; (7) providing for long-term protection of piping plovers and their habitats; (8) conducting research to inform conservation implementation; and (9) coordinating, reviewing, and refining recovery efforts.

Each threat or conservation need, described in more detail in Part I of this document, is presented below with recommended conservation actions (outlined in Table 6). These actions synthesize tasks for protection of nonbreeding piping plovers that are contained in the approved recovery plans (USFWS 1988b, 1996, 2003) and recommendations for future action in the 2009 5-Year Review (USFWS 2009d). Examples and guidance are also provided with the goal of improving the effectiveness and consistency of conservation efforts across the migration and wintering range.

1 Maintain natural coastal processes that perpetuate wintering and coastal migration habitat.

The review of threats to piping plovers and their habitats in their migration and wintering range documents continuing loss and degradation of the mosaic of habitats used by plovers due to development, dredging and sand mining, inlet stabilization and relocation, groins, seawalls and revetments, sand placement projects, invasive vegetation, and wrack removal. This cumulative habitat loss is, by itself, of very serious concern for conservation of piping plovers and the many other shorebird species competing with them for foraging resources and roosting habitats in their nonbreeding range. However, artificial shoreline stabilization also impedes the processes by which coastal habitats adapt to accelerating sea level rise, thus setting the stage for compounding future losses.

Priority 1 actions in the 1996 Atlantic Coast and 2003 Great Lakes recovery plans identify tasks (2.21 and 2.22, respectively) 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 plan states that, as winter habitat is identified, current and potential threats to each site should be determined (Task 2.33) and calls for modification of construction activities that may reduce or negatively alter winter habitat (Task 4.37).

Table 6. Conservation action outline.

1. **Maintain natural coastal processes that perpetuate wintering and coastal migration habitat.**
   - 1.1 Protect nonbreeding plovers and their habitat from direct and indirect impacts of development.
   - 1.2 Protect natural processes of inlet formation, migration, and closure.
   - 1.3 Protect habitat from direct and indirect impacts of shoreline stabilization and sand placement projects.
   - 1.4 Protect important foraging and roosting habitats.
     - 1.4.1 Protect and maintain important intertidal habitats including algal flats, sandbars, shoals, and ebb and flow tidal deltas.
     - 1.4.2 Maintain natural beach habitat and overwash and wrack formation processes.
   - 1.5 Maintain native vegetation by managing invasive species.

2. **Protect wintering and migrating piping plovers and their habitat from human disturbance.**
   - 2.1 Manage sites to reduce human-caused disturbance to nonbreeding plovers
     - 2.1.1 Manage pedestrian access to reduce disturbance to nonbreeding piping plovers.
     - 2.1.2. Manage off-road vehicle access to reduce disturbance, mortality, and habitat degradation.
     - 2.1.3 Implement and enforce pet restrictions in key plover habitat areas
     - 2.1.4 Prevent disturbance from other activities.
   - 2.2 Develop and implement site stewardship plans that address human disturbance and other limiting factors.
   - 2.3 Develop an effective migration and wintering range outreach strategy and customize it for use in site stewardship plans.
   - 2.4 Develop and implement training for monitors and stewards.

3. **Monitor nonbreeding plovers and their habitat.**
   - 3.1 Monitor nonbreeding piping plovers to assess regional abundance and distribution.
   - 3.2 Monitor nonbreeding sites to identify limiting factors and effects of management.
   - 3.3 Provide robust monitoring of piping plover abundance, distribution, survival, and habitat characteristics before and after major projects that have the potential to substantially modify important migration and wintering piping plover habitat.
   - 3.4 Record and promptly report observations of banded piping plovers.
   - 3.5 Develop a state-by-state atlas or other database containing geospatial information on wintering and migrating piping plovers.

4. **Protect nonbreeding plovers and their habitats from contamination and degradation from oil or other chemical contaminants.**
   - 4.1 Update and refine contaminant exposure response protocols to protect plovers and their habitats. Incorporate updated procedures and protocols into all appropriate federal, state, and local oil and chemical spill contingency plans.
   - 4.2 Develop a rigorous experimental design to evaluate short- and long-term effects of alternative contaminant clean-up techniques on nonbreeding plovers and their habitat.
   - 4.3 Identify and remediate any sources of contaminants with potential to adversely affect piping plover survival and reproduction.

5. **Assess predation as a potential limiting factor for piping plovers on wintering and migration sites.**
   - 5.1 Survey for the presence of avian or mammalian predators (especially non-native predators, such as feral cats) on nonbreeding plover sites and include appropriate monitoring and management recommendations in site stewardship plans.
   - 5.2 Consider ancillary benefits to nonbreeding plovers when developing predator management plans for sites, including national wildlife refuges and state parks.

Table 6. Conservation action outline (continued).

6. Improve application of regulatory tools.
- 6.1 Fully utilize ESA authorities to conserve piping plovers and their habitats.
  - 6.1.1 Maximize avoidance of adverse effects to piping plovers and their habitats through section 7 consultations with federal agencies.
  - 6.1.2 Adopt effective piping plover protections in Habitat Conservation Plans under section 10(a)(1)(B) of the ESA.
- 6.2 Provide appropriate Coastal Barrier Resources Act determinations.
- 6.3 Provide exemplary protection for migrating and wintering piping plovers on federal lands.
- 6.4 Encourage effective use of state and local laws and regulations to enhance conservation of nonbreeding piping plovers and their habitat.

7. Develop mechanisms to provide long-term protection of nonbreeding plovers and their habitat.
- 7.1 Seek long-term agreements with landowners to protect nonbreeding plovers and their habitats.
- 7.2 Acquire important habitat if it becomes available.
- 7.3 Seek non-regulatory recognition for sites.
- 7.4 Institutionalize plover site management through long-term planning at the local, state and federal levels.
- 7.5 Address long-term climate change threats, including accelerating sea level rise.

8. Conduct scientific investigations to refine knowledge and inform conservation of migrating and wintering piping plovers.
- 8.1 Evaluate factors in the coastal migration and wintering range that may affect piping plover survival and subsequent fecundity.
- 8.2 Refine the characterization of optimal winter and migration habitat.
- 8.3 Determine the effects of shoreline stabilization projects.
- 8.4 Develop design specifications and monitoring for restoring, creating, and enhancing roosting and foraging habitat.
- 8.5 Investigate methods to determine the quantity and distribution of wintering and coastal migration habitat needed for long-term conservation of the three populations.
- 8.6 Determine impacts of human disturbance on nonbreeding plovers.
- 8.7 Evaluate piping plover flight patterns and behaviors to inform risk assessments for wind turbine generators.
- 8.8 Develop strategies to reduce threats from accelerating sea level rise.
- 8.9 Investigate the full spectrum of other impacts from climate change on piping plovers in their nonbreeding range.
- 8.10 Ascertain impacts of predation on wintering and migrating piping plovers.

9. Coordinate, review, and refine recovery efforts.
- 9.1 Foster communication among recovery partners.
- 9.2 Facilitate use of new information.
- 9.3 Support conservation of wintering piping plovers outside the continental U.S.

1.1 Protect nonbreeding plovers and their habitat from direct and indirect impacts of development.

Studies have documented the adverse effects of development on the quantity and quality of migrating and wintering habitat as well as the tendency of plovers to avoid developed coastline features (Drake et al. 2001, LeDee et al. 2008, Arvin 2008, Lott 2009, Foster et al. 2009, Zdravkovic and Durkin 2011) (see page 14). In addition to degrading the physical suitability of plover habitat, beach development also increases the likelihood of disturbance to plovers through associated recreational activity (see page 33-35). This includes residential finger canal networks constructed in bayside areas. Not only do these finger canals destroy habitat within the development footprint, they also pollute the water, change the hydrology of a given area and concentrate people and pets on former bayside plover habitat.

Potential conflicts between rare species and protection of property can be reduced through coastal zone planning. Resources available to assist communities in identifying and avoiding development in high-risk coastal areas include the National Oceanic and Atmospheric Administration's Digital Coast information and tools, the Federal Emergency Management Agency's coastal flood hazard analyses and maps, and state and local coastal planning data and maps.

The impacts of shoreline development are sometimes exacerbated by efforts to protect access roads. Careful planning can substantially reduce the need for future shoreline stabilization. Planners and project sponsors should also weigh the additional economic and environmental costs of maintaining overland access, compared to alternative modes of access (including boat services and relocation of projects away from dynamic beach areas). Specific actions to protect nonbreeding piping plovers from the impacts of development include:

A. Direct construction and associated coastal infrastructure away from highly vulnerable beaches and shorelines to more stable areas.

B. Encourage relocation and buy-outs of storm- or flood-damaged beachfront structures. Where beachfront structures are heavily damaged by storm events or as a result of flooding, property owners should be informed of coastal hazard analyses and maps (described above) and encouraged to rebuild significantly farther landward or on the mainland, where feasible.

C. Through county comprehensive planning and other venues, inform and forewarn developers, homeowners, and other parties about the risks and potential long-term costs of protecting beach development projects, as well as risks to piping plovers and other birds.

D. Consider the need for subsequent shoreline stabilization (especially hard structures) and the resulting likelihood of additional habitat degradation when evaluating permit requests under federal or state agency jurisdiction.

E. Implement the best management practices described in Appendix 1a (Rice 2009) for shoreline construction of all projects that cannot be avoided in and near dunes and estuarine habitats. Every effort should be made to minimize adverse impacts, including fragmentation and degradation of plover nonbreeding habitat caused by construction of finger canals, walkways, access points, docks, piers, and other structures.

1.2 Protect natural processes of inlet formation, migration, and closure.

Inlet stabilization prevents the natural formation of new inlets, washover passes, and important bayside intertidal foraging habitat that are strongly preferred by piping plovers and other shorebirds (Nicholls and Baldassarre 1990b, Harrington 2008, Tarr 2008, Lott et al. 2009b, Addison 2012). As of 2011, an estimated 40% of navigable mainland or barrier island tidal inlets throughout the piping plover's U.S. mainland wintering range have some form of hardened structure, including jetties, seawalls or revetments (Table 3). At least eight inlets have been relocated in North Carolina, South Carolina, Louisiana, Texas and Florida, one of them (Captain Sam's Inlet in South Carolina) repeatedly (USFWS 2012a, Rice 2012a). At least 30 inlets have been artificially opened and 64 closed within the U.S. mainland wintering range (Rice 2012a). Protecting natural inlet processes will also enhance habitat resiliency during a period of accelerating sea level rise. Recommendations to conserve natural coastal processes include:

A. Protect and maintain natural sand/sediment budgets and formation processes of key piping plover feeding and roosting habitats in inlets. Avoid sand mining and dredging in the vicinity of inlets and their associated bars and shoals. Strongly discourage dredging of new navigational channels through previously undisturbed inlets. Dispose of dredged material where it can naturally bypass to downdrift beaches at existing navigational channels between the Atlantic/Gulf waters and the bays.

Explore all potential avoidance and minimization options as a first step in any proposed inlet stabilization project. Apply the best management practices described in Rice (2009, Appendix 1a) to minimize adverse impacts through improved project design if an inlet stabilization project is still deemed necessary and develop rigorous design specifications that best simulate and perpetuate natural processes. Avoid the use of hard structures (including jetties, terminal groins, seawalls, revetments, riprap, geotubes, sandbags or any other structure) in new inlet stabilization projects. Remove or modify existing hard stabilization structures (such as jetties) wherever practicable. If existing inlet structures are in need of repair or rehabilitation, encourage removal of hard structures and replacement with alternatives such as leaky (low profile) groins. The intent should be to facilitate long-term natural maintenance of tidal inlets as sea level rises, allowing these inlets to shift along with the adjacent barrier islands and naturally maintain migratory and winter habitat. Wherever possible, navigational channels and their associated dredging locations should also be allowed to shift over time in order to accommodate migrating islands and inlets.

B. Work with the appropriate regulatory agencies to revise Inlet Management Plans (e.g., those prepared under the Florida Beach Erosion Control Program) to support the strategies listed above and to improve the conservation and re-establishment of shoals within the federal navigation channels.

C. Incorporate robust monitoring and evaluation measures into any approved projects to open, relocate or close inlets or their channels (e.g., USFWS 2009a, 2009b, 2012a, and Action 3.3).

1.3 Protect habitat from direct and indirect impacts of shoreline stabilization and sand placement projects.

Shoreline stabilization, dune building, and sand placement projects have led to loss, fragmentation and degradation of habitats throughout the nonbreeding range. As sea levels rise, developed areas are more likely to receive coastal protection efforts (Klein et al. 2001, Brown and McLachlan 2002, CCSP 2009, Pilkey and Young 2009, Rice 2009, Titus et al. 2009). Shoreline protection projects that block the migration of beaches and wetlands have already had a cumulative environmental impact on bayside habitats (Titus et al. 2009), inlet habitats (Rice 2012a) and sandy oceanfront habitats (Rice 2009, 2012b). Due to the demonstrated preference of plovers for unarmored beaches, stabilization should be used only in places where dense development has already occurred. Further, the best management practices described in Rice (2009, Appendix 1a) should be followed to avoid and minimize impacts wherever possible. Shoreline stabilization should be avoided in less developed and protected areas to minimize habitat losses due to accelerating sea level rise (see page 30-31).

Maintenance dredging activities at three deep-draft navigation channels along the Mississippi-Alabama coast have led to progressive land loss on the region’s barrier islands as their sediment supply has been reduced (Morton 2008). In Louisiana and other Gulf beaches, certain specific sediment placement projects therefore are deemed environmental restoration projects by the USFWS, because without the sediment, key plover habitat would erode below sea level as sea level rises and coastal lands subside (USACE 2010). These projects are designed to mimic low, overwash-prone natural barrier beaches. Pre- and post-construction monitoring should play a critical role in refining the design and evaluation of future coastal restoration projects in Louisiana, and potentially elsewhere in the piping plover nonbreeding range (see Actions 3.3, 8.3, and 8.4). Specific actions to reduce the impacts of shoreline stabilization and sand placement projects on piping plover habitats include:

A. Protect and maintain natural sand/sediment budgets and formation processes of key piping plover foraging and roosting habitats by avoiding shoreline stabilization whenever possible in these areas.

B. Require rigorous project monitoring for any stabilization project deemed necessary (see Actions 3.3, 6.1.1, and 8.3).

C. Minimize the frequency of beach nourishment, "renourishment," or "maintenance" to avoid long-term suppression of the prey base for piping plovers and continued degradation of plover habitat.

D. Conduct a thorough environmental analysis for any new hard stabilization project proposed. The potential loss of ecosystem function should be considered in the project design. Soft stabilization (i.e., "beach nourishment") likewise should only be undertaken after a thorough analysis. The design of a beach nourishment project should incorporate empirical evidence on the performance of other nearby beach nourishment or dredged material disposal projects. New sediment must be compatible with the native sediment on the existing beach (see Appendix 1a for specific guidelines).

E. Incorporate the best management practices described in Rice (2009, Appendix 1a) into dune building, restoration and stabilization projects, including those that pertain to beach scraping, sand fencing and vegetation-planting activities.

F. Maximize use of flexible project designs to allow for modifications as conditions change, especially in response to rising sea levels. Sand placement projects, for example, can be modified in their volume of fill, berm height and width, dune height and width, and geographic extent to allow for overwash areas and refuges for the invertebrate prey base to maintain piping plover habitat over the life of the project.

1.4 Protect important foraging and roosting habitats.

Nonbreeding plovers use a suite of habitats for both foraging and roosting (see pages 9-11). The birds may shift habitats within a day or between seasons in response to a host of variables, including tides and weather (Zonick 1997, Drake 1999b, Zonick 2000, Smith 2007, Arvin 2008, Ecological Associates 2009, Lott et al. 2009b, Zdravkovic and Durkin 2011). Wintering plovers are found at accreting ends of barrier islands, along sandy peninsulas, and near coastal inlets where they appear to prefer sandflats adjacent to inlets or passes, sandy mudflats along prograding spits, and overwash areas as foraging habitats (Cohen et al. 2008, Maddock et al. 2009). These types of substrates may have a richer infauna than the foreshore of high energy beaches and they attract large numbers of shorebirds (Nicholls and Baldassarre 1990b). Periodic overwash events create many of these habitat types and need to be allowed to occur to maintain many of them in their unvegetated or sparsely vegetated state.

Roosting plovers are generally found along inlet and adjacent ocean and estuarine shorelines and their associated berms (with wrack and other debris often used as wind-shields), and on nearby exposed tidal flats (Fussell 1990, Nicholls and Baldassarre 1990b, Lott et al. 2009b). Surveys on Laguna Madre, Texas have confirmed high plover use of both ocean beaches and bay shorelines, as well as back flats and island habitats for both foraging and roosting. They found that temporal habitat use shifts from the migratory to the winter survey period, and that spatial habitat use shifts as weather conditions (especially wind) affect lagoon habitat availability (Zonick 2000, Zdravkovic and Durkin 2011).

1.4.1 Protect and maintain important intertidal habitats including algal flats, sandbars, shoals, and ebb and flow tidal deltas.

Exposed intertidal areas were reported as the dominant foraging substrate in South Carolina (Maddock et al. 2009), northwest Florida (Smith 2007) and southwest Florida (Lott et al. 2009b). Algal flats and occasionally exposed seagrass beds have also been documented as important foraging sites for nonbreeding plovers and other shorebird species in Texas (Zonick 2000, Drake et al. 2001, Zdravkovic and Durkin 2011). Many of these habitats are threatened by a range of factors including permanent inundation due to sea level rise and potential dredging of channels. Off-road vehicles can damage the algal mat, leaving tracks and ruts that hold rain water and allow vegetation to encroach.

Shoals also provide important roosting and foraging habitat for birds. They are an essential element of the inlet ecosystem, also providing spawning areas for marine fauna and shelter for submerged aquatic vegetation (Ecological Associates, Inc. 2009). The mining of shoals for sediment unbalances the natural equilibrium of coastal processes, disrupts the sand budget, displaces fish and wildlife, and results in habitat loss and fragmentation. Removal of material from shoals often increases erosion on adjacent shorelines as the system attempts to fill the sediment deficit, which further increases threats to private property and infrastructure in developed inlet hazard zones (Cialone and Stauble 1998, Dabees and Kraus 2008, Morton 2008, Otvos and Carter 2008, Rice 2009). Recommended actions to protect intertidal habitats include:

A. Protect key intertidal areas (i.e., flats, seagrass and oyster beds, shoals, as well as the ocean intertidal zone), as identified in site stewardship plans (see Action 2.2).

B. Avoid and discourage sediment mining of flood and ebb tidal shoals for beach nourishment projects or to re-align channels away from threatened structures.

C. Protect emergent shoals (e.g., by restricting boating or land access to minimize human and pet disturbance, preventing sand mining, or acquiring the lands for conservation) as mitigation for increased development activity facilitated by shoreline stabilization projects on nearby beaches.

1.4.2 Maintain natural beach habitat and overwash and wrack formation processes.

Beach cleaning efforts remove accumulated wrack, fill topographic depressions, and destroy 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. Beach cleaning or grooming can result in habitat loss (Dugan and Hubbard 2010) and abnormally broad un-vegetated zones that are inhospitable to dune formation or plant colonization, thereby increasing the likelihood of erosion (Defeo et al. 2009). Tilling artificially nourished beaches to reduce compaction, as is sometimes required by the USFWS for sea turtle protection after beach nourishment activities, should only be conducted above the wrackline to avoid removal of valuable wrack habitat.

Natural beach processes that maintain washover sites should be allowed and even promoted, because they provide the sparsely vegetated habitat essential for diurnal roosting as well as foraging habitat for wintering piping plovers (Zonick 1997). These key habitats should be identified and given priority for protection in stewardship plans. The following actions are recommended to protect wrack and overwash processes:

A. Protect wrack by refraining from mechanical beach raking, cleaning, and tilling activities on nonbreeding plover sites. Where necessary, litter should be carefully removed by hand. If a beach must be mechanically cleaned or raked during the nonbreeding season, these activities should at least be prohibited within one mile of inlets (Appendix 2a).

B. If it is necessary for sea turtle protection after beach nourishment, limit tilling to the beach landward of (above) the wrackline.

C. Promote and maintain conditions for washover areas by allowing natural beach processes and natural geomorphological disturbance regimes to occur. Sand placement and dune stabilization projects should not construct a continuous dune ridge or high berm that prevents overwash processes. Where vegetation plantings and sand fencing cannot be avoided, adhere to the best management practices described by Rice (2009, Appendix 1a).

1.5 Maintain native vegetation by managing invasive species.

Invasive plants are a growing threat to migration and wintering plover habitat because they spread quickly, exhibit dense growth, and frequently out-compete native plants. The colonizing abilities and rates of spread of invasive (non-native) plants have also been identified as a potential challenge under certain climate-change scenarios (Truscott et al. 2006, Yamalis and Young 2010). Invasive plants can 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. Beach vitex, crowfootgrass, Australian pine, and other invasive plant species continue to change the vegetative structure of the coastal community throughout the wintering range, resulting in impacts to plovers and other shorebirds by reducing habitat suitability. The following actions are recommended to reduce habitat degradation caused by non-native, invasive plants:

A. Monitor the presence and level of threat posed by invasive vegetation. A number of databases that track emerging invasive species and management techniques (e.g., North American Invasive Species Network, Invasive.org) may provide useful tools for beach managers. Site stewardship plans (see Action 2.2) should include monitoring and appropriate management to prevent habitat loss and degradation caused by invasive plants.

B. Prohibit the introduction of invasive species in coastal areas and remove them where they have been found.

C. Provide technical assistance and incentives to private landowners for monitoring and management of invasive plant species in piping plover habitat. Work with partners through invasive species networks and programs to survey, monitor and control invasive plants in key plover habitats throughout the nonbreeding range.

2 Protect wintering and migrating piping plovers and their habitat from human disturbance.

Protecting nonbreeding piping plovers from human disturbance in the face of widespread demand for beach recreation is a continuing challenge (see pages 33-35). Efforts to manage and reduce human disturbance to migrating and wintering piping plovers at some sites have been implemented in recent years, but substantial threats remain. Recovery tasks pertaining to protection of migrating and wintering piping plovers from human disturbance include Great Lakes Task 2.14, Atlantic Coast Task 2.22, and Northern Great Plains Task 3.221.

2.1 Manage sites to reduce human-caused disturbance to nonbreeding plovers

Managers of key wintering sites surveyed by LeDee et al. (2010a) noted that improved monitoring to identify the sites receiving high use by plovers, careful enforcement of leash laws, limiting beach access, restricting the amount of beach traffic, and educating visitors to understand the meaning of restrictive signage would improve piping plover management at these sites. Management techniques for snowy plovers that included a roped-off area, signage, and a volunteer program to educate the public resulted in high visitor compliance, a 50% reduction in disturbance, an increase in plover abundance, and a redistribution of plovers into the protected area (Lafferty et al. 2006).

Techniques for minimizing disturbance to non-breeding plovers include vehicle, pedestrian, and pet restrictions. A few sites are entirely closed to public use (e.g., Egg Island Bar and St. Catherine's Island Bar in Georgia, T. Keyes, Georgia Department of Natural Resources, pers. comm. 2012). Other land managers only allow very limited access to designated areas (e.g., Deveaux Bank and Bird Key Stono in South Carolina) or only allow access by special permission (e.g., J. S. Phipps Preserve in Florida). Signs (and sometimes string fencing) excluding pedestrians, dogs, and vehicles from piping plover roosting and foraging areas are more widely used and impinge less on human recreation than site-wide restrictions. Examples include St. Vincent National Wildlife Refuge in Florida and mudflats and upland sandy habitats at Florida Fish and Wildlife Conservation Commission's Big Marco Pass Critical Wildlife Area in Collier County (B. Gruver, Florida Fish and Wildlife Conservation Commission, in litt. 2012). However, effective implementation of this approach requires regular monitoring to verify plover locations. Visitor education and patrolling by stewards and law enforcement personnel are also needed to support compliance with signs and fences. General actions recommended to minimize the effects of human disturbance on piping plovers include:

A. Identify key migrating and wintering sites and their important habitat features and manage public use to minimize disturbance to piping plovers. Techniques will depend on habitat type and location, and should protect the full diversity of beach, tidal flats and bars/shoals, and other roosting and foraging habitats used by plovers at each site.

B. Promptly plan and implement public use management at newly overwashed or emergent habitat areas.

C. Monitor sites to determine management effectiveness, as well as changes in habitat and piping plover distribution (see Action 3.2).

2.1.1 Manage pedestrian access to reduce disturbance to nonbreeding piping plovers.

Strategies to manage disturbances should be determined on a site-by-site basis and should consider the location of piping plover habitats, as well as types and amounts of recreational activity that typically occur at the site. Specific actions to minimize pedestrian disturbance to piping plovers include:

A. Post signs at points leading to areas of high recreational use with information about piping plovers and why protective symbolic fences (one or two strands of light-weight string tied between posts) are needed. In Pinellas County, Florida, Forys (2011) found significantly less human-related disturbance to red knots and American oystercatchers at a protected area (posted with signs) compared with three nearby unprotected (unposted) beaches. Signs and/or fencing should be posted and maintained from 15 July to 15 May, especially in areas where heavy recreational use coincides with high quality piping plover habitat (see examples of signs in Appendix 2e).

B. Extend the duration of protected areas currently established for breeding shorebirds (e.g., snowy and Wilson's plovers and American oystercatchers) and other sensitive wildlife to provide protection for nonbreeding piping plovers. Expand existing protected areas as needed to encompass key nonbreeding piping plover foraging and roosting sites. At Bon Secour National Wildlife Refuge in Alabama, for example, inter-dune and upper beach habitats symbolically fenced and posted for the endangered Alabama beach mouse and nesting snowy plovers also protect roosting nonbreeding piping plovers (J. Isaacs, USFWS, pers. comm. 2012).

C. Place parking lots, boardwalks, dune crossovers, and other access infrastructure to channel human use away from key plover habitats (Appendix 1a).

D. Manage boat landing locations to channel human use away from key plover habitats. Because boaters may originate from dispersed launch sites, providing them with information about management measures to prevent disturbance to piping plovers and other sensitive beach species may require targeted distribution efforts, such as at boat ramps and marinas (see Action 2.3).

E. Implement complete or partial closures of plover sites during the nonbreeding season, especially within designated critical habitat and on key federal or state conservation lands, where wildlife protection is a primary objective.

F. Develop outreach and education programs to explain beach restrictions that protect piping plovers and other shorebirds from human disturbance (see Action 2.3). Examples of management and interpretive signs are found in Appendix 2e.

G. Provide bird stewards at critical locations to educate beachgoers about restrictions to protect piping plovers and other shorebirds, especially during days and times of heavy beach use (see Action 2.4). The presence of a steward reduced by nine-fold the number of intruders into a beach area posted for bird protection in Pinellas County, Florida (Forys 2011).

2.1.2. Manage off-road vehicle access to reduce disturbance, mortality, and habitat degradation.

The effects of off-road vehicles on migrating and wintering piping plovers and their habitat, and prey base are discussed on page 34. The magnitude of these effects is particularly significant because vehicles extend impacts to remote stretches of beach where human disturbances would be much lower if access were limited to pedestrians. One of the best ways to protect the beach ecosystem is to prohibit off-road vehicles driving on beaches.

Where land managers and other stakeholders believe that beach-driving opportunities must be preserved, vehicle traffic should be channeled away from high-use plover habitats such as inlets. Parking should be prohibited in washover passes. Roosting habitats can be symbolically fenced and posted to protect wrack and to prevent vehicles from disturbing piping plovers. At Boliver Flats Sanctuary in Texas, cabled bollards exclude vehicles from intertidal flats used by large numbers of shorebirds, including nonbreeding piping plovers (W. Burkett, Houston Audubon, pers. comm. 2011; J.O. Woodrow, USFWS, pers. comm. 2012). Preliminary results from areas where off-road vehicles were excluded on South Texas Refuge Complex lands on South Padre Island show decreased disturbance of plovers and reduced habitat damage (Zdravkovic and Durkin 2011; M. Sternberg and S. Perez, USFWS, pers. comm. 2012). In order to minimize the effects of off-road vehicles on nonbreeding piping plovers and their habitat, the following actions are recommended:

A. Discourage beach driving at important migrating and wintering piping plover sites.

B. Where beach-driving is allowed, identify important piping plover roosting and foraging areas and restrict vehicles from driving or parking there.

2.1.3 Implement and enforce pet restrictions in key plover habitat areas

Restrictions on pets, especially dogs, have been implemented at a number of sites in the piping plover's coastal migration and wintering range. Whether the motivation for prohibiting pets or requiring short leashes is human health and safety, general protection of shorebirds, or conservation of piping plovers in particular, benefits include reduced disturbance to plovers. Examples of pet restrictions include the City of Folly Beach, South Carolina where there is an ordinance protecting Lighthouse Inlet (Title XV: Land Use, Chapter 151 151.50) (City of Folly Beach 2011). This ordinance states that "the property is also designated a protected area for birdlife in general and particularly for all shorebirds. There shall be no domestic animals whatsoever allowed starting at the gate on the east end of Folly Beach and continuing on the entire parcel known as the Old Coast Guard Base and below and above the high tide line." Restrictions on dogs in piping plover critical habitat were included in the biological opinion for the Captain Sams beach project in South Carolina (USFWS 2012a). Fort DeSoto County Park in Florida, for example, has a designated dog park, while another beach area is posted to restrict human and pet access for the benefit of birds (Pinellas County 2012). Pets are not allowed on Horn and Petit Bois Islands in the Mississippi District of Gulf Islands National Seashore (NPS 2012). In order to reduce disturbances to piping plovers by pets, the following actions are recommended:

A. Work with state agencies, municipalities, and key stakeholders to develop and enforce ordinances and other restrictions limiting pet access to important plover sites.

B. Engage local governments and dog owners in exploring options directing dog use to areas that are not important to shorebirds.

2.1.4 Prevent disturbance from other activities.

Fireworks, hang-gliding, kite surfing, horseback riding, and livestock grazing are examples of activities that may require management to prevent disturbance to migrating and wintering piping plovers. Targeted outreach and enforcement efforts may be needed to communicate the need for restrictions on when and where these kinds of activities occur and to steer participants to alternative locations (see Actions 2.2 and 2.3).

2.2 Develop and implement site stewardship plans that address human disturbance and other limiting factors.

Site stewardship plans should assess and address site-specific conditions, threats, and management needs at coastal migration and wintering piping plover sites (see recommendations in Appendix 2a). As much as possible, these plans should address the needs of all the site's sensitive flora and fauna. Site stewardship plans should include:

- site and threat assessment (e.g., see Western Hemisphere Shorebird Reserve Network's *Site Assessment Tool*, available online at http://whsrn.org/tools) that considers sensitive beach flora and fauna, including piping plovers,
- a summary of habitat conditions and ongoing human activities (e.g., land-based and boat access, pets, off-road vehicles),
- management practices to avoid or minimize disturbance to piping plovers and other sensitive species from human disturbance,
- management practices to address threats such as invasive plant species (see Action 1.5) and beach-raking (see Action 1.4.2) and to maximize the resiliency of the site to threats from climate change (see Actions 1 and 7.5),
- monitoring at appropriate frequency and intensity to support implementation of management (e.g., fencing of roost locations), as well as periodic plan review and evaluation,
- an outreach strategy (see Action 2.3),
- performance measures to gauge the effectiveness of management activities with regard to each identified threat, and
- defined responsibilities of participating partners.

As appropriate to their guiding mandates, landowners and managers should invite participation of regulatory agencies, user groups, and other stakeholders in the stewardship planning process. The following specific actions are recommended:

A. Incorporate stewardship of piping plovers and other shorebirds into federal, state, and local governmental planning processes (e.g., comprehensive conservation plans for national wildlife refuges and general management plans for national seashores; see also Action 6.3).

B. Conduct stewardship planning in conjunction with permitting of projects that affect piping plover habitat (see Action 6.1.1) and habitat conservation plans (see Action 6.1.2).

C. Give first priority to stewardship planning at sites with high amounts of plover use and high levels of human disturbance or other threats.

D. Coordinate and integrate site stewardship plans with state plover atlases (see Action 3.5), state wildlife action plans, and with other larger-scale planning efforts, as appropriate and useful.

2.3 Develop an effective migration and wintering range outreach strategy and customize it for use in site stewardship plans.

A rangewide outreach strategy should identify target audiences and facilitate coordinated messaging. Its goal should be to reach the full diversity of coastal habitat users in the eight migratory and wintering states and thereby increase awareness and understanding of management to conserve nonbreeding plovers and their habitat. See also sections 4 and 5 in Appendix 2a. Recommended outreach and education actions include:

A. Provide clear and consistent messages and guidance about the plight of the plover and how it serves as an indicator species for the beach ecosystem. Encourage compatibility and consistency among management efforts for multiple species cohabiting beach ecosystems.

B. Develop and distribute educational information, such as informational signs and brochures (see Appendices 2a and 2e). Customize materials and their distribution to effectively reach specific user groups (e.g., birders, boaters, beach homeowners, dog-owners).

C. Involve private landowners and beach user groups in development of education and outreach strategies that address local or site-specific conditions.

D. Focus outreach to government officials on both regulatory and non-regulatory (voluntary and incentive-based) coastal habitat conservation tools to address the threats identified at plover sites in their jurisdictions. Provide examples that show where and how these tools have been used effectively.

E. Use websites (see Action 9) to share outreach materials and up-to-date information about conservation of nonbreeding piping plovers. See, for example, USFWS South Carolina Field Office, http://www.fws.gov/charleston/piping_plover.html. Linking local communities (through Western Hemisphere Shorebird Reserve Network's sister school initiatives and exchanges or through other social media) may create a network for effective outreach and education.

2.4 Develop and implement training for monitors and stewards.

Trained staff and volunteers patrolling sites can provide public education, as well as increase adherence of beach users to restrictions on entering posted and fenced areas, controlling pets, using off-road vehicles, and other shorebird protection measures. Written materials and training workshops should furnish information about piping plover biology and habitat requirements, on local management practices and regulations, and also suggest communication strategies.

Mechanisms should be provided to respond to questions that arise and to give other support to stewards.

3 Monitor nonbreeding plovers and their habitat.

Monitoring is essential to ensuring that piping plover protection efforts contribute effectively to their conservation. At the regional level, tracking large-scale changes in habitat suitability, plover distribution, and threats helps set management and protection priorities. Site-specific monitoring identifies local factors limiting plover abundance and habitat use, ascertains site protection needs, and assesses whether ongoing management is effective. Habitat modification projects merit the most intensive monitoring to compare estimated and actual effects and inform assessment of similar future proposals. Observations of banded piping plovers inform understanding of the migration routes and wintering distribution of the breeding populations, regional movement patterns, and survival estimates. Recovery plan tasks pertaining to monitoring in the nonbreeding range include Great Lakes Tasks 2.12, 2.13, and 2.21; Atlantic Coast Tasks 2.1 and 2.31; Northern Great Plains Tasks 1.2 and 1.3**.**

Monitoring should be designed to answer specific questions, and methods should be tailored to objectives. In practice, each monitoring program may serve multiple goals and fall along a continuum of intensity, frequency, and duration. Thus, monitoring recommendations discussed below distinguish among relatively coarse-scale information needs regarding abundance and distribution (Action 3.1), more specific information needs pertinent to site management (Action 3.2), and monitoring appropriate to major habitat modification projects (Action 3.3). Monitoring efforts should be conducted by personnel who have the appropriate expertise and equipment to effectively accomplish the intended tasks.

3.1 Monitor nonbreeding piping plovers to assess regional abundance and distribution.

Range-wide and regional monitoring should be conducted to detect major changes in piping plover abundance and distribution and to reveal seasonal patterns of habitat use across the migration and wintering range. Monitoring protocols should reflect differences in survey methods needed for different parts of the nonbreeding range. For example, survey recommendations for roosting and foraging Atlantic coast birds are closely associated with daily tide levels (Cohen et al. 2008, Lott et al. 2009b), whereas wind-driven tides are an important factor at Texas sites (Drake et al. 2001, Zdravkovic and Durkin 2011).

More frequent monitoring and consistent regional data collection and assessment methodology will better inform management decisions with regard to site importance and management needs. Piping plover abundance during migration may vary substantially from mid-winter numbers. Seasonal habitat shifts may occur within a region; Texas surveys, for example, have documented major shifts from ocean beaches to bays as migration progresses into winter (Pinkston 2004, Zdravkovic and Durkin 2011). Survey frequency in South Carolina affected the accuracy of abundance estimates (Cohen, pers. comm. 2009). Where access is difficult or survey resources are limited, it may be advisable to survey a subset of sites on a rotating schedule. Examples of long-term consistent surveys of nonbreeding piping plovers include Cape Lookout National Seashore, North Carolina (monthly, starting in 2000; NPS 2004, 2010b), Mustang and San Jose Islands, Texas (respectively, more than 4,000 surveys since 1978 and more than 600 surveys since 1995; Amos pers. comm. 2010), mainland beaches in Mississippi (every two weeks during the nonbreeding season between fall 2008 and spring 2012; N. Winstead, Mississippi Department of Wildlife, Fisheries, and Parks, pers. comm. 2012) and Georgia (one-day statewide survey, annually in mid-winter since 2001; Keyes pers. comm. 2012).

Future International Piping Plover Winter Censuses (see Elliott-Smith et al. 2009) and other regional surveys should enhance understanding of piping plover abundance, distribution, and threats in locations where data gaps are most pressing. For example, planning and regulatory reviews for proposed Louisiana and Mississippi coastal restoration projects would benefit from additional surveys on offshore islands. Appendix 2c provides examples of survey data collection forms.

Outside the continental U.S., anecdotal reports of piping plover observations in the Caribbean and Central America (see page 5) warrant follow-up to ascertain piping plover abundance, precise locations, and consistency of presence. Although surveys in the Bahamas during the 2011 International Piping Plover Winter Census were more comprehensive than any prior effort and more than doubled the abundance estimate, not all potential habitats were covered (Elliott-Smith pers. comm. 2012a); some of these areas were the focus of surveys in 2012. Additional survey needs have also been identified in Mexico (Mabee et al. 2001, Banda *in* Elliott-Smith et al. 2009).

3.2 Monitor nonbreeding sites to identify limiting factors and effects of management.

Understanding of site-specific stressors underpins planning and implementation of effective and efficient site management (see Action 2.2). Site-level monitoring should identify within-site plover distribution patterns, local threats, and management needs; assess the effectiveness of management activities; and facilitate adaptation of management efforts to changing conditions. Monitoring at Kiawah Island, South Carolina, for example, has revealed a seasonal shift in piping plover distribution from the ends of the island during the winter, to the length of the ocean beach during the spring migration (M. Bimbi, pers. comm. 2012). Recommended survey protocols are provided in Section 3 of Appendix 2a.

Ideally, all wintering and key migration sites should have site-level monitoring as a component of their site stewardship plans (see Appendix 2a). However, managers faced with resource constraints may need to prioritize sites. Ranking factors should include: (1) abundance and consistency of wintering or migrating plovers (relative to other sites in the region); (2) documented presence of Great Lakes plovers; (3) magnitude of threats and their potential manageability; (4) contribution to the mosaic of nearby habitats used by piping plovers. In some cases, diversity of other shorebirds using a site may increase the priority for piping plover monitoring as a component of multi-species survey efforts. Since critical habitat unit conditions may vary and non-designated sites may improve over time, critical habitat designation does not automatically reflect a site's current importance. For example, a large undesignated flat west of Mustang Island State Park in Texas becomes emergent when seasonal water levels are lowest, exposing seagrass and oysters, and supporting high numbers of piping plovers (>230) and other shorebirds (Cobb pers. comm. 2011). Managers should periodically review and revise priorities, especially after major habitat enhancing events, but also if habitat declines due to changes in coastal processes. The following site monitoring actions are recommended:

A. Monitor all critical habitat units and other sites with preferred habitat features (inlets, washovers, ephemeral pools, sand bars, algal mats, etc.) on a regular schedule, with the frequency dependent on factors listed above. If habitat conditions are steady and the number of piping plovers is fairly consistent from year to year, it may be sufficient to monitor plover abundance and distribution two to three times per month during a full nonbreeding season at three to five year intervals. Important sites supporting high plover abundance and use that are not designated as critical habitat should also receive consistent monitoring and protection efforts.

B. Provide monitoring coverage for the full mosaic of habitats used by piping plovers in an area whenever possible. Understanding use of habitats that are difficult to access or that receive irregular use may require specially-focused methods. For example, understanding plover use of seasonally emergent habitat in four Texas bays and threats to those habitats is one objective of an ongoing study (Newstead 2010).

C. Conduct surveys following major habitat-modifying events (e.g., hurricane, oil spill) and compare with prior surveys to assess impacts on the plovers and their habitat. Such surveys may discover newly-created or enhanced habitats that support plover use.

D. Customize long-term monitoring protocols consistent with site-specific management and threats. Periodically review monitoring protocols and revise as needed.

3.3 Provide robust monitoring of piping plover abundance, distribution, survival, and habitat characteristics before and after major projects that have the potential to substantially modify important migration and wintering piping plover habitat.

Monitoring of piping plovers and their habitat is an important component of any major project (including coastal restoration projects) that will modify habitat that is currently used by substantial numbers of migrating or wintering piping plovers. Within the authorities and funding capability of the project sponsors, robust monitoring should be required as a means to compare estimated and actual take, assess the efficacy of conservation measures included in the project description or terms and conditions of the incidental take statement, determine if incidental take has been exceeded, and inform assessment of future project proposals. Several recent USFWS biological opinions for major habitat stabilization or restoration projects contain complementary components to compare the pre- and post-project piping plover abundance and distribution during each season, invertebrate community (foraging resources), and topography of the habitat (USFWS 2010a, 2012a). Because monitoring methods are rapidly evolving, project planners and USFWS biologists should keep apprised of new approaches and use the most suitable methods to detect changes (with measures of precision) in numbers of piping plovers using the site during each season and their emigration and survival rates. Rapid feedback from monitoring of coastal stabilization and restoration projects is essential to refinement of future proposals for similar projects.

3.4 Record and promptly report observations of banded piping plovers.

Resighting of banded plovers informs understanding of migration routes and wintering distribution of the breeding populations, site fidelity and regional movement patterns within the nonbreeding range, and survival estimates. Since piping plovers have a shorter average life-span than many other shorebird species, opportunities to capture information from each banded bird are relatively limited. Recording and reporting of banded piping plovers should be incorporated into all monitoring programs, regardless of purpose and intensity. The following actions are recommended to facilitate recording and reporting banded piping plovers:

A. Establish and publicize efficient procedures for reporting of band sightings. Banding combinations applied in both the breeding and nonbreeding range must be carefully coordinated to avoid confounding unique identifiers and maximize accuracy of resighting observations. Appendix 2b provides instructions for recording and reporting band combinations. In some cases, these have been effectively supplemented by banding and reporting information pertinent to a particular study. For example, see information cards for resighting piping plovers banded in the Bahamas by Environment Canada in 2010 (Gratto-Trevor 2010).

B. Increase the accuracy of data and sightings by providing training for key biologists and volunteers across the piping plover range, including those working in the breeding range who may encounter birds banded during the winter. Detailed information about band resighting may be found in Maddock (2010, also online).

3.5 Develop a state-by-state atlas or other database containing geospatial information on wintering and migrating piping plovers.

A state-by-state site atlas would provide a central repository for data collected at each individual site and foster comprehensive and consistent information to guide management efforts in the wintering and coastal migration range. Contents and format should be customized to meet the needs of biologists and other users in each state. Information might include piping plover abundance and distribution, land ownership, habitat conditions, threats, ongoing management and monitoring efforts, and additional management recommendations. See example in Appendix 2d. Specific recommendations include:

A. Create and maintain a state-by-state piping plover atlas, incorporating pertinent data from site stewardship plans (Action 2.2). Appendices A and C in Lott et al. (2009b) provide another example.

B. Summarize the statewide abundance and distribution of piping plovers, seasonal patterns, and inter-annual trends. Where appropriate data are currently lacking, multiple surveys by qualified personnel across several migration and wintering seasons should be conducted to determine seasonal patterns. For example, monitoring at two intensities was conducted in South Carolina in 2006-07 and 2007-08 (Maddock et al. 2009).

C. Track future changes to habitat conditions by reporting information on new projects that modify plover habitat and fill information gaps to update databases described in Appendices 1b and 1c.

4 Protect nonbreeding plovers and their habitats from contamination and degradation from oil or other chemical contaminants.

Although the 2009 5-Year Review concluded that contingency plans made threats from contaminants in the coastal migration and wintering range a minor threat, the 2010 Deepwater Horizon oil spill demonstrated the potential for large-scale impacts from leaks or spills to affect nonbreeding piping plovers. The substantial infrastructure and transport operations associated with oil and other chemicals along the Gulf of Mexico pose risks that are now well-recognized. However, six oil spills of known origin in the Atlantic Coast breeding range since 1986 (Mierzykowski 2009) illustrate that no part of the coastal range is immune from oil spill and contaminants threats. Prevention should be the first line of defense against this threat, but procedures must also be in place to guide responses and facilitate a careful balance between efforts to contain and remove contaminants and minimize the disturbance to piping plovers and their habitat, as well as other sensitive flora and fauna.

Specific current threats of exposure to pesticides and other contaminants during migration and wintering have not been identified (see page 37). However, vigilant attention to any contaminated substrates or potential piping plover prey is warranted. Likewise, diligent efforts should be exerted to seek sources of exposure if high contaminant loads are detected in plovers or their eggs that do not appear to be present in the breeding environment.

Recovery plan tasks relevant to protection of nonbreeding piping plovers from contaminants, including oil spills, are Great Lakes Task 2.15, Atlantic Coast Task 2.23, and Northern Great Plains Task 3.222.

4.1 Update and refine contaminant exposure response protocols to protect plovers and their habitats. Incorporate updated procedures and protocols into all appropriate federal, state, and local oil and chemical spill contingency plans.

Experience during the Deepwater Horizon oil spill illustrates the need for up-to-date information about plover distribution and abundance to inform emergency response efforts. In addition to potential direct habitat degradation from oiling of intertidal habitats and retraction of stranded boom, impacts to piping plovers may occur from the increased human disturbance associated with boom deployment and retraction, clean-up activities, wildlife response, and damage assessment crews working along affected shorelines. Time-sensitive decisions must evaluate trade-offs among such impacts.

During the Deepwater Horizon response, the USFWS developed best management practices and contingency plans. They were designed to help avoid or minimize impacts to threatened and endangered species by protecting plovers and key habitat features such as beach wrack line, dunes, tidal pools, and intertidal and bayside flats. However, development and coordination of management practices and plans during a major spill is, at best, highly challenging.

Priority should be accorded to oil spill contingency planning for habitats located near shipping lanes, especially those that also support dense aggregations of piping plovers. A number of critical habitat units throughout the plovers' nonbreeding range are located either along or near inlets that open to shipping channels serving the major ports of Atlantic and Gulf coasts. These include Morehead City and Wilmington, North Carolina; Charleston, South Carolina; Savannah, Georgia; Jacksonville, Tampa, and Pensacola, Florida; Mobile, Alabama; Gulfport and Pascagoula, Mississippi. Examples of Texas sites supporting large numbers of piping plovers in proximity to shipping lanes include (but are not limited to): Bolivar Flats along the Houston Ship Channel (more than 100 piping plovers), North Pass near the Aransas Pass into Corpus Christi Bay (more than 70 piping plovers), South Bay adjacent to the Brownsville Ship Channel (more than 150 piping plovers), and Surfside to Galveston Seawall (more than 130 piping plovers). In Louisiana, habitats hosting 75-100 piping plovers are located within a 38-km radius of Port Fourchon and the Louisiana Offshore Oil Platform facility (S. Maddock, Audubon North Carolina, pers. comm. 2009). Recommendations pertinent to reducing effects of oil spills and other contaminants include:

A. Develop consistent, updated protection measures and best management practices for protecting nonbreeding piping plovers during contaminant response operations, and incorporate them into all appropriate local, state, federal, and corporate spill response plans. Best management practices should be developed with assistance from oil spill response and contaminants specialists. Best management practices and contingency plans should address season- and habitat-specific needs of piping plovers throughout the annual cycle.

B. Coordinate piping plover-specific protections with best management practices for other beach-dependent shorebirds and waterbirds to minimize confusion and contradictions and to facilitate rapid decision-making in an emergency.

C. Prioritize protection efforts (both preventive and remedial actions) during response operations in locations with the highest plover abundances based upon the best available plover surveys.

D. Create and post "no disturbance" closure zones on priority bayside habitats not affected by oil or other contaminants to ensure their continued availability for plover use.

E. Weigh relative risks of prolonged contact with and ingestion of oil versus the risks associated with capture and rehabilitation (Frink et al. 1996) when determining response to oiled piping plovers.

F. If sand placement projects are considered to prevent or reduce future effects of contaminants (e.g., where human-caused sediment deficits have affected the natural dynamics and functions of beach systems), careful consideration should be given to potential adverse effects on piping plovers and their habitats (see Action 1.3 and Appendix 1a).

G. Evaluate impacts on piping plovers from any contaminants and response operations, and use new information to improve future response.

4.2 Develop a rigorous experimental design to evaluate short- and long-term effects of alternative contaminant clean-up techniques on nonbreeding plovers and their habitat.

Trade-offs among the potential direct, indirect, and cumulative impacts of oil and other contaminant spills and application of alternative remediation techniques are poorly understood. A rigorous scientific approach (with replicate treatments) to measure direct and indirect effects of contaminants, disturbance from clean-up operations, and other effects should be designed for rapid implementation in the event of a major oil or contaminant spill.

4.3 Identify and remediate any sources of contaminants with potential to adversely affect piping plover survival and reproduction.

Recognition and assessment of any threats from contaminants in the piping plover's migration and wintering range will require close communication and coordination among biologists in the nonbreeding and breeding range. If contaminant concentrations sufficient to affect piping plover health are detected in substrates or prey at known wintering sites, an analysis of risks associated with alternative responses (including temporary exclusion of piping plovers from the site) should be conducted. Communication should be established with biologists in known or suspected breeding locations, and the need for testing of unhatched eggs should be evaluated. Conversely, if elevated contaminants are detected in breeding piping plovers or their eggs that are unlikely due to breeding area exposure and the birds' specific wintering locations are known, biologists should assess the need for testing of substrates and prey at wintering sites.

5 Assess predation as a potential limiting factor for piping plovers on wintering and migration sites.

Although the extent of predation to nonbreeding piping plovers is unknown, it remains a potential threat (see page 39). The 2003 Great Lakes recovery plan expresses concern about increased predator abundance on the wintering grounds, and investigations into predation threats in the coastal migration and wintering range falls under Great Lakes Recovery Plan Task 2.16 (i.e., identification and reduction of additional threats to winter populations). The potential need for research to ascertain impacts of predation is articulated in Action 8.10, but is accorded low priority based on current information.

5.1 Survey for the presence of avian or mammalian predators (especially non-native predators, such as feral cats) on nonbreeding plover sites and include appropriate monitoring and management recommendations in site stewardship plans.

The USFWS South Carolina Field Office (T. Hall, USFWS, in litt. 2007) has endorsed removal of free-roaming cats through humane capture by licensed animal care and control facilities, cat licensing and leashing requirements, and prohibitions on abandonment of domestic animals. If monitors detect regular use of posts, signs, and other structures as perches for raptors, the perches should be modified or removed.

5.2 Consider ancillary benefits to nonbreeding plovers when developing predator management plans for sites, including national wildlife refuges and state parks.

Examples of predator management programs in the nonbreeding range include a public lands predator control partnership in northwest Florida (USFWS 2009d) and the Complex Integrated Predator Management Plan at the Florida Keys National Wildlife Refuge (USFWS 2011a).

6 Improve application of regulatory tools.

Regulatory tools provide the legal framework for consistent, effective application of conservation and management recommendations (see pages 41-45). This section provides recommendations and examples pertinent to the ESA, the Coastal Barrier Resources Act, and legal authorities for the protection and management of federal lands. State and local regulations and policies provide further opportunities for piping plover conservation and should be fully utilized.

The recommendations in this section will enhance implementation of actions to protect nonbreeding piping plovers from habitat degradation and human disturbance (see Actions 1 and 2). They also serve many recovery tasks for nonbreeding piping plovers in the Great Lakes, Atlantic Coast (especially Task 2.24), and Northern Great Plains recovery plans.

6.1 Fully utilize ESA authorities to conserve piping plovers and their habitats.

Sections 7 and 10 of the ESA provide key tools for piping plover conservation (see pages 41-42).

6.1.1 Maximize avoidance of adverse effects to piping plovers and their habitats through section 7 consultations with federal agencies.

At least 43 formal biological opinions addressing nonbreeding piping plovers were completed by the USFWS between 2005 and early 2012; these attest to the potential contribution of section 7 consultation to piping plover conservation. Furthermore, this tally does not include many informal consultations, including several that resulted in changes to the federal action that eliminated substantial adverse effects to piping plovers. The U.S. Army Corps of Engineers has been the most frequent action agency requesting formal consultation, but biological opinions have also been provided to the Federal Highway Administration, the Federal Emergency Management Administration, the Department of Defense, and the National Park Service. Proposed projects have included beach nourishment, inlet dredging and relocation, municipal harbor improvements, creation of a fish pass through a barrier island, and beach maintenance (including removal and burial of seaweed).

Avoidance of all adverse impacts is always the most desirable outcome of consultation and allows the consultation process to be concluded informally. Management of federal lands, including national wildlife refuges, National Park Service units, and military lands to avoid adverse effects provides important direct benefits to piping plovers, and also furnishes positive examples to nonfederal landowners (see Action 6.3). When adverse effects cannot be completely avoided, incorporation of measures to minimize them can help preserve the overall habitat conditions and reduce disturbance to plovers. The informal phase of the consultation process also provides opportunities for federal agencies or applicants to mitigate adverse effects of a project through incorporation of conservation measures into the project description, thereby assuring benefits to completely or partially offset adverse effects. Take, which includes harm and harassment, is further reduced through requirements to implement "Reasonable and Prudent Measures."

Sharing biological opinions that incorporate conservation measures in the proposed action or specify reasonable and prudent measures to reduce incidental take can stimulate more effective and consistent approaches to consultations across the nonbreeding range. Programmatic consultations can provide a regional framework that strives to minimize the additive effects of many small or medium-sized projects, thereby preserving overall habitat conditions for plovers and avoiding the likelihood that a cumulative habitat loss will become a major obstacle to future project proposals. If sufficient protections for the listed species are provided through the programmatic consultation, other benefits may include streamlined consultations for individual projects.

Biological opinions must consider the short- and long-term effects of prior consultations on both the status of the species and its critical habitat. Analyses conducted for consultations on habitat modifications (whether or not it is designated as critical habitat) should recognize that habitat is not homogeneous and that piping plovers depend on a mosaic of microhabitats. A project that adversely affects a particularly important foraging or roosting habitat feature may reduce the overall ability of a much larger area to support migrating and wintering piping plovers. Furthermore, consultations should give due consideration to areas not designated as critical habitat if abundance of piping plovers or presence of a particular habitat feature demonstrates its importance to the species.

All consultations should include efforts to:

A. Avoid and minimize impacts to piping plovers and their foraging and roosting habitat before, during, and after project implementation. Effects of projects that disrupt or counteract natural coastal formation processes may grow over time.

B. Whenever possible, conduct several years of pre-project monitoring to locate and map habitats used by piping plovers for foraging and roosting throughout the migration and wintering cycle.

C. Evaluate and reduce indirect effects, such as increased human disturbance at nearby sites. Examples of projects that can induce disturbance include preserving or increasing recreational access through stabilization of roads, construction of marinas and docks, and maintenance of navigation channels used by recreational boaters.

D. Incorporate appropriate monitoring to assess project-induced take, including harm and harassment. See, for example, USFWS (2010a) and USFWS (2012a).

Additional considerations for planning and evaluating beach nourishment, artificial berm or dune creation and enhancement projects (including coastal restoration projects) follow:

A. Map preferred piping plover habitats (including washover passes, inlets, ephemeral ponds and pools, lagoons, and bayside mud and sand flats) before project implementation. Examples include: USFWS (2008b) and USFWS (2008d). For emergency consultations, even cursory mapping is preferable to none.

B. Involve coastal geomorphologists in consultations to evaluate project features and assure that long-term effects on plover habitat features are anticipated and minimized (if not avoided). Examples include: USFWS (2006) and USFWS (2007c).

C. Include “notches” (breaks in dunes or berms) in proposed sand placement projects to preserve natural overwash processes, especially on public lands. Examples include: USFWS (2007c) and USFWS (2008a). Notch widths should vary depending on local conditions and geomorphic features. Post-project monitoring should be conducted, and modifications may be necessary if notches prove too narrow or high to allow overwash. If artificially enhanced berms or dunes that are present in or adjacent to the project are no longer needed, consider removing or lowering them to promote restoration of overwash.

D. Prior to placement of dredged material, clearly mark avoidance areas to prevent accidental spillover into areas intended for protection. Also mark access points for vehicles and other equipment to minimize the extent of disturbance to plovers and their habitat. Examples include: USFWS (2007c) and USFWS (2012a).

E. Avoid or reduce damage to wrack during and after project construction by requiring that vehicles drive above or below the primary wrack line (e.g., USFWS 2008d). Provide wrack protection during post-project beach management activities by ceasing or reducing wrack removal during beach-cleaning activities. Examples include: USFWS (2007b), USFWS (2008c), USFWS (2008d), USFWS (2010b), and USFWS (2012a).

F. Conduct pre- and post-project surveys of the prey base in important habitats to document the extent of harm to habitat, as well as to inform evaluation and improved design of future projects. Examples include: USFWS (2006) USFWS (2010a), USFWS (2010b), and USFWS (2012a).

G. Incorporate provisions prohibiting introduction of (and requiring removal of existing) invasive plant species that degrade beach and dune habitats. This requirement has been used in south Florida (USFWS 2008b) to remove the invasive Australian pine (*Casuarina equisetifolia*), but it may also be applied to other invasive species.

H. Reduce impacts of post-project disturbances by identifying and posting piping plover roosting areas between 15 July and 15 May. Examples include: USFWS (2010b) and USFWS (2012a).

I. Reduce impacts of post-project disturbances by prohibiting dogs on the beach between 15 July and 15 May. Examples include: USFWS (2006) and USFWS (2012a).

Additional considerations for planning and evaluating inlet dredging and relocation projects include:

A. Seek alternatives to inlet relocation.

B. Experiment with creation of piping plover habitat with sediments removed during inlet dredging. Examples include: USFWS (2009a), USFWS (2009b), and USFWS (2010e). Potential locations for habitat creation include the inlet zone itself or adjacent to bayside habitat.

C. Minimize disturbance from boaters landing on shoals, spits, or baysides (e.g., USFWS (2007a)). Post signs and distribute maps and outreach materials. Provide stewards during high use periods.

D. Avoid dredging submerged and emergent shoals in order to preserve beach dynamics and plover habitat. Examples include USFWS (2009a) and USFWS (2010f).

6.1.2 Adopt effective piping plover protections in Habitat Conservation Plans under section 10(a)(1)(B) of the ESA.

Permits under section 10(a)(1)(B) should incorporate pertinent actions recommended in other sections of this CCS. See, for example, the summary of protections provided by the Volusia County Habitat Conservation Plan (see page 42). The Florida Fish and Wildlife Conservation Commission, in cooperation with Florida's Department of Environmental Protection, is preparing a habitat conservation plan for activities regulated under Coastal Construction Control Line permits. These activities include new construction and rebuilding of developments, coastal armoring, beach scraping, beach raking and debris removal, beach berm and dune restoration, post-storm actions such as debris removal, and vegetation planting (Florida Department of Environmental Protection 2012). The habitat conservation plan permitting process may be a mechanism for providing long-term protections described in the delisting criteria specified in the Atlantic Coast and Great Lakes piping plover recovery plans.

6.2 Provide appropriate Coastal Barrier Resources Act determinations.

The USFWS is responsible for issuing concurrence to federal agencies that propose spending federal funds within the Coastal Barrier Resources System. The USFWS is on record stating that beach nourishment and dune and berm construction projects are inconsistent with the purposes of the Coastal Barrier Resources Act (USFWS in litt. 1996, 2009a, 2009b, 2010). These determinations concluded that the proposed projects were designed to protect structures, not wildlife and dynamic coastal barrier resources. By contrast, the USFWS has determined that a sand placement project designed to restore and enhance a natural shoreline that supports a high density of nesting sea turtles in an area with an active shorebird management plan was consistent with the Coastal Barriers Resources Act (USFWS in litt. 2009c).

6.3 Provide exemplary protection for migrating and wintering piping plovers on federal lands.

More than 30 percent of designated critical habitat for nonbreeding piping plovers is on federal lands managed by the USFWS's National Wildlife Refuge System, the National Park Service, and the Department of Defense[18]. The legal authorities guiding each of these agencies accord them responsibilities for conservation of threatened and endangered species (see page 43) that complement ESA requirements. Ongoing piping plover conservation efforts on federal lands

[18] The estimated proportion of federal land comprising the critical habitat has remained relatively constant through the redesignations in North Carolina and Texas (USFWS 2008f, 2009e). However, the critical habitat designation under-represents the proportion of important federally-owned wintering piping plover habitat. Most notably, the Padre Island National Seashore in Texas was excluded from the designation, but protections for piping plovers and their habitat are effected through other provisions of the ESA and Seashore management plans (USFWS 2009e).

should be continued. For example, recreational off-road vehicle use is not allowed on any national wildlife refuge beaches in the Southeast Region (C. Hunter pers. comm. 2011b).

Land management planning requirements (i.e., comprehensive conservation plans for national wildlife refuges, general management plans for national parks, and integrated natural resource management plans for military lands) formalize review of current protection programs and evaluation of potential improvements. See, for example, provisions in the Comprehensive Conservation Plan for Laguna Atascosa National Wildlife Refuge to prevent disturbance to piping plovers and habitat degradation along beaches, washover passes, and algal flats (USFWS 2010c). However, new information about piping plover management needs, natural habitat improvements, or changes in public use or military activities outside of formal plan revisions may bring to light conservation needs that should be addressed between revisions of long-term plans. Protection of piping plovers and their habitat on federal lands is important not only because of its direct benefits to plovers that use these areas, but because plover protection programs on federal lands serve as examples to nonfederal landowners.

6.4 Encourage effective use of state and local laws and regulations to enhance conservation of nonbreeding piping plovers and their habitat.

State and local laws can provide important protections for piping plovers and their habitat. Effective use of authorities, such as state and local zoning regulations, can prevent developments in locations where subsequent artificial stabilization will likely be needed (see resources for identification of high risk coastal areas in Action 1.1). The Jekyll Island Conservation Plan, for example, articulates desired future conditions, management priorities, and strategies for the conservation of beaches and interdunal swales, including beach-dwelling wildlife (Jekyll Island Authority 2011). Likewise, rules controlling access of dogs to beaches are typically under the jurisdiction of landowners, including municipal and state agencies. Compilation of pertinent existing state and local laws, regulations, and policies can facilitate the effective use of these authorities. Recommendations to improve or refine existing regulations and their implementation may also be appropriate.

7 Develop mechanisms to provide long-term protection of nonbreeding plovers and their habitat.

Threats to nonbreeding plovers are pervasive and persistent. Improved application of ESA authorities (see Action 6.1) can increase their contributions to recovery, but eventual removal of ESA protections will likely be contingent on alternative mechanisms to reduce and manage these threats (see delisting criteria from recovery plans on page 3). Furthermore, development of protocols to address future conditions (including, but not limited to, those induced by climate change) is essential in the context of long-term protection of migrating and wintering piping plovers. The need for long-term conservation commitments in the nonbreeding range is articulated in Atlantic Coast Recovery Plan Task 2.26, and the Northern Great Plains Recovery Plan discusses elimination of current and potential threats to wintering and migration habitat (Tasks 2.23 and 2.33). Delisting criterion 5 in the Great Lakes Recovery Plan articulates the need for long-term protection and management activities in essential wintering habitat.

7.1 Seek long-term agreements with landowners to protect nonbreeding plovers and their habitats.

Experience gained through implementation and periodic evaluation of site stewardship plans (see Action 2.2) should be incorporated into long-term agreements that remove or manage the threats that currently warrant listing of piping plovers under the ESA. Prototype agreements should be developed at sites with a history of intensive and successful piping plover protection, a high degree of commitment to the piping plover protection program, and where experienced on-site shorebird biologists can provide expertise to devise and test alternative types of agreements. For example, Bolivar Flats Sanctuary in Texas is managed by the Houston Audubon Society under a long-term lease agreement with the Texas General Land Office (Houston Audubon Society 2012, Woodrow pers. comm. 2012). Ingenuity will be required to develop agreements that are flexible enough to: (1) respond to the changeable nature of habitat conditions and site-specific threats, and (2) avoid unnecessary restrictions on other beach uses, but (3) also ensure adequate protection for piping plovers. Habitat Conservation Plans (see Action 6.1.2) may offer one mechanism for long-term agreements, but commitments may be articulated in a variety of other ways, such as memoranda of agreement.

7.2 Acquire important habitat if it becomes available.

Federal and state conservation agencies and private conservation organizations should continue efforts to acquire piping plover habitat as it becomes available. For example, important piping plover habitats on South Padre Island in Texas have been acquired by the South Texas Refuge Complex, and Audubon Florida completed purchase of Lanark Reef in September 2012. The USFWS and other organizations should undertake further efforts to identify other important sites that may become available for acquisition, and the USFWS should continue to monitor excess federal lands for plover habitat and apply for it as it becomes available.

7.3 Seek non-regulatory recognition for sites.

Some piping plover sites receive recognition under programs such as BirdLife International's Important Bird Area program (implemented in the U.S. by National Audubon Society) and the Western Hemispheric Shorebird Reserve Network. Other sites may be eligible for these and similar designations. However, criteria associated with these and other programs may be incompatible with the distribution of sparse populations or rare species such as piping plovers. The minimum threshold for nomination to the Western Hemispheric Shorebird Reserve Network, for example, is visits by 20,000 shorebirds per year, so importance to piping plovers is unlikely to play a major role in this designation. Where such recognitions can be gained, they may stimulate added interest in habitat conservation and stewardship from scientists, volunteers, and others.

7.4 Institutionalize plover site management through long-term planning at the local, state and federal levels.

Appropriate agencies and organizations should incorporate plover protection strategies into their plans and operations, so these can become standard operating procedures. In addition to furnishing legally mandated reviews and approvals, the USFWS and state wildlife agencies should readily provide technical assistance to maximize opportunities to build and maintain momentum for self-sustaining long-term conservation of nonbreeding piping plovers. Non-governmental organizations and researchers can also provide valuable technical assistance.

7.5 Address long-term climate change threats, including accelerating sea level rise.

Ongoing coastal stabilization activities will strongly influence the effects of sea level rise on piping plover habitat, and near-term efforts to increase habitat resiliency are critical (see Actions 1.2, 1.3 and 1.4). However, long-term protections must also accommodate sea level rise and other potential climate change-induced threats. Potential threats include shifts in the piping plover's nonbreeding range, flooding of key habitat areas, changes in phenology, increased disease or parasites, changes in abundance and composition of prey, increased salinity of barrier beach groundwater, spread of non-native vegetation, and new competitor or predator species (Schneider and Root 2002, Lovejoy and Hannah 2005, UNEP 2006).

The USFWS and National Park Service (USFWS 2010d, NPS 2010a) and other key federal agencies have published strategic plans addressing climate change. The 2012 draft National Fish, Wildlife, and Plants Climate Adaptation Strategy and attendant Coastal Ecosystems Background Paper (USFWS et al. 2012) also provide strategies and guidance on the spectrum of anticipated impacts related to climate change. Mawdsley et al. (2009) also provide adaptation strategies for conserving wildlife and biodiversity with climate change. These strategies should be incorporated into all levels of short- and long-term planning for coastal ecosystems and wildlife conservation, as well as piping plover-specific stewardship plans. For example, voluntary guidance encourages incorporation of climate change considerations into state wildlife action plans (Association of Fish and Wildlife Agencies 2009). State coastal zone management plans provide another potential vehicle for identifying and implementing climate change adaptation measures.

Several tools for assessing the effects of climate change on shorebird habitat are available, and new approaches are under development. For example, the Manomet Center for Conservation Sciences' Shorebird Recovery Project, in partnership with the USFWS Northeast Region's

Division of Refuges, has developed the Climate Change Vulnerability Assessment for Shorebird Habitat, an Excel-based assessment and decision-making tool (Stolley 2010, available online). Another approach to forecast the effects of sea level rise on Atlantic Coast piping plover breeding habitat that incorporates predicted changes in beach morphology (Karpanty 2012) may be adaptable to nonbreeding habitat. The Florida Fish and Wildlife Conservation Commission is developing predictive models using The Nature Conservancy's climate change vulnerability index, climate change models developed by Massachusetts Institute of Technology, and information provided by Florida species experts. This effort incorporates many variables over a range of time intervals and includes socioeconomic variables as well as data on conservation lands, sea level rise, migration of vegetative communities, and conversion of land types (J. Brush, Florida Fish and Wildlife Conservation Commission, pers. comm. 2011). Recommendations to address climate change include:

A. Forestall permanent loss of piping plover habitats with rising sea level and climate change by discouraging coastal development and shoreline hardening (see Actions 1.1, 1.2, and 1.3).

B. Implement other strategies to reduce threats from accelerating sea level rise (see also Action 8.8).

C. Evaluate the projected effects of sea level rise not mitigated through implementation of recommendations A and B, above, on the distribution of piping plover habitats over time and at multiple scales (i.e., local, regional, national, and international).

D. As information about other effects from changes in precipitation, water and air temperatures, and other weather patterns on nonbreeding piping plover habitat becomes available (see Action 8.9), develop and implement strategies to reduce related threats to piping plovers.

E. Customize climate change adaptation and mitigation strategies to local habitat conditions and coastal processes and incorporate them into long-term management plans and agreements.

8 Conduct scientific investigations to refine knowledge and inform conservation of migrating and wintering piping plovers.

Past research efforts have made important contributions to the conservation of nonbreeding piping plovers and several studies are currently in progress. However, there are many needs for further information. Research tasks related to wintering ecology and threats were recommended in the recovery plans (Great Lakes Task 4.4, Atlantic Coast Task 3.1, Northern Great Plains Task 2.3). The 2009 5-Year Review also identified a number of research and information needs in the migration and wintering range of the piping plover.

Activities related to surveying and monitoring migration and wintering habitats, including monitoring before and after habitat modification projects, are provided in Action 3. Action 4.2 addresses the need for an experimental design to evaluate trade-offs among contaminant clean-up techniques, and Action 4.3 outlines potential studies to identify any sources of contaminants that might originate in the nonbreeding range.

8.1 Evaluate factors in the coastal migration and wintering range that may affect piping plover survival and subsequent fecundity.

Results of Roche et al. (2010) indicate that shared wintering or stopover sites may influence annual variation in survival among geographically disparate breeding populations. LeDee (2008) and LeDee et al. (2010b) highlighted the need to assess piping plover survival during nonbreeding periods. Further studies should investigate if and how winter habitat quality or other factors (e.g., see page 33 regarding potential effects of severe winter cold periods) influence survival and subsequent reproductive success. Because resightings of individually marked plovers are crucial to filling this information need, increased efforts to enhance the communication network and clearinghouse for banding information are also needed (see Action 3.4 and Appendix 2b). This could result in additional and more accurate band observations and resightings.

8.2 Refine the characterization of optimal winter and migration habitat.

There is a need to further refine the characterization of optimal winter and migration habitat and to determine factors affecting piping plover use of different microhabitats (e.g., ocean intertidal zones, wrack, inlet shoreline, soundside flats, etc.) during the winter and migrating seasons. Research approaches should recognize that piping plovers may move among nearby habitat patches. Habitat management would be enhanced by greater knowledge of the entire suite of sites used by distinct groups of plovers. Plover habitat use patterns and needs may also vary geographically (across their nonbreeding range) and seasonally. Studies focusing on areas with substantial sand deficits, specifically the coasts of Louisiana and Mississippi (USFWS 2010a, USACE 2010), could inform potential restoration projects there (see Action 1.3). Models predicting the probability of occupancy could also help set priorities for future stewardship needs as storms and other coastal processes improve the suitability of habitats in areas that may have had sparse piping plover use in the past.

8.3 Determine the effects of shoreline stabilization projects.

Research is needed on the effects of habitat modification projects, especially inlet stabilization and relocation, shoal mining, and beach nourishment. Pertinent questions may include the magnitude and duration of effects on the prey base, short- and long-term habitat formation and maintenance processes, and on the abundance and survival of piping plovers using the site during each season.

It may also be useful to refine estimates of historic habitat loss. For example, comparison of modified inlets with historical plover use should be conducted to determine how many modified inlets (Rice 2012a) overlap with documented historical use by plovers and which inlets are no longer usable by shorebirds due to habitat modifications.

8.4 Develop design specifications and monitoring for restoring, creating, and enhancing roosting and foraging habitat.

Research is needed to refine the understanding of impacts on piping plover habitats (including spits, updrift and downdrift ocean and bayside beaches, ebb and flood shoals) due to inlet modifications (Rice 2012a). Such studies should be designed to identify any potential opportunities for restoration and enhancement of those habitats. Research also is needed on the effects of dredge-material deposition for habitat creation and on the long-term suitability of these artificially created sites. Pilot or experimental projects should be carefully evaluated to determine if suitable habitat (providing for average or above-average survival of piping plovers) can be created.

8.5 Investigate methods to determine the quantity and distribution of wintering and coastal migration habitat needed for long-term conservation of the three populations.

Maintaining sufficient migration and wintering habitat is critical to long-term conservation of piping plovers. Therefore, developing and implementing studies to quantify habitat needs of recovered populations and to track changes in availability of storm-created (i.e., frequently changing) habitat would be very valuable. Alternative methods (e.g., Stillman and Goss-Custard 2010) should be investigated and promising approaches should be tested. Challenges that must be addressed in study design include understanding how piping plovers share their nonbreeding habitat with other shorebird species (so that sufficient habitat is conserved for all species) and assessing appropriate juxtaposition of foraging and roosting habitats.

8.6 Determine impacts of human disturbance on nonbreeding plovers.

Determine the extent to which human and pet disturbance in wintering and migration habitats affects piping plover abundance, behavioral patterns, survival, and productivity during the subsequent breeding season. Potentially useful study designs include before-after control-impact (e.g., Tarr 2008, Forgues 2010) and individual-based models (Stillman and Goss-Custard 2010). New information should be used to refine and improve implementation of Action 2.

8.7 Evaluate piping plover flight patterns and behaviors to inform risk assessments for wind turbine generators.

Wind turbine generators may be an emerging threat to piping plovers in their nonbreeding range (see page 38). Information needs include location, frequency, and altitude of flights between roosting and foraging habitats and among habitat complexes used by plovers under varying tidal and weather conditions. Other important information needs include piping plover avoidance rates under varying visibility conditions. Coastal migration routes and altitudes within the nonbreeding range should also be determined.

8.8 Develop strategies to reduce threats from accelerating sea level rise.

Studies are needed that examine the predicted impacts of sea level rise and the resulting changes in beach morphology on the amount and quality of piping plover roosting and foraging habitat across the coastal migration and wintering range. An ongoing collaborative effort among the U.S. Geological Survey Coastal Geology Program, Virginia Tech University, and other recovery partners to model effects of sea level rise on Atlantic Coast piping plover breeding habitat and to develop management recommendations and case studies (Karpanty 2012) may be adaptable (with appropriate modifications) to migration and wintering habitat.

Results of sea level rise models and other studies must also be translated into recommended land-management practices to maximize resiliency of habitat to sea level rise (e.g., advance planning for how to respond to new inlet formation in susceptible areas). Due care must be exercised to account for localized rates of sea level rise, especially in areas where subsidence rates are very high.

8.9 Investigate the full spectrum of other impacts from climate change on piping plovers in their nonbreeding range.

Obvious or subtle climate changes (e.g., water or air temperature, precipitation patterns, wind velocity or direction) may affect migrating and wintering piping plovers. Effects may be exerted directly (e.g., storm-induced mortality) or indirectly (e.g., through changes in foraging resources or wrack formation). Understanding any such changes will be crucial to the development of strategies to buffer harmful effects on piping plovers and to foster beneficial adaptations.

8.10 Ascertain impacts of predation on wintering and migrating piping plovers.

The extent of predation threats to nonbreeding piping plovers is currently unknown (see Action 5) and related research is a low priority. If, however, new evidence suggests that predation threats are high or growing, directed study may be warranted. The most likely suspected concerns are impacts from raptors, especially if anthropogenic factors (e.g., landscape modification, human-supplied perches) might exacerbate natural rates of raptor predation. If predation is determined to be a threat, options to reduce predation-induced mortality should be evaluated.

9 Coordinate, review, and refine recovery efforts.

The piping plover's wide geographic wintering range and the large number of recovery partners dictate prompt sharing of new information and innovative management actions (see also Atlantic Coast Recovery Plan Task 5, Great Lakes Recovery Plan Task 8, and Northern Great Plains Recovery Plan Task 5.2 and 6).

9.1 Foster communication among recovery partners.

The USFWS inter-regional piping plover coordination team (see page 45) should intensify communication efforts across the coastal migration and wintering range. A website dedicated to conservation of migrating and wintering piping plovers should be developed and maintained to provide background and contextual information, non-copyright literature, examples of successful conservation efforts, and links to piping plover websites maintained by USFWS field offices (e.g., South Carolina Field Office, http://www.fws.gov/charleston/Piping_Plover.html), state wildlife agencies, and other partner organizations. Periodic workshops (e.g., USFWS 2012b) provide a forum for formal and informal vetting of new information, including proposed and on-going research, new management techniques, and outreach materials. Ongoing efforts to solicit and use information from the Canadian Wildlife Service and other Canadian partners pertinent to the wintering needs of piping plovers that breed in Canada should be continued and expanded as appropriate.

9.2 Facilitate use of new information.

Updated information should be incorporated into USFWS biological opinions, habitat conservation plans, and technical assistance documents. New information should be used to refine the conservation actions recommended in this document.

9.3 Support conservation of wintering piping plovers outside the continental U.S.

Communication and collaboration with agencies, organizations, and individuals involved in conservation of wintering piping plovers outside the continental U.S., especially in the Bahamas and Mexico, should be increased.

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APPENDICES

APPENDIX 1: HABITAT LOSS AND PROTECTION

Appendix 1a. Best Management Practices for Shoreline Stabilization to Avoid and Minimize Adverse Environmental Impacts

Appendix 1b. Inventory of Habitat Modifications to Tidal Inlets in the Continental U.S. Coastal Migration and Wintering Range of the Piping Plover *(Charadrius melodus)*

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APPENDIX 3. AGENCIES, ORGANIZATIONS, AND UNAFFILIATED INDIVIDUALS INVOLVED IN CONSERVATION OF MIGRATING AND WINTERING PIPING PLOVERS

Appendix 1a. Best Management Practices for Shoreline Stabilization to Avoid and Minimize Adverse Environmental Impacts[1]

Prepared for the USFWS, Panama City Ecological Services Field Office

Tracy Monegan Rice
Terwilliger Consulting, Inc.
November 2009

Shoreline stabilization projects can cause significant adverse environmental impacts to the coastal ecosystem. By incorporating conservation measures into a project during the planning, design, construction, and post-construction phases, many of the potential adverse environmental impacts can be avoided and minimized. This paper outlines best management practices (BMPs) that can be utilized as conservation measures to avoid, minimize, and mitigate adverse environmental impacts from shoreline stabilization projects. The first approach that best avoids and minimizes adverse environmental impacts from shoreline management is to "do nothing" and retreat roads and structures away from the shorelines as sea level rises and climate changes, and to prevent new development in naturally hazardous or migrating areas. Where shoreline stabilization *is* proposed, BMPs are presented in sections for dune, beach, nearshore, offshore, inlet and estuarine habitats, and an adaptive management framework is presented for project management (i.e., operations and maintenance) and issues relating to climate change and rising sea level. A glossary is included for key words and an extensive bibliography summarizes the scientific literature that provided scientific background and data in the development of these BMPs as conservation measures.

SECTION I: DUNES

Artificial dunes should not be constructed by heavy equipment (i.e., bulldozers) by scraping the beach for sediment or through the addition of beach fill material mined elsewhere and pumped or hauled to the beach. Artificial dunes are typically constructed in continuous ridges that act like levees or dikes to protect inland areas from flooding and overwash, but they do not function like natural dunes or possess the same ecological services.

Wherever and whenever possible, new dunes should be created through the planting of native vegetation to trap natural windblown sediment. In undeveloped areas especially, vegetation alone should be used so that the resulting dunes are the most natural in size, shape and location, and to mimic natural dune development and growth processes (e.g., upward and lateral growth over time). Vegetation builds better dunes in the long-term (albeit after a short time lag) and maintenance is nearly nonexistent, avoiding environmental impacts after the initial installation.

In highly developed areas and on a small scale, the judicious use of sand fencing could be used as long as appropriate maintenance and removal provisions are undertaken and enforced. For example, fencing should be raised periodically to keep pace with incipient dune growth and should be removed once the new dunes are a few feet tall (e.g., less than 3 feet) or after 18 months have passed so that damage caused by the removal to the surrounding environment is minimized; native plants can then be planted at grade to facilitate further dune growth. Sand fencing materials should never be left on the beach, buried under

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[1] *Suggested citation*:
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dunes, as it poses a hazard during storms and will become exposed as dunes migrate or are eroded by storms. Multiple rows of sand fencing should not be used, as they do not mimic natural dune development and growth processes, hinder the movement of wildlife and people, and limit the fetch with which supplemental rows can trap windblown sand.

Sand fencing should not be continuous but should be intermittent to allow passage for people, nesting and hatchling sea turtles, unfledged shorebird and waterbird chicks, and other wildlife that move between the dune line and the rest of the beach. Fencing should be placed perpendicular to prevailing wind directions to best trap naturally blowing sediments. Protective buffers of at least 100 – 180 meters (m) should be maintained around known locations of sensitive or listed wildlife and at least 10 m around sensitive or listed plant species so that fencing and the installation process does not trample or harm nests or vulnerable plant species. Sand fencing should not use materials that create perches for avian predators near known bird nesting areas and should be configured and oriented in accordance with existing guidelines to protect listed species such as sea turtles.

Vegetation plantings on existing or new dunes should consist of native species that reflect the local plant communities for the planting zone (e.g., foredune, dune face, dune crest, back of dune). Botanical surveys should be taken prior to the planting of any vegetation to identify the local plant community assemblages, and where possible historical records should be reviewed to ensure that only plants native to a specific barrier island or beach are used. For example, if historic records indicate that a threatened or endangered species used to occur on a particular beach and is now locally extirpated, it could be reintroduced.

Vegetation should be locally grown, where possible, and not harvested from wild stock unless the plants are being transplanted from an area where they would otherwise be destroyed by a development or construction project or where harvesting will not adversely affect local populations. Plantings should not be a monoculture but instead a diverse assemblage that reflects the local plant community type(s). Plants should not be planted on a regular spacing with rows but instead should be more random and reflect their natural spacing(s), which should be identified during the botanical survey. Long-term fertilization with nitrogen should not be conducted in order to avoid long-term alterations to species diversity, composition and density (Day et al. 2004).

When using sand fencing or vegetation to restore or create new dunes on a large scale, a geomorphological survey of the barrier island or beach (or a nearby undeveloped, natural area if the project beach is developed) should be conducted prior to action in order to identify the existing, undisturbed dune morphology for replication. The dune length, height, and width; number of dune ridges and their spacing(s); whether wetland swales are present; and the spacing of natural gaps should all be identified. These factors should guide the design of fencing and/or vegetation placement so that any restored or created dunes should blend seamlessly with the existing environment. If the project area is developed and a nearby natural area is utilized as a design model, the surveys should utilize areas in a state as close to the project area as possible; for example, a natural area of heavily vegetated, mature dunes would not be appropriate as a model for a project area devoid of any dunes or vegetation. Rather, incipient dunes and pioneering vegetation would be the more appropriate model.

In all cases, overwash should be allowed to continue unimpeded, including in dune gaps. Off-road vehicle (ORV) traffic should be prohibited on and in between dunes.

Pedestrian traffic should be encouraged to use dune crossovers or designated pedestrian paths to avoid disturbing the dune ecosystem, particularly in areas that host vulnerable species such as nesting birds, beach mice and listed plants.

Beach access points should not be cut into existing dunes but should utilize dune crossovers and boardwalks that avoid disturbing the dune system. Access points should not be located in areas with known wildlife nesting or breeding areas, such as remnant early successional habitats, dune blowouts and overwash areas, in order to avoid impacts to vulnerable or sensitive wildlife and vegetation. Access points should not align with streets or driveways that are perpendicular to the beach, as they can funnel flooding and overwash farther inland than would naturally occur, potentially damaging property and facilitating island breaches.

SECTION II: BEACHES

Hard stabilization should only be used in cases where extreme development has occurred on a shoreline, such as in highly urban areas like Manhattan. Where hard stabilization (e.g., seawalls, bulkheads, revetments, riprap, sandbags, groins) is installed, the eventual loss of the beach and its associated habitats is virtually assured. Therefore, if and when new hard stabilization is justified, a thorough environmental impact statement (EIS) should be prepared and mitigation for the loss of ecosystem services and habitat should be incorporated into the project design. Mitigation measures can include the removal of hard stabilization structures in other nearby locations, the relocation of buildings and structures that are impeding the natural landward migration of the beach system as sea levels rise, or the restoration of beaches where they have been historically lost to shoreline stabilization.

Soft stabilization (i.e., “beach nourishment”) causes significant adverse environmental impacts and likewise should only be undertaken after a thorough EIS has been prepared. The design of a beach fill project should incorporate empirical evidence on the performance of other nearby beach fill or dredged material disposal projects; for example, if a nearby beach fill project typically ‘disappears’ or erodes within 3 years, the engineering design of a new project should not realistically assume that the new project will last 5 to 7 years before requiring “maintenance” with more “renourishment.” Emergency “berms” should be considered beach fill projects and be subject to the same BMPs or conservation measures as a planned fill or dredge disposal project; the only difference between an emergency berm project and a planned beach nourishment project is the level of planning and consultation involved.

Where a beach fill or dredged material disposal project is proposed, the new sediment must be compatible with the native sediment on the existing beach. Visitors and wildlife should not be able to distinguish the fill material from the existing native beach material in color, grain size, mineralogy, compaction, or any other characteristic. The native beach sediments should be sampled and analyzed at the dune, across the berm, in the surf zone, and the nearshore before any project is undertaken. The fill material should also be sampled periodically during construction, especially in areas with sensitive plants or wildlife, to catch any incompatible or unexpected material as soon as possible. Comparison of the native sediments to the proposed fill material should be conducted prior to construction, with compatible material defined as:

1. Material consisting solely of natural sediment and shell material, containing no construction debris, toxic material or other foreign matter;
2. Material consisting predominantly of quartz, carbonate (i.e., shell, coral) or similar material with a particle size distribution ranging between 0.0625 millimeters (mm) and 4.76 mm, classified as sand by either the Unified Soils or Wentworth classification systems;
3. Material similar in color and grain size distribution (sand grain frequency, mean and median grain size and sorting coefficient) to the native material in the project area;
4. Material containing less than or equal to 2 % fine-grained sediment (< 0.0625 mm, considered silt, clay and colloids) by weight, unless sufficient sampling of the project area indicates that the native sediment grain size distribution contains > 2 % fine-grained material, in which case compatible material should be considered the percentage of fine-grained native material plus no more than an additional 2 % by weight;

5. Material containing coarse gravel, cobbles or material retained on a ¾ inch sieve in a percentage or size not greater than found on the native beach;
6. Material that does not result in cementation of the beach; and
7. Material that does not contain carbonate (i.e., shell) material that exceeds the average percentage of carbonate material on the native beach by more than 15% by weight.

The overall volume of fill material to be added to the beach in any fill episode should not exceed 50% of the estimated annual net sediment transport for the beach in order to minimize the magnitude of the disturbance to the ecosystem and to prevent large-scale alterations of the local coastal processes.

The beach fill design that avoids the most adverse environmental impacts to the beach is probably the one begun in 2004 at Assateague Island National Seashore in Maryland, where sand bypassing at the adjacent inlet is conducted by using a shallow hopper dredge to place fill only in the nearshore environment, as close to the beach as possible. As the hopper slowly dumps its fill, the dredge moves closer to shore as its load lightens. No fill is placed on the subaerial portions of the beach, avoiding impacts to those habitats and their resident and migratory wildlife and plants. Impacts will still occur on nearshore habitats, however.

Where beach fill is proposed for the subaerial portions of the beach, the design template should replicate the natural, existing beach profile, including any bar and trough morphology. Several small-scale fill projects minimize adverse impacts when compared to a single, large-scale project. Fill should not be placed in a continuous section of beach, but should be divided into several short sections where every other section is filled. This design leaves undisturbed refugia for fish and wildlife resources, which then can enhance the recovery of invertebrates within the fill sections by having source populations scattered throughout the project length instead of only at the ends. Sediment will naturally move from the fill sections into the unfilled sections on the littoral drift, increasing the beach width in unfilled sections over time but without direct burial of the benthic ecosystem. Subsequent ‘renourishment’ episodes can alternate which sections receive fill. Individual sections should not exceed 2000 feet in length unless scientifically rigorous monitoring indicates that this length is too long to facilitate benthic recovery or that benthic recovery occurs relatively fast and the length may be increased. The timing of the deposition (e.g., the season – fall, winter, spring or summer) should avoid the most biologically productive seasons, including spawning and recruitment periods for benthic invertebrates; this should enhance recovery rates following deposition of the fill material. For the eastern and southeastern United States, the best construction window is generally from November to February.

Beach fill should be of the thinnest depth possible (Defeo et al. 2009 recommend repeated application of layers of sediment, none thicker than 30 centimeters (cm)) to facilitate the repopulation of fill areas with benthic invertebrates. Some invertebrate species may survive shallow burial, minimizing mortality of these resources. The berm height should not be uniform but should vary along the beach fill, allowing waves, tides and overwash to penetrate the beach to varying degrees and creating a diversity of topographical microhabitats while maintaining necessary beach profiles for successful sea turtle nesting. If necessary, contract specifications should explicitly prohibit overfill so that these conservation measures are implemented as intended.

Heavy equipment use should not leave ruts on the beach. Storage of heavy equipment and pipe on the beach should be avoided to the extent possible, using staging areas off of the beach wherever available.

Construction schedules should avoid the most productive biological seasons, typically the nesting season for sea turtles, shorebirds and waterbirds but in some areas also may include migration or overwintering periods where fauna are present in high concentrations.

Construction should avoid sensitive habitats and areas with high ecological value such as migratory bird staging sites, aquatic spawning areas, and colonial waterbird nesting sites. Buffers of 100 m should be maintained around wading bird colonies, 200 m around mixed tern / skimmer colonies, and 100 - 200 m around solitary bird nests and larger for species with precocial chicks. Buffers of at least 10 m should be maintained around sensitive plants. In project areas where construction will be conducted 24 hours a day, 7 days a week, with multiple pieces of heavy equipment, buffers may need to be enlarged since the disturbance would be continuous (versus periodic disturbances with pedestrians). During non-breeding periods, buffers may be needed around roosting sites or migratory staging areas for sensitive bird species.

Renourishment episodes should only be conducted after all of the ecological monitoring (e.g., invertebrate, avian, fisheries, listed species) shows that the beach ecosystem has fully recovered (100% as compared to control areas) for a duration of at least one year, preferably two or three, in order to avoid permanent perturbations to the system. Disturbances should be episodic and their ecological impacts should not overlap between fill episodes (i.e., a renourishment episode should not take place before the impacts from the previous fill event have completely abated).

Scientifically rigorous pre-project, during construction, and post-project monitoring should be conducted according to the design protocols recommended by Peterson and Bishop (2006).

Beaches should not be raked or mechanically cleaned; wrack material should be left in place with the exception of marine litter or human trash, which should be collected by hand. Wrack materials are an essential component of the food web of sandy beach ecosystems, as well as a source of organic material and traps for windblown sediment to create foredunes.

In areas where beach nourishment creates a beach seaward of existing hard stabilization or heavy development, where the beach has been lost due to erosion and/or sea level rise, associated ecosystem functions such as nesting habitat for shorebirds, waterbirds or sea turtles, may be restored. Future renourishment episodes should then follow the aforementioned BMPs (e.g., protective buffers) for protection of ecological resources that have returned to or colonized the re-created beach.

SECTION III: NEARSHORE

The nearshore environment, which for ecological purposes can be defined as the active littoral or surf zone, contains a variety of ecological resources, including foraging fish and benthic invertebrates. In some areas, reefs and hard bottoms or other geologic outcrops may be present. These resources and habitats may be directly or indirectly impacted by shoreline stabilization projects.

Significant buffers should be maintained around all reefs (natural or artificial), hard bottoms, submerged aquatic vegetation (SAV) and other high value habitats, including areas designated as Essential Fish Habitat (EFH) or Habitat Areas of Particular Concern (HAPC). Buffers should be delineated prior to construction so that the design and construction planning can incorporate avoidance measures in advance. Buffers should be at least 500 m surrounding these sensitive and valuable habitats.

If beach fill sediment for a dredge disposal or nourishment project is compatible with the native material, nearshore communities should not be adversely affected by raised turbidity levels as the fill material dewaters and the sediment is reworked by wave and tidal action. Some turbidity is likely, however, and should be monitored with appropriate instrumentation and monitoring protocols. Where water quality standards are exceeded, work should cease and appropriate mitigative measures incorporated into the construction methods and design. Similarly, if introduced fill material contains too much coarse material, the benthic fauna may be adversely affected in their ability to burrow into the sediment and predators such as fish and birds may be less able to locate benthic prey; if such a situation occurs, post-construction mitigation should occur, including the removal of excess coarse material where warranted and the avoidance of that sediment source for future fill projects.

Long-term monitoring should also be conducted where geologically limited habitats such as reefs and hardbottoms are present near the work area to ensure that fill material does not move off of the artificially constructed beach / berm and bury or smother these fragile habitats. If such burial is documented, post-construction mitigation should be pursued and any renourishment episodes should increase protective measures such as buffer size.

Nearshore areas including sandbars and tidal shoals should not be used as a sediment source for beach fill projects. Removal of nearshore material for beach placement can increase wave energy reaching the beach by altering the nearshore bathymetry, defeating the purpose of an "erosion control project" and exacerbating the need for shoreline stabilization project(s).

Hard stabilization structures such as breakwaters and rubble mounds should not be constructed in nearshore areas due to their significant adverse environmental impacts. Artificial reefs may have ecological value if designed, installed and monitored properly and if they are located in appropriate areas.

SECTION IV: OFFSHORE

Similar to the BMPs for nearshore areas, offshore areas may also contain rare and valuable habitats like hardbottoms and reefs that should be protected with large buffers (at least 500 m). Offshore areas are typically used as the source for sediment for beach fill projects, which mine suitable materials from the seafloor and transport the material to the beach via dredges, barges and/or pipelines. Mine sites also should be located away from significant spawning areas or other habitats valuable to local fishery or benthic resources, including areas designated as EFH, HAPC or Marine Protected Areas (MPA).

Mine sites for beach fill material should not be excavated such that large depressions or holes are left on the seafloor, significantly altering the local bathymetry (and thus coastal processes and ecological habitats). Excavation should use a series of shallow, staggered cuts (furrows) that limit the area of disturbance and allow undisturbed areas in between cuts to serve as refugia and a source for repopulation of benthic resources; this method also limits alterations to the seafloor bathymetry, which may have regional and long-term adverse effects. Dredging should leave a sufficient layer of sediment that matches as closely as possible the original surface layer to avoid exposing a dissimilar sediment on the surface.

SECTION V: INLETS

Inlets are particularly valuable ecosystems, as they provide foraging, spawning, nesting, staging, roosting and migratory habitat for countless shorebirds and waterbirds, anadromous and catadromous fish, crabs, shrimp, invertebrates, waterfowl and other fish and wildlife resources. The highly dynamic nature of inlets creates a complex assemblage of habitats, including bare and sparsely vegetated spits; subaerial, intertidal and submerged shoals; sandbars; overwash and tidal flats; and passageways for aquatic resources. The constantly shifting nature of inlets creates a cycle of emergence, growth and renewal of these habitat types that is self-sustaining when left undisturbed.

Due to their incredible ecological significance and the significant adverse environmental impacts that hard stabilization generates, inlets should not be stabilized with jetties, terminal groins, revetments, riprap, geotubes, sandbags or any other hard structure. The cumulative impacts of inlet management and manipulation along the Atlantic and Gulf coasts of the U.S. already are significant and adverse and should preclude any undisturbed or relatively undisturbed inlet from being stabilized, mined or otherwise managed.

The flood and ebb tidal deltas of an inlet should not be mined for sediment for use in beach fill projects or to re-align channels away from threatened structures. Shoals are spawning areas for crab and shrimp, roosting and foraging habitat for birds, shelter for SAV, and an essential element of the inlet ecosystem. Mining shoals for sediment unbalances the natural equilibrium of coastal processes, disturbing and displacing fish and wildlife resources and leading to habitat loss and fragmentation. Removal of material from inlet shoals typically leads to increased erosion on adjacent shorelines as the system attempts to fill the sediment deficit, which can increase hazards to private property and infrastructure in developed inlet hazard zones. In some areas, protection of subaerial shoals (e.g., restricting boater access and activities such as parties, fires and dogs) may be a form of mitigation for increased recreational or development activity facilitated by shoreline stabilization projects on nearby beaches.

Dredging of new navigational channels through previously undisturbed inlets should be discouraged as this process removes sediment from the system much like shoal mining does. Undisturbed inlets naturally bypass sediment from one side of the inlet to the other, and navigational channels can become sediment sinks, depriving downdrift beaches and habitats of their sediment supply. Deep channels may have regional impacts as sediment is continuously removed via maintenance dredging from the channels and moved elsewhere, generally outside of the inlet and nearby coastal system. Excessively deep channels may also alter the salinity regime in adjacent estuaries by increasing the tidal prism and altering the hydrodynamics of the inlet, resulting in adverse ecological impacts well beyond the actual inlet area.

For existing navigational channels, dredged material should be disposed of within the inlet system, placed where it can bypass to downdrift beaches on wave and tidal processes. Nearshore placement of dredged material would avoid impacts to the beach and dune ecosystem and most closely replicate natural sand bypassing processes, which are subaqueous at inlets. Channel maintenance activities should occur on more frequent small scales instead of infrequent large scales in order to minimize the magnitude of the disturbance to the coastal ecosystem.

Restoration of inlet complexes provides an opportunity for mitigation required by other disturbance projects. Hard structures can be removed, dredged channels abandoned, and buildings and infrastructure relocated away from inlet shoulders. Preservation (e.g., conservation easements, fee title) of undisturbed inlet complexes with large buffers along each shoreline to allow natural movement of the inlet over time should be encouraged and pursued wherever possible.

ORVs should not be allowed in inlet areas during periods of nesting or migration, or if significant overwintering populations of wildlife are present.

SECTION VI: ESTUARINE

Estuaries should not provide a sediment source for oceanfront beach fill projects due to sediment compatibility issues and the adverse impacts sediment removal would have on the estuarine ecosystem. Where dredging is necessary, dredge disposal materials should stay within the local system as close to the project area as possible. Dredged materials disposal should not occur in areas with significant benthic resources where burial is likely to occur. Disposal should not bury marshes, tidal flats, SAV, oyster reefs, clam beds, or other valuable benthic or fishery resources occur; buffers of at least 500 m should be maintained around such areas.

In some cases, dredged material can be beneficially used to restore or enhance habitat. Dredge disposal islands in certain areas have become valuable bird nesting areas and their creation and/or maintenance with compatible material may offset the adverse impacts of dredging (albeit with out-of-kind services). The beneficial use of dredged material may also aid in the restoration of SAV, or where the material is rocky, in the restoration of oyster reefs. In areas where hard stabilization along the estuarine shoreline has led to the loss of intertidal habitat, dredged material may potentially restore such habitat through localized, small-scale fill projects in front of the hard structures or where such structures can be removed. Restoration of intertidal estuarine shoreline habitats may benefit nesting horseshoe crab and diamondback terrapin as well as foraging waterbirds and shorebirds. New canals or channels should not be dredged to reach habitat restoration project areas, nor should adjacent marsh, SAV, oyster reefs, etc., be disturbed during the construction phase. Any beneficial use of dredged material project should include appropriate post-construction monitoring to determine if the intended benefits are realized, and the project should be adaptively managed to incorporate the results of such monitoring in future operations and maintenance activities.

Overwash material should not be removed from estuarine areas or habitats; overwash fans and flats are a natural component of the coastal ecosystem and a necessary process to aid in the migration of estuarine habitats during rising sea levels. As these habitats (both on barrier island and mainland shorelines) are naturally maintained with raised elevations from overwash, adjacent mainland development should benefit from enhanced storm protection in the long-term as the risk of inundation is lessened with higher elevations.

Finger canals should not be dredged in estuarine areas or on the bayside of barrier islands or spits; these canals increase the naturally shallow bathymetry, lead to the loss of intertidal and shallow bottom habitats such as marsh and SAV, and serve as a conduit for storm surge during severe storms.

Hard stabilization structures should not be constructed along estuarine shorelines, including bulkheads for new marinas and personal boat slips. Riprap and rubble debris should not be placed along the estuarine shoreline. All hard stabilization structures lead to the loss of intertidal habitat over time, and prevent the migration (and thus maintenance) of estuarine shoreline habitats (i.e., tidal marshes and flats, beaches) during rising sea levels.

The cumulative impacts of personal docks and piers (which are often associated with bulkheads) should be carefully considered prior to the permitting or rebuilding of new docks and piers. Docks, piers and similar structures built over estuarine waters are generally demolished during severe storms, leading to significant amounts of debris following the storm. This debris should be carefully and quickly removed so that estuarine resources and habitats are not permanently harmed or buried by these materials.

SECTION VII: CLIMATE CHANGE AND RISING SEA LEVEL

Given the current trends and predictions for climate change and continuously rising sea levels, shoreline stabilization projects should utilize an adaptive management approach that allows for designs to be modified with changing conditions over time. Beach nourishment of the seaward shoreline, for instance, will not allow a barrier island or mainland beach to migrate to higher ground as sea level rises higher and higher. Instead, beachfront structures should be relocated away from the beach and the beach system (including dunes) should be allowed to migrate landward in space over time. After severe storm events where beachfront structures are heavily damaged, they should not be rebuilt in place but rebuilt significantly farther landward where feasible or not rebuilt at all where not feasible. Hard stabilization structures such as jetties should be removed to facilitate the long-term natural maintenance of tidal inlets as sea level rises and inlets shift in space along with the adjacent barrier islands. Similarly, navigational channels should shift in location over time to accommodate migrating islands and inlets.

In highly developed areas where beach fill is maintained (at ever increasing costs) in the long-term, the frequency of beach fill "renourishment" or "maintenance" episodes should be determined by the actual performance of the initial fill material (as documented by long-term monitoring) instead of the predicted performance based on engineering and mathematical modeling. Hard stabilization structures are not consistent with an adaptive management approach, nor are they practical in the long-term as sea levels rise an estimated one meter or more by 2100.

Shoreline stabilization projects should include pre-project (identifying baseline conditions), construction, and post-project monitoring that is scientifically rigorous and incorporates control areas and other features as recommended by Peterson and Bishop (2006). The results of ecological monitoring should guide the "maintenance" of shoreline stabilization projects, with design features or construction methods modified to avoid or minimize any adverse effects documented by the monitoring.

Some level of monitoring should persist for the entire lifespan of a shoreline stabilization project (often 50 years for a beach fill project), but the monitoring protocols may be modified over time as warranted by previous monitoring results. Shoreline stabilization projects such as beach fill should not disturb the ecosystem more than a severe storm would disturb the system, so that the faunal recovery period is similar to that of a natural disturbance. For example, the individual pulse perturbation to a sandy beach ecosystem from a single beach fill episode should not decrease or depress essential ecosystem functions by more than 50% so that the perturbation does not permanently alter the ecosystem; monitoring may indicate that the 50% perturbation threshold may not sufficiently minimize adverse impacts to critical resources such as threatened or endangered species, Important Bird Areas, critical habitat for listed species, or migration or overwintering staging sites. In such a case, the adaptive management approach would incorporate these monitoring findings and lower the perturbation threshold for future fill events. Likewise, if monitoring determines that a fill episode had no significant, lengthy adverse impacts on critical ecosystem functions, the perturbation threshold could be raised for future fill events.

The distribution of microhabitats within the coastal ecosystem, including beaches, dunes, inlets and estuaries, are shifting in location as sea level rises at an accelerating rate and climate change alters sea surface temperatures and other oceanographic processes. A hands-off approach to shoreline management would best avoid the permanent loss of coastal ecosystem habitats. As a result, overwash materials should not be removed from the interior or bayside of islands or spits (including roads and driveways), dune ridges should not be built to function as levees, and inlets and shorelines should not be locked in place by hard structures. Where buildings are damaged and left exposed in intertidal areas following severe storm events, they should be removed and not rebuilt instead of rebuilt and protected in place with shoreline stabilization projects. If these BMPs can be incorporated into shoreline stabilization projects, habitat loss, fragmentation and degradation may be minimized in a period of changing climate and rising seas.

GLOSSARY

Adaptive management An iterative process where monitoring or learning by doing better informs future management decisions when precise information is lacking or uncertainty remains as to the extent, intensity and duration of effects resulting from a set of actions (e.g., shoreline stabilization or management); subsequent management decisions are improved through the incorporation of new information obtained by monitoring the effects of previous actions

Aeolian Of or pertaining to the wind, in this case windblown (aeolian) sediment transport or movement of sand

Beach	The area of unconsolidated sediments, stretching from the dunes to the intertidal zone; the underwater portion of the beach profile is sometimes referred to as the shoreface
Beach nourishment	The placement of sediments mined or transported from another location on a beach in order to temporarily reverse or slow down long-term erosion and protect structures located behind the beach
Benthic	Living on the bottom, in this case animals that live on the sea, bay or estuary floor and generally remaining submerged at all times
Best management practice (BMP)	Methods or techniques that can be used to avoid or minimize environmental harm or impacts in land management or construction activities
Breakwater	An engineering structure built in the water off of a shoreline with the intention of slowing down waves before they strike the beach, sheltering the adjacent shoreline
Bulkhead	A wall, typically built on the estuarine shoreline, to protect adjacent structures from erosion or storm flooding, or to allow for deep water immediately next to the shoreline for the mooring of boats
Downdrift	The direction in which the littoral drift or longshore sediment transport is moving sediment
Dune	A mound or ridge of unconsolidated sediment, usually sand-sized particles, that is built through the accumulation of windblown sand
Ebb tidal delta or shoals	Bodies (shoals) of sediment formed by the interaction of ebb, or falling, tides with incoming waves at a tidal inlet; ebb tidal shoals are generally smaller than flood tidal shoals and remain submerged during all tidal periods
Estuary	A semi-enclosed body of water which has open connections to the ocean and within which marine waters are diluted or mixed with freshwater, forming a body of water with lower salinity than the ocean and higher salinity than rivers
Fetch	The distance over which wind or waves can move unobstructed
Flood tidal delta or shoals	Bodies (shoals) of sediment formed by the interaction of flood, or rising, tides with the relatively calmer waters of a bay or estuary at a tidal inlet; flood tidal shoals are generally larger than ebb tidal shoals and can be exposed at periods of low tide
Geomorphology	The topography, or landforms, of a given area
Geotube	A very large sandbag, generally about one meter in diameter and tens of meters in length; geotubes can be stacked on top of each other to form a wall or mound to protect structures from the encroaching ocean and are sometimes buried under sediment to reinforce artificial dunes

Groin	An engineering structure perpendicular to the beach, typically constructed of wood pilings, sheet metal, large rocks, or concrete, with the intention of trapping sediment in the littoral drift and slowing local erosion rates
Infauna	Invertebrate animals that live within the sediment near the surface, such as mole crabs, polychaete worms and clams
Inlet	A water passageway between barrier islands or spits that connects the ocean with estuaries, bays or freshwater rivers
intertidal	The area of a shoreline that is alternately exposed to air and submerged under water with changing positions of the daily tide
Jetty	An engineering structure, typically constructed out of large stone, concrete or sheet metal that is built perpendicular to the shoreline along an inlet shoulder in order to hold or stabilize the inlet and its channels in place
Littoral drift, or longshore sediment transport	The current formed by waves striking a shoreline at an angle which moves sediment along a shoreline, predominantly in one direction (from updrift to downdrift)
Marsh	An area of partially submerged vegetation, typically saltmarsh reed grasses such as *Spartina* spp. or *Juncus* spp. along a shoreline or in an estuary, which may be exposed at low tide and mostly submerged at high tide
Nearshore	The active littoral, or surf, zone where wave action moves significant amounts of sediment on a daily basis
Offshore	The area of the seafloor or ocean that is farther away from the beach or shoreline, seaward of the surf zone
Revetment	An engineering structure, typically a sloping wall constructed of large rocks, installed along a shoreline to protect adjacent structures from erosion and encroaching waters
Riprap	Material or debris such as rock, brick, concrete block or similar hard materials that is placed along a shoreline to slow down local erosion rates
Rubble mound	A mound or ridge of rubble debris (rock, concrete, etc.) placed in the water off of a shoreline that acts like a breakwater to slow down waves and shelter adjacent shorelines
Sandbar	An underwater mound or ridge of sediment in the outer surf zone portion of a beach profile, typically noticed by the area where waves are breaking before striking the beach
Seawall	A wall, typically built of sheet metal or concrete, that is installed parallel to and on the landward side of the beach in order to protect structures from tidal flooding and wave action

Sediment supply	The volume of sediment moved annually along a beach by the littoral drift, or longshore sediment transport
Shoal	A body of sediment that rises in elevation from the surrounding sea or bay floor and that may be exposed during periods of low tide; shoals are generally found near or within tidal inlets
Subaerial	The portion of the beach that remains dry and not submerged during periods of high tide
Subaqueous	The portion of the beach, estuary or ocean that remains submerged under water during all tidal periods
Submerged	Under water
Surf zone	The area adjacent to a shoreline in which waves are breaking and running up on to the beach
Terminal groin	A groin that is placed at the end of an island adjacent to an inlet
Tidal flat	A marshy, muddy or sandy, nearly flat, landform that is alternately exposed and submerged during periods of low and high tides
Trough	A shallow, straight depression on the landward side of a sandbar
Updrift	The direction from which the predominant littoral drift or longshore sediment transport is moving; jetties and groins can trap this sediment on their updrift sides, blocking its movement to downdrift beaches
Wrack	Organic materials such as seaweed, marsh grass and other vegetation that is deposited on a beach by waves and tides

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Appendix 1b. Inventory of Habitat Modifications to Tidal Inlets in the Continental U.S. Coastal Migration and Wintering Range of the Piping Plover (*Charadrius melodus*)[1]

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The U.S. Fish and Wildlife Service's (USFWS's) 5-Year Review for the piping plover (*Charadrius melodus*) recommends developing a state-by-state atlas for wintering and migration habitat for the overlapping coastal migration and wintering ranges of the federally listed (endangered) Great Lakes, (threatened) Atlantic Coast and Northern Great Plains piping plover populations (USFWS 2009). The atlas should include data on the abundance, distribution, and condition of currently existing habitat. This assessment addresses this recommendation by providing these data for one habitat type – namely sandy tidal inlets within the migration and wintering range of the southeastern United States (U.S.). Inlets are a highly valuable habitat for piping plovers, other shorebirds, and waterbirds for foraging, loafing, and roosting and have been documented to be preferentially used over other habitat types during the wintering period (Harrington 2008, Lott et al. 2009, Maddock et al. 2009).

Although some information is available for the number of inlets stabilized with jetties, revetments, and other hard structures, these data have not been combined with other information that is available for navigational dredging, inlet relocations, shoal mining, and artificial opening and closing of inlets. Altogether this information can provide an assessment of the cumulative impacts of habitat modifications at tidal inlets for piping plovers and other birds. This assessment does **not**, however, include habitat disturbances at tidal inlets such as off-road vehicle (ORV) usage, pet and human disturbance, or disturbance to dunes or vegetation on inlet shoulders.

A description of the different types of stabilization structures typically constructed at or adjacent to inlets – jetties, terminal groins, groins, seawalls, breakwaters and revetments – can be found in Appendix 1a (Rice 2009) as well in the *Manual for Coastal Hazard Mitigation* (Herrington 2003, online at http://www.state.nj.us/dep/cmp/coastal_hazard_manual.pdf) and in *Living by the Rules of the Sea* (Bush et al. 1996).

METHODS

This assessment was compiled by examining many disparate sources of information regarding tidal inlets within the piping plover's migration and wintering range into one central Microsoft Excel database. Sources include peer-reviewed literature, books, gray literature (e.g., conference presentations, project applications, or proposals), government reports and files, maps such as Google Earth, U.S. Geological Survey (USGS) topographic maps, nautical charts and state Gazetteers, and on-line databases and government websites (federal, state, county, and municipal).

Google Earth imagery (using the most recent dates available, generally from 2010 and 2011 at inlet locations) and the Federal Inlet Aerial Photo Database (http://www.oceanscience.net/inletsonline/map/map.html) were used to create a database of inlets within

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the migration and wintering range of the piping plover, namely those within the states of North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas. Zooming in to each inlet allowed identification of existing hard structures and whether the land ownership on the inlet shoulders was developed or undeveloped. Viewing publicly posted digital photographs linked to each location within Google Earth allowed further verification of the existence and type of hard structures or absence thereof.

An inlet, sometimes called a "pass" or a "cut," is defined as an opening between barrier islands, spits, or peninsulas that allows ocean and bay water to freely exchange and that contains an inlet throat (the main channel) and a series of shoals (Leatherman 1988; Figure 1). Inlets are influenced by sediment supply, the wave climate, the tidal prism (the volume of water passing through the inlet on a tidal cycle), the longshore sediment transport system, sea level rise, and human modifications of the inlet, estuary, river discharging through the inlet, and adjacent shorelines (Leatherman 1988, Davis and Gibeaut 1990, Bush et al. 1996). These various coastal processes and variables are connected with feedback loops, producing inlet features and behavior that are in a state of dynamic equilibrium. Thus the wildlife habitat associated with inlets is constantly changing due to natural processes.

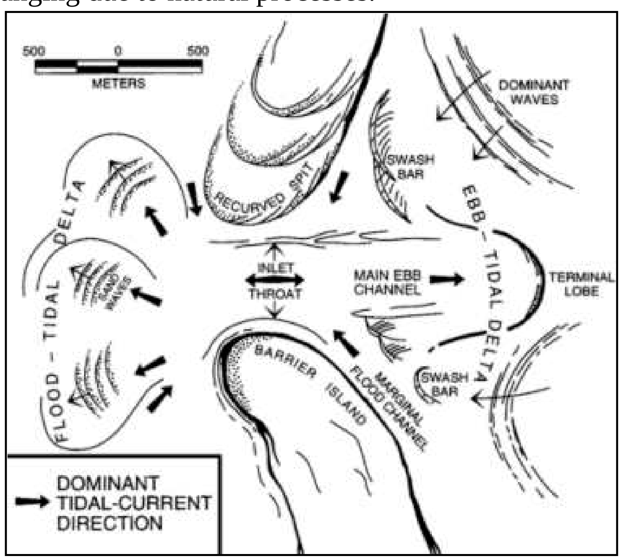

Figure 1. Schematic diagram of a typical tidal inlet with its morphological features. The ocean or Gulf is to the right in the diagram and the lagoon, bay or estuary is on the left. The net longshore sediment transport is from the top of the diagram to the bottom, the same direction as the dominant waves. Marine waters from the ocean freely exchange with brackish water from the bay, lagoon, sound, or estuary through the inlet on the incoming (flood) and outgoing (ebb) tides. From Schrader et al. (2000).

Davis and Gibeaut (1990, p. 2) characterize tidal inlets in the following manner:

> *Tidal inlets are geologically ephemeral environments which act as dynamic conduits between the sea and coastal bays and which divide the coast into barrier-island segments. Inlets may close and open, migrate or become stable on the order of tens of years in response to changing sediment supply, wave climate and tidal regime, rate of sea level rise, and back-bay filling or dredging. In turn, the associated sediment bodies, ebb- and flood-tidal deltas, may rapidly change character. Because most material making up the inlet sand bodies is taken from the littoral-drift system which feeds adjacent beaches, changes in inlet behavior are reflected by changes in adjacent shorelines and overall barrier-island morphologies ….Tidal inlets are very dynamic and commonly show major changes in inlet size and shape, in some*

cases even without intervention by man's activities. Changes in wave climate, sediment availability, and nearshore bottom configuration can cause perturbations in coastal processes, and therefore, in the morphology of the inlet or inlets.

An inlet shoal complex, which consists of both ebb and flood tidal shoals, is the group of sand bodies within and near an inlet that is created by an interaction between the tides, waves and sediment supply (Figure 1). Individual shoals are separated by tidal channels. Ebb shoals are on the ocean side of an inlet and are more influenced by waves, whereas flood shoals are on the bay or estuarine side of the inlet and may be emergent during low tide or even maintain some dry (subaerial) lands that could become vegetated over time. A group of ebb tidal shoals is also referred to as an ebb tidal delta, and a group of flood tidal shoals as the flood tidal delta (Leatherman 1988, Bush et al. 1996). Shoals may become relict when an inlet closes, allowing the ebb tidal shoals to weld to the new beach and the flood shoals to stabilize and possibly become vegetated over time. Along deltaic coasts such as in Louisiana, shoals may become relict if sea level rise outpaces the sediment supply allowing the inlets essentially to drown in place, thus converting the shoals into subaqueous (submerged) sand bodies and some inlets into open bay mouths. Wide, open bay or sound entrances (e.g., East Cote Blanche Bay in Louisiana, St. George Sound in Florida) were not categorized as inlets in this assessment due to their width and the absence of active inlet shoal complexes.

Inlets along deltaic coasts in Louisiana are distinct from the tidal inlets typically seen along non-deltaic coasts in the southeastern U.S. The Mississippi and Atchafalaya delta coasts are river-dominated instead of the wave- or tide-dominated inlets and coasts elsewhere in the range (Suter 1994). In Texas, the Rio Grande and Brazos River deltas are relatively small and wave-dominated, with most of their distributary streams discharging into estuaries as "bayhead deltas" (Suter 1994, p. 109); as a result, inlets along some Texas coastal segments more closely resemble tidal inlets along the non-deltaic coasts . The flats and shoals associated with the bayhead deltas within the lagoons provide valuable habitat for piping plovers and other birds. In the absence of human intervention, the deltaic coast of Louisiana would consist of a series of active distributaries, delta plains, extensive wetlands, distributary-mouth bars, and abandoned deltas in which marine processes may have reworked the coarser deltaic sediments into barrier islands or spits, producing sections of coast that are wave-dominated rather than river-dominated. Abandoned distributary channels may convert into brackish estuaries, as the Bayou Lafourche has done since it ceased to be an active distributary of the Mississippi River roughly 300 years ago (Suter 1994). "The natural geomorphology of a given delta is the result of complex interactions between sediment supply, relative sea-level changes, and marine reworking. Human interference with any of these factors inevitably alters the form and evolution of the delta. … [On the Mississippi delta,] through the construction of the levees, the natural processes of the delta were drastically altered. … Depleted sediment supply from overbanking has accelerated the long-term degradation of the deltaic plain" (Suter 1992, pp. 112-3). As a result, the tidal inlets along the current Louisiana deltaic coast have a very limited sediment supply, preventing them from being self-sustaining without additional sediment input from coastal restoration projects. Where sandy shorelines are present along the Louisiana deltaic coast, tidal inlets were included in this assessment when they exhibited features generally similar to inlets elsewhere in the range (as in Figure 1).

Ephemeral breaks or breaches in shorelines or islands were considered inlets in this assessment if they appeared to maintain a tidal exchange of water from the ocean to the bayside; conversely, inlets were considered closed if they did not appear to allow the free flow of water at low tide. This assessment represents a snapshot in time of the inlets open along the southeastern and Gulf coasts of the U.S., using the most recent imagery, publications and personal knowledge available. Inlets are very dynamic, however, and some ephemeral breaches or smaller inlets may have shifted in space or closed and others opened after the publication date of this assessment. Overwash-dominated barrier islands or coasts are especially dynamic, their inlets and breaches repeatedly opening and closing naturally; these areas are included in this survey as a snapshot assessment of the condition of inlet habitats valuable or potentially valuable to the piping plover on its migration and wintering range. The database can be updated by contacting the author via email at tracymrice@yahoo.com to report any modifications to the current status or new habitat modifications to inlets contained within the geographic area covered in this assessment. Updated copies of the database will be posted on-line at the Program for the Study of Developed Shorelines website (http://www.wcu.edu/1037.asp).

Where barrier islands exist offshore of the mainland, entrances or passes that are located on a mainland shoreline are not included as they are geomorphologically distinct from inlets between sandy barrier islands or spits and are estuarine in nature. The mainland coast of Mississippi, for example, provides habitat for the piping plover, but its bay entrances are not included in this assessment because Petit Bois, Horn, Ship and Cat Islands are located offshore and separated by inlets. When the mainland coast does **not** have offshore barrier islands, and the mainland coast is sandy and has direct ocean or Gulf exposure, then mainland passes or inlets are included when they are geomorphologically similar to inlets between barrier islands. Some of these inlets may have been artificially created to provide access to inland water bodies, whereas others may be river drainages. Examples of such areas include the Matagorda Peninsula in Texas, the Holly Beach area of Louisiana, and the Grand Strand area of South Carolina.

Mainland areas lacking sandy coastlines are excluded. Thus, for example, only two sandy coastlines qualify on the western Florida coast: one located in the Northwest Barrier Chain, eastward from the Alabama state line to Ochlockonee Bay in Franklin County, and the other the West-Central Barrier Chain, from Anclote Key south to Cape Romano. Specifically excluded are the "plant-dominated, sediment-starved, low-wave energy and tide-dominated coastlines" that are "natural geologic boundaries" of the Big Bend Marsh Coast between the two barrier island chains and the Ten Thousand Islands Mangrove Coast to the south (Hine et al. 2003, p. 2; Davis and Gibeaut 1990, Morton and Peterson 2003a, 2003b, 2004). Bush et al. (2001, p. 171) characterize the Big Bend Marsh Coast as an area where "barrier islands are absent and sandy beaches and dunes are rare." Critical Habitat Unit FL-14 at Hagens Cove in Taylor County, therefore, is excluded from consideration because it contains no true tidal inlets.

Outlets that discharge freshwater or brackish water from lagoons or lakes of the Gulf Coast in the Florida panhandle, Louisiana and Texas were also omitted from this assessment because they generally have no visible tidal deltas, their channels are generally narrow and meandering, and they are not tidally flushed but merely allow outflows from inland bodies of water. The Florida Keys were also excluded from this inventory, specifically those from Soldier Key south due to their geologic nature. These islands, or keys, are "a different kind of island chain" that "are quite different from the beach and barrier island systems of East Florida" (Bush et al. 2004, p. 232). They are composed of limestone, are often fringed by mangroves, and natural beaches are rare and limited in length (Bush et al. 2004). The area of Atlantic Florida included in this assessment, therefore, stretches from the Georgia state line to Cape Florida on Key Biscayne south of Miami Beach.

Maps in other published sources (e.g., the *Living with the Shore* series of books for individual state coastlines, government reports, journal publications) were then used to confirm the number and geographic location of currently open tidal inlets, thereby adding non-federally maintained inlet data to the inventory (e.g., inlets dredged by state or local agencies). These map sources were also used to identify the proper political boundaries (i.e., county) in which each inlet is located. News reports and information supplied by relevant public officials and academic sources were consulted to identify the location of new inlets formed within the past few years, typically as a result of storms. History and geology books, literature and government files were referenced to identify inlets that have been relocated or artificially opened or closed since the late 1800s.

In determining the ownership of the inlet shorelines, available maps and on-line directories were searched to identify and verify public properties such as National Wildlife Refuges, National Seashores, state parks and refuges, state wildlife management areas, county and municipal parks and preserves, and lands owned by non-governmental conservation organizations (e.g., Audubon, The Nature Conservancy). Where no records of public ownership were found, the lands were assumed to be privately owned and were recorded as such. Notations were made as to whether the private land was developed or undeveloped; land with low-density development such as a small number of structures with no significant infrastructure (e.g., a few fishing cottages) were considered undeveloped due to their dominant land use as being natural.

The primary data source for stabilized inlets was the Coastal Inlets Research Program (CIRP) prepared by the U.S. Army Corps of Engineers (USACE), which maintains an on-line database of 156 federally-maintained tidal inlets of the U.S. (available at http://cirp.usace.army.mil/wiki/Inlet_Database). This Federal Inlets Database provides information on stabilization structures including jetties as well as physical characteristics such as tidal prism, inlet dimensions and wave conditions (where data are available). USACE construction history reports, often available for federal structures maintained at inlets included in the database (accessible through http://www.oceanscience.net/inletsonline/map/map.html), provide details on the dates of construction (and thus dates of habitat modification).

These data were combined within a centralized Microsoft Excel database containing the following data fields for each inlet: inlet name, state, north / east land ownership, south / west land ownership, county where the inlet occurs, type of hard structure, location of the structure, structure ownership, date built, dredging (yes or no), dredging maintenance agency, location(s) of dredged material disposal, sand bypassing (yes or no), shoal mining (yes or no), mining sponsor, date mined, fill location, other miscellaneous but relevant details, and data sources.

A separate Microsoft Excel database was created to catalog the number and location of inlets that have been relocated either naturally or artificially opened or closed since the 1890s. Relocated inlets are those in which the inlet has been physically moved to a new location – typically hundreds to thousands of feet away – and the old inlet closed with sediment or other materials and the new inlet excavated through land. An inlet generally is relocated as an erosion control measure to protect property or infrastructure from loss due to inlet migration. An inlet that was moved to a new location but where the old inlet was allowed to remain open was categorized as artificially created and not as a relocated inlet. If the old inlet subsequently closed naturally, that inlet was categorized as naturally closed. Inlets that have opened or closed due to natural processes include those that were created during storm events or filled in and closed by natural sediment transport processes. Artificially created inlets include those cut through barrier islands or spits where previously no channel existed; these have been created predominantly for navigational purposes but less frequently for water quality or fish passage purposes.

Inlets that have been artificially closed tend to be those opened during a storm event (e.g., Hurricanes Hugo (1989), Katrina (2005) or Irene (2011)) in a location where property owners, governing agencies or politicians consider them undesirable; closure of these new inlets is oftentimes considered a storm recovery endeavor, particularly where it is necessary to restore a road that has been severed by the new inlet. Artificially closed inlets provide a different mosaic of habitats than those that have closed naturally. Naturally closed inlets tend to be low in elevation, to have no or sparse vegetation initially, and are wide, especially if the tidal deltas or shoals have welded to the island. Artificially closed inlets, on the other hand, have higher elevations, tend to have a substantial constructed berm and dune system tying in to the adjacent beach and dune systems, and are manually planted with dune grasses and/or other vegetation to stabilize the area. The materials used to fill the inlet and construct the berm and dune ridge typically are mined nearby, often disturbing the local sediment supply and transport system. The overwash occurring periodically at a naturally closed inlet is prevented at an artificially closed inlet by the constructed dune ridge, or in some cases by additional hard structures or sandbags such as those installed at the Rodanthe

Breach in North Carolina when it was artificially closed in the fall of 2011. However, inlets that have been artificially closed in Louisiana as part of coastal restoration projects are purposefully designed to approximate the natural system and to allow overwash in the future (B. Firmin, USFWS, personal communication, March 9, 2012). Katrina Cut in Alabama is considered an existing inlet in this assessment (see Table 7) despite its closure with a rock dike during Deepwater Horizon oil spill response efforts because the dike was permitted as a temporary structure (but now, in 2012, is undergoing review to remain in place as a permanent structure).

Shoal mining is defined as a project that intentionally mines sediment from a tidal shoal within an inlet complex, typically for nourishment of nearby beaches. These projects tend to target ebb shoals, are located outside of any authorized and/or maintained navigational channels, and tend to require new permits or environmental review. Dredging activities that have occurred within authorized and/or maintained navigational channels with the dredged materials placed on nearby beaches to address erosion are not considered mining projects within this assessment. Such types of projects may be considered by the USACE as "beneficial use of dredged material" or as Section 933 projects under the Water Resources Development Act (as amended) but do not create new areas of disturbance to the seafloor as a true mining project does. Both dredging of channels and shoal mining create similar geological and ecological impacts, however, in that they disrupt the sediment transport system within and around inlets, creating sediment sinks within the inlet which can lead to increased erosion rates of adjacent shorelines and shoals.

Data on each inlet were confirmed with information from multiple sources wherever possible and the sources for each inlet's data recorded.

The data in both databases were then compiled, sorted and analyzed using common assessment techniques (e.g., the proportion of inlets modified in a particular way within individual states and the range) to identify trends and patterns. Numerous USFWS staff members within the range have reviewed a draft of this assessment in order to verify and correct details, where necessary.

RESULTS

Of the 221 tidal inlets that were open in December 2011 within the migration and wintering range of the piping plover, 30 (14%) had been artificially created (i.e., cut where there was previously no inlet or dredged open after closing naturally), 8 (4%) had been relocated to entirely new positions, 89 (40%) have been stabilized with one or more hard structures, 97 (44%) had been dredged at least once, and at least 20 (9%) had been mined as a sediment source for beach nourishment. Altogether 119 (54%) of the 221 inlets currently open have been significantly modified in one or more of these ways. Furthermore, at least 64 inlets have been closed artificially and thus are not included in the 221 total inlets that are presently open (Table 1).

The states with the highest proportion of inlets modified by any means are North Carolina (85%), Atlantic Florida (90%) and Alabama (100%). In fact only two states (Georgia and Louisiana) have modified fewer than 45% of their inlets. Florida has modified a 43 of 69 inlets (62%). In sum, over half (54%) of all the sandy inlets within the migration and wintering range of the piping plover have been modified in one way or another.

Of the 89 inlets with at least one hard structure, 6 (7%) have one jetty, 45 (49%) have two jetties, 28 (31%) have terminal or other groin structures, 24 (27%) have revetments (sandbag or rock) or seawalls, and 4 (4%) have offshore breakwaters (NOTE: the numbers total more than 89 because many inlets have more than one type of structure). The highest number of inlets with structures is found along the Gulf coast of Florida (20) but the highest proportion of inlets stabilized with hard structures is along the Atlantic coast of Florida (90%), where 19 inlets of 21 have been stabilized (Table 1).

Table 1. The number of open tidal inlets, inlet modifications, and artificially closed inlets in each state as of December 2011.

State	Existing Inlets							Artificially closed
	Number of Inlets	Total Number of Modified Inlets	Habitat Modification Type					
			structures†	dredged	relocated	mined	Artificially opened	
NC	20	17 (85%)	7	16	3	4	2	11
SC	47	21 (45%)	17	11	2	3	0	1
GA	23	6 (26%)	5	3	0	1	0	0
FL – *Atlantic*	21	19 (90%)	19	16	0	3	10	0
FL – *Gulf*	48	24 (50%)	20	22	0	6	7	1
AL	4	4 (100%)	4	3	0	0	0	2
MS	6	4 (67%)	0	4	0	0	0	0
LA	34	10 (29%)	7	9	1	2	0	46
TX	18	14 (78%)	10	13	2	1	11	3
TOTAL	221	119 (54%)	89 (40%)	97 (44%)	8 (4%)	20 (9%)	30 (14%)	64 (N/A)

† Structures include jetties, terminal groins, groin fields, rock or sandbag revetments, seawalls, and offshore breakwaters.

The state with the highest proportion of unmodified (natural) inlets is Georgia (74%). The highest number of adjacent (or consecutive), unmodified inlets is the 15 inlets between Little Tybee Slough at Little Tybee Island Nature Preserve (GA) and the entrance to Altamaha Sound at the south end of Wolf Island National Wildlife Refuge (GA), a distance of approximately 54 miles. The longest stretch of adjacent, unstabilized inlets is in Louisiana, where 17 inlets between a complex of breaches on the West Belle Pass barrier headland in Lafourche Parish and Beach Prong, located just to the west of the western boundary of the state Rockefeller Wildlife Refuge, have no stabilization structures. One of these inlets, however, has been dredged, namely the Freshwater Bayou Canal. South Carolina also has a lengthy section of coast with no stabilization structures, i.e., the 16 inlets from a small unnamed inlet separating the Tom Yawkey Wildlife Center Heritage Preserve from the Santee Coastal Reserve Wildlife Management Area in Georgetown County to Dewees Inlet in Charleston County (although 1 of them has been modified by dredging: Clarks Creek Channel within Bulls Bay). Mississippi is the only state to have no stabilization structures at any of its 6 inlets; all are within Gulf Islands National Seashore where all of the barrier islands are undeveloped (4 of the 6 inlets are dredged, however).

The highest number of inlets that have been modified is along the Atlantic coast of Florida, where 17 of 19 stabilized inlets are adjacent to one another, extending from the St. John's River in Duval County to Norris Cut in Miami-Dade County, a distance of approximately 341 miles; a shorebird would have to travel about 344 miles between unstabilized inlets along this stretch of coast.

State-specific Results

North Carolina

Twenty tidal inlets currently are open in North Carolina, of which 7 (35%) have been stabilized with hard structures along at least one shoulder (Table 2). Of the inlets with hard structures, 2 have jetties (one with a single jetty and one with dual jetties), one has a terminal groin, one has a landlocked groin, one has a sandbag groin field, one has a non-functional / submerged breakwater, and 2 have sandbag revetments (one of which also has sheet piling). Sixteen (80%) inlets have been or continue to be periodically dredged for navigation or erosion control purposes to redirect channels away from buildings or infrastructure. Three inlets (Masonboro Inlet in 1947, Tubbs Inlet in 1970, and Mason Inlet in 2002) have been relocated, with artificial closures of existing inlets and openings of new inlets nearby, whereas another inlet (Bogue Inlet) has had its main channel relocated in 2006 (Masterson et al. 1973, Cleary and Marden 1999, Erickson et al. 2003, Cleary and Fitzgerald 2003, USACE 2004). New inlets have been cut artificially in two locations (Carolina Beach Inlet in 1953, New Drum Inlet in 1971), but neither has been hardened with structures (Pilkey et al. 1998, Mallinson et al. 2008). The shoal complexes of at least 4 inlets have been mined to supply sediment for beach nourishment projects (Shallotte Inlet in 2001, Bogue Inlet in 2005, Barden Inlet in 2006, and Rich Inlet in 1996, 1999 and 2002); two additional inlets have been proposed for mining – Mason Inlet (for Figure Eight Island) and New River Inlet (for Onslow Beach).

At least 11 inlets or breaches have been closed artificially after having been opened by storm events (Mary's Inlet in the early 1950s, an unnamed breach in Long Beach on Oak Island in 1958, Masonboro Inlet South in 1959, Buxton Inlet in 1963, Moore's Inlet in 1965, Isabel Inlet in 2003, and unnamed breaches on Topsail Island in 1996 and 3 on Hatteras Island near Rodanthe in 2011), while at least 8 inlets were allowed to close as a result of natural coastal processes (New Inlet in 1945, an unnamed inlet on Long Beach in 1956, Mad Inlet in 1997, Old Topsail Inlet in 1998, New / Corncake Inlet in 1999, Old Drum Inlet in 1910, 1971 and 1999, New Drum Inlet in 2008-09, and New-Old Drum Inlet in 2009) (Pilkey et al. 1998, Cleary and Marden 1999, Wamsley and Kraus 2005, Mallinson et al. 2008, Google Earth 2012). Hurricane Isabel in 2003 opened a large new inlet on Hatteras Island near the village of Hatteras, south of Cape Hatteras and within the Cape Hatteras National Seashore, severing North Carolina Highway 12 (Mallinson et al. 2008, Morgan 2009a). The USACE, on behalf of the North Carolina Department of Transportation (NC DOT) and Federal Emergency Management Agency filled in the inlet with material dredged from nearby in 40 days, allowing vehicular traffic to be restored in near record-time (Wamsley and Kraus 2005, Mallinson et al. 2008). Hurricane Irene in August 2011 opened at least 2 inlets and other breaches near Rodanthe on Hatteras Island, north of Cape Hatteras and within or adjacent to the Pea Island National Wildlife Refuge and Cape Hatteras National Seashore; of these breaches, all but one were filled manually within two months while the most significant new inlet (the Pea Island Breach) was temporarily bridged by the NC DOT while long-term alternatives are being evaluated (NC DOT, http://www.ncdot.gov/travel/nc12recovery/). On the undeveloped Cape Lookout National Seashore, 2 inlets have opened since 1999 (New-Old Drum and Ophelia Inlets) and three have naturally closed (Old Drum Inlet, New-Old Drum, and New Drum Inlet – the last of which merged with Ophelia Inlet in 2008-09). Recent studies forecast that the North Carolina Outer Banks will continue to see a series of new inlets open as sea level rises and climate changes (Riggs and Ames 2003, Mallinson et al. 2008).

Table 2. Open tidal inlets from north to south along the North Carolina coast as of December 2011 with actual (X) and proposed (P) habitat modification(s) at each. Note that an X in the Jetties column indicates one jetty is present and a D indicates two (dual) jetties.

Inlet	Type of Habitat Modification							
	Artificially created	Jetties	Terminal groins / groin field	Seawalls / revetments	Breakwaters	Dredging	Relocation of channel or inlet	Mined for beach fill
Oregon Inlet			X			X		
Pea Island Breach				X				
Hatteras Inlet						X		
Ocracoke Inlet						X		
Ophelia Inlet								
Barden Inlet					X	X		X
Beaufort Inlet		X	X			X		
Bogue Inlet				X		X	X	X
Bear Inlet								
Brown's Inlet								
New River Inlet						X		P
New Topsail Inlet			P			X		
Rich Inlet						X	P	X
Mason Inlet						X	X	P
Masonboro Inlet		D				X	X	
Carolina Beach Inlet	X					X		
Cape Fear River			X			X		
Lockwood's Folly Inlet						X		
Shallotte Inlet						X		X
Tubbs Inlet						X	X	

South Carolina

South Carolina currently has 47 tidal inlets open, of which 17 (36%) have been stabilized with hard structures along at least one shoreline (Table 3). Of the inlets with hard structures, 10 have some form of groins (adjacent groins, terminal groins, and/or groin fields), 4 have dual jetties, and 6 have rock revetments and/or seawalls. Eleven (23%) inlets have been or continue to be dredged for navigation or erosion control purposes (i.e., to redirect channels away from buildings or infrastructure). One inlet (Captain Sam's Inlet) has been relocated twice (in 1983 and 1996), with artificial closures of the existing inlet and opening of a new inlet in a nearby location (Kana et al. 1987, Lennon et al. 1996). In addition, an unnamed inlet near Stono Inlet was relocated in 2006 and mined material from the adjacent lower beach was used as beach fill on Kiawah Island to the west (USFWS 2006). No new inlets have been artificially created in South Carolina (except for those that have been relocated). One inlet or breach on Pawley's Island was closed artificially after creation by Hurricane Hugo in 1989 (Lennon et al. 1996). Eleven new inlets or breaches have opened as a result of storms since 1989, with Hurricane Irene in August 2011 opening three new breaches on Cape Island at Cape Romain NWR most recently (Lennon et al. 1996, Sarah Dawsey, USFWS Cape Romain NWR pers. comm.). At least 3 inlets have closed naturally, one in Cherry Grove in the late 1950s (Lennon et al. 1996) and two at Cape Romain NWR around 1992 and 2006 (Sarah Dawsey, USFWS, pers. comm.). The shoal complexes of at least 3 inlets have been mined to supply sediment for beach nourishment projects (Hog Inlet in 1989/1990, Murrell's Inlet in 1989/1990, and Fripp Inlet in 1975).

Table 3. Open tidal inlets from north to south along the South Carolina coast as of December 2011 with actual (X) habitat modification(s) at each. Note that an X in the Jetties column indicates one jetty is present and a D indicates two (dual) jetties.

Inlet	Type of Habitat Modification							
	Artificially created	Jetties	Terminal groins / groin field	Seawalls / revetments	Breakwaters	Dredging	Relocation of channel or inlet	Mined for beach fill
Little River Inlet		D				X		
Hog Inlet				X		X		X
Murrell's Inlet		D				X		X
Midway Inlet								
Pawleys Inlet			X					
North Inlet								
Winyah Bay Entrance		D				X		
small unnamed inlet separating Cat or Sand Island from South Island								
North Santee River								
South Santee River								
small unnamed inlet into a lagoon on the north end of Murphy Island adjacent to South Santee River mouth								
Cape Romain Harbor (between Murphy and Cape Islands)								
Unnamed inlet 1 at south end of Cape Island								
Unnamed inlet 2 at south end of Cape Island								
Unnamed inlet 3 at south end of Cape Island								
Unnamed inlet separating Cape Island from Lighthouse Island								
Key Inlet								
Unnamed inlet 1 on Raccoon Key								
Unnamed inlet 2 on Raccoon Key								
Bulls Bay						X		
Price Inlet								
Capers Inlet								
Dewees Inlet								
Breach Inlet			X	X				
Charleston Harbor Entrance		D				X		
Lighthouse Inlet			X					
Stono Inlet						X		
small unnamed inlet into tidal lagoon on east end of Kiawah Island						X	X	
Captain Sams Inlet						X	X	

Inlet	Type of Habitat Modification							
	Artificially created	**Jetties**	**Terminal groins / groin field**	**Seawalls / revetments**	**Breakwaters**	**Dredging**	**Relocation of channel or inlet**	**Mined for beach fill**
North Edisto River Inlet								
South Creek Inlet								
Frampton Inlet								
Jeremy Inlet				X				
St. Helena Sound Entrance			X					
Johnson Creek			X					
Fripp Inlet			X			X		X
Skull Inlet			X	X				
Price Creek								
Pritchards Inlet								
small unnamed inlet on Little Capers Island								
Trenchards Inlet								
Morse Creek								
Port Royal Sound Entrance			X			X		
Folly Creek			X					
Calibogue Sound Entrance				X				
Mungen Creek			X	X				
Wright River								

Georgia

There are 23 tidal inlets currently open in Georgia, of which 5 (22%) are stabilized with hard structures along at least one shoulder (Table 4). Of the inlets with hard structures, 2 have terminal groins, 2 have adjacent groin fields, 1 has dual jetties, 1 has an offshore breakwater, and 4 have rock revetments and/or seawalls. Three (13%) inlets have been dredged for navigation or erosion control purposes. No inlets have been relocated, artificially opened or artificially closed in Georgia. The inlet separating Williamson Island from Little Tybee Island opened naturally sometime between 1957 and 1960 (Clayton et al. 1992), but no other inlets have naturally opened or closed since then. The shoal complex of at least one inlet has been mined to supply sediment for a beach nourishment project (Hampton River Inlet in 1990).

Table 4. Open tidal inlets from north to south along the Georgia coast as of December 2011 with actual (X) habitat modification(s) at each. Note that an X in the Jetties column indicates one jetty is present and a D indicates two (dual) jetties.

Inlet	Type of Habitat Modification							
	Artificially created	Jetties	Terminal groins / groin field	Seawalls / revetments	Breakwaters	Dredging	Relocation of channel or inlet	Mined for beach fill
Savannah River Entrance		D			X	X		
Savannah River South Channel			X	X				
Tybee Inlet			X	X				
Little Tybee Slough								
Little Tybee Creek								
Wassaw Sound Entrance								
Ossabaw Sound Entrance								
Bradley Slough								
Unnamed slough on middle of Ossabaw Island								
Big Slough								
Saint Catherine's Sound Entrance								
Seaside Inlet (at Fish Creek)								
McQueen Inlet								
Sapelo Sound Entrance								
Cabretta Inlet								
Big Hole (between Cabretta and Sapelo Islands)								
Doboy Sound Entrance								
Altamaha Sound Entrance								
Hampton River Inlet						X		X
Gould's Inlet				X				
Saint Simons Sound Entrance				X		X		
Saint Andrews Sound Entrance								
Christmas Creek								

Florida Atlantic Coast

Twenty-one tidal inlets currently are open on Florida's Atlantic coast from the Georgia state line south to Key Biscayne, of which 19 (90%) have been stabilized with hard structures along at least one shoulder (Table 5). Of the inlets with hard structures, 2 have terminal groins, 16 have jetties (all 16 with 2 jetties), 1 has a rock revetment, 2 have offshore breakwaters and 1 has an adjacent groin field. Sixteen (76%) inlets have been dredged for navigation or erosion control purposes. No inlets have been relocated, but new inlets have been cut artificially in 10 (48%) locations for various purposes (St. Augustine, Sebastian, Fort Pierce, St. Lucie, Lake Worth, Boynton, Boca Raton, Port Everglades, Haulover, and Government Cut Inlets); all of these inlets were cut where no inlets existed at the time except for Boca Raton Inlet, which has been repeatedly reopened following natural closures by storms from 1966-1969; all of the new inlets have jetties (Sargent 1988, Bush et al. 2004, Palm Beach County 2003). No inlets have been closed artificially after having been opened by storms , but four inlets have closed as a result of natural coastal processes: old St. Augustine Inlet, Sebastian Inlet in 1941, an inlet near Lake Worth in 1919, and Boca

Raton Inlet several times from 1966-1969. Old St. Augustine Inlet between Villano Beach and Conch Island and the one near Black Rocks near Lake Worth were allowed to remain closed, with the other two being reopened artificially. A nor'easter in 1973 opened a small breach near Ponce Inlet, which presumably closed shortly thereafter (Bush et al. 2004). An ephemeral inlet periodically opens and closes in the Summer Haven area south of Matanzas Inlet; it is currently closed (John Milio, USFWS, pers. Communication 3/8/12). The shoal complexes of at least three inlets have been mined to supply sediment for a beach nourishment project (Boca Raton Inlet in 1985, Jupiter Inlet in 1995, and St. Augustine Inlet in 1996;Cialone and Stauble 1998, Bush et al. 2004).

Table 5. Open tidal inlets from north to south along the east Florida coast as of December 2011 with actual (X) habitat modification(s) at each. Note that an X in the Jetties column indicates one jetty is present and a D indicates two (dual) jetties.

Inlet	**Type of Habitat Modification**							
	Artificially created	**Jetties**	**Terminal groins / groin field**	**Seawalls / revetments**	**Breakwaters**	**Dredging**	**Relocation of channel or inlet**	**Mined for beach fill**
St. Mary's Entrance		**D**				**X**		
Nassau Sound Entrance			**X**					
Fort George Inlet								
St. John's River		**D**				**X**		
St. Augustine Inlet	**X**	**D**				**X**		**X**
Matanzas Inlet				**X**	**X**			
Ponce de Leon Inlet		**D**				**X**		
Port Canaveral		**D**				**X**		
Sebastian Inlet	**X**	**D**				**X**		
Fort Pierce Inlet	**X**	**D**				**X**		
St. Lucie Inlet	**X**	**D**			**X**	**X**		
Jupiter Inlet		**D**				**X**		**X**
Lake Worth Inlet	**X**	**D**				**X**		
Boynton Inlet (aka South Lake Worth Inlet)	**X**	**D**				**X**		
Boca Raton Inlet	**X**	**D**				**X**		**X**
Hillsboro Inlet		**D**				**X**		
Port Everglades Channel	**X**	**D**				**X**		
Haulover Inlet	**X**	**D**	**X**			**X**		
Government Cut	**X**	**D**				**X**		
Norris Cut			**X**					
Bear Cut								

Florida Gulf Coast

There are 48 tidal inlets currently open along Florida's Gulf coast between the Alabama state line on the panhandle and Cape Romano, of which 20 (42%) have been stabilized with hard structures along at least one shoulder (Table 6). Of the inlets with hard structures, 7 have some sort of groin (adjacent groins, terminal groins and/or groin fields), 11 have jetties (3 inlets with 1 jetty and 8 inlets with dual jetties), 1 has an offshore breakwater, and 5 have rock revetments and/or seawalls. At least 22 (46%) inlets have been or continue to be dredged periodically for various purposes. No inlets have been relocated along the Gulf coast of Florida, although two new inlets have been opened artificially to replace existing inlets which subsequently closed naturally – new East Pass (Destin Pass) and West Pass (Panama City).

New inlets have been cut artificially (either in new locations or to reopen an inlet that closed naturally) in 8 locations (5 of which now have hard structures): East Pass (Destin Pass) in 1926, West Pass (Saint Andrews Bay - Panama City Harbor) in 1933-1934, Venice Inlet before 1937, Bob Sikes Cut in 1954, Clam Pass in 1976 and again in 1981, Midnight Pass in 1983, Blind Pass (Lee County) in 2000 and again in 2009, and St. Andrew Pass on Crooked Island in 2001; a ninth inlet, Big Hickory Inlet, was reopened artificially in 1976 but it closed naturally in 1979 and then has reopened naturally since (Sargent 1988, Davis and Gibeaut 1990, Bush et al. 2001, Antonini et al. 2002). Mexico Beach Canal, also artificially created, has been stabilized on both shorelines, and requires dredging to remain open. However, it was not included in this assessment because it is a manmade canal with no discernible tidal inlet geomorphology. At least one inlet (Philips Inlet) was closed artificially to block oil spilled in the Deepwater Horizon disaster, and at least 17 inlets were allowed to close as a result of natural coastal processes (Sargent 1988, Davis and Gibeaut 1990, Bush et al. 2001, Antonini et al. 2002, Dezember 2010). At least 12 inlets have been opened naturally by storms along the Florida Gulf coast (Sargent 1988, Davis and Gibeaut 1990, Antonini et al. 1999, Bush et al. 2001, Antonini et al. 2002). The shoal complexes of at least 6 inlets have been mined to supply sediment for beach nourishment projects: Pass-a-Grille Channel in the 1980s, Redfish Pass in 1981 and 1988, Johns Pass in 1988, Longboat Pass in 1993, New Pass (Sarasota County) in 1993, and Caxambas Pass in 1990, 1997, 2006 and proposed again for 2012 (Davis and Gibeaut 1990, Cialone and Stauble 1998, Bush et al. 2001, Antonini et al. 2002, Coastal Engineering Consultants 2012). Altogether, 24 of the 48 (50%) west Florida inlets have been modified in some manner.

Table 6. Open tidal inlets from north (west) to south (east) along the west Florida coast as of December 2011 with actual (X) habitat modifications at each. Note that an X in the Jetties column indicates one jetty is present and a D indicates two (dual) jetties.

Inlet	Type of Habitat Modification							
	Artificially created	Jetties	Terminal groins / groin field	Seawalls / revetments	Breakwaters	Dredging	Relocation of channel or inlet	Mined for beach fill
Pensacola Pass			X			X		
East Pass (aka Destin Pass)	X	D				X		
West Pass (St. Andrew's Bay - Panama City)	X	D				X		
St. Andrew Sound Entrance								
Indian Pass								
West Pass (between St. Vincent and Little St. George Islands)								
Bob Sikes Cut	X	D				X		
East Pass (between eastern St. George Island State Park and Dog Islands)								
Unnamed pass between Anclote Key and Anclote Bar to the north								
Unnamed pass between Three Rooker								

Inlet	Type of Habitat Modification							
	Artificially created	Jetties	Terminal groins / groin field	Seawalls / revetments	Breakwaters	Dredging	Relocation of channel or inlet	Mined for beach fill
Bar and Anclote Key								
Unnamed pass between Three Rooker Island and Three Rooker Bar								
St. Joseph Sound (between Honeymoon and Three Rooker Islands)								
Hurricane Pass								
Clearwater Pass		D				X		
Johns Pass		X		X		X		X
Blind Pass (Pinellas County)		D						X
Pass-a-Grille Channel		X				X		X
Bunces Pass								
Unnamed inlet into lagoon on Mullet Key at Fort De Soto Park								
Egmont Channel				X		X		
Southwest Channel								
Passage Key Inlet								
Longboat Pass		X				X		X
New Pass (Sarasota County)			X	X		X		X
Big Sarasota Pass				X				
Venice Inlet	X	D				X		
Stump Pass						X		
Gasparilla Pass								
Boca Grande Pass			X			X		
Captiva Pass								
Redfish Pass			X			X		X
Blind Pass (Lee County)	X		X			X		
Matanzas Pass						X		
Big Carlos Pass								
New Pass (Lee County)								
Unnamed breach in Big Hickory Island								
Big Hickory Pass	X[†]		X			X		
Wiggins Pass						X		
Clam Pass	X					X		
Doctors Pass		D				X		
Gordon Pass		D				X		
Little Marco Pass								
Big Marco Pass								
Caxambas Pass			X	X	X	X		X
Unnamed breach between Dickman's and Kice Islands								
Blind Pass (Collier County)								
Unnamed pass between Big Morgan Island and the island to the north								
Morgan Pass								

† Big Hickory Inlet closed naturally and was reopened artificially in 1976, but the inlet closed again in 1979; the existing Big Hickory Inlet naturally opened since that time.

Alabama

All 4 tidal inlets currently open in Alabama have been stabilized with hard structures along at least one shoulder (Table 7): one has a groin field, one has dual jetties, one is "temporarily" closed with a rock berm, and 3 have rock or sheet pile revetments and/or seawalls. Three (75%) inlets have been or continue to be dredged periodically. No inlets have been relocated. No new inlets have been cut artificially , but West Pass (aka Little Lagoon Pass) was temporarily closed with a sand dike during the Deepwater Horizon oil spill response effort in May 2010 and then was artificially reopened in September 2010 (Dezember 2010). At least two inlets created by hurricanes were allowed to close on Dauphin Island as a result of natural coastal processes (Bush et al. 2001). Hurricane Ivan in 2004 opened a new inlet at Pine Beach in the Bon Secour National Wildlife Refuge (Morgan 2009a), but the inlet appear to be closed in 2009 Google Earth imagery. The shoal complexes of no inlets have been mined to supply sediment for beach nourishment projects in Alabama.

Dauphin Island has had several inlets cut across the island by hurricanes, including a 5-mile wide shallow inlet cut by an early 20th century hurricane (which had closed by 1942), a September 1948 hurricane, and Hurricane Katrina in 2005 (Bush et al. 2001, USACE 2011). Katrina Cut, opened on the western end of Dauphin Island by Hurricane Katrina, was "temporarily" closed with a rock berm or dike in 2010-2011 with the original purpose to block oil from the Deepwater Horizon spill from reaching Mississippi Sound. Alabama has since requested that the USACE allow the berm to remain as a permanent structure (USACE 2011).

Table 7. Open tidal inlets from west to east along the Alabama coast as of December 2011 with actual (X) habitat modification(s) at each. Note that an X in the Jetties column indicates one jetty is present and a D indicates two (dual) jetties.

Inlet	Type of Habitat Modification							
	Artificially created	Jetties	Terminal groins / groin field	Seawalls / revetments	Breakwaters	Dredging	Relocation of channel or inlet	Mined for beach fill
Katrina Cut†								
Mobile Pass			**X**	**X**		**X**		
West Pass‡				**X**		**X**		
Perdido Pass		**D**		**X**		**X**		

† Katrina Cut was "temporarily" closed with a rock dike as part of the Deepwater Horizon oil spill response efforts in 2010 but the state is currently seeking permission from the USACE to make the structure permanent (USACE 2011).

‡ West Pass (aka Little Lagoon Pass) was temporarily closed with a sand dike from in May 2010 as part of the Deepwater Horizon oil spill response efforts but was artificially reopened in September 2010 (Dezember 2010).

Mississippi

Six tidal inlets currently are open in Mississippi, none of which has been stabilized with hard structures (Table 8). Four (67%) are dredged for navigation (Morton 2008). No new inlets have been cut artificially in barrier islands, been closed artificially after having been opened by storms, been relocated, or naturally closed in recent years. At least 7 inlets have been opened by storms, including Camille Cut opened by Hurricane Camille in 1969 on Ship Island, thereby creating West and East Ship Islands (Bowden 1994, Otvos 2006, Otvos and Carter 2008). At least 7 breaches or inlets have closed naturally since 1952 (Otvos and Carter 2008, Stockdon et al. 2010).

The Mississippi Coastal Improvements Program (MsCIP) comprehensive plan for coastal Mississippi proposes the use of dredged material from the Horn Island ship channel to provide beach fill for a portion of West Ship Island within Gulf Islands National Seashore (NPS 2010) and to close Camille Cut between West and East Ship Islands with sediment mined from Sand Island (USACE 2009, Paul Necaise, USFWS, pers. Communication 3/6/12). No inlet shoal complexes have been mined to supply sediment for beach nourishment projects in Mississippi.

Table 8. Open tidal inlets from west to east along the Mississippi coast as of December 2011 with actual (X) habitat modifications at each.

Inlet	Type of Habitat Modification							
	Artificially created	Jetties	Terminal groins / groin field	Seawalls / revetments	Breakwaters	Dredging	Relocation of channel or inlet	Mined for beach fill
Ship Island Pass						X		
Camille Cut†								
Dog Keys Pass						X		
Unnamed inlet between Sand Island and Horn Island								
Horn Island Pass						X		
Petit Bois Pass						X		

†Camille Cut is proposed to be artificially closed as part of the MsCIP comprehensive plan.

Louisiana

At least 34 tidal passes (inlets) with sandy shorelines are currently open along the deltaic coast of Louisiana. This total does not include passes without sandy shorelines and counts the Chandeleur Island chain and the West Belle Pass barrier headland as one inlet complex each. The Chandeleur Island chain was fragmented with 44 inlets by Hurricane Katrina in 2005 but roughly 11 inlets were closed by the state during the Deepwater Horizon oil spill response effort, resulting in a highly dynamic and uncertain series of islets and inlets. As of September 2011 approximately 7 breaches were present along the West Belle Pass barrier headland shoreline (none of which existed in 2010), but a federally-funded beach restoration project scheduled for 2012 would close any of these breaches that remain open at the time of construction. The vast majority of passes or inlets in Louisiana are connected to extensive wetland complexes and are not inlets separating barrier islands as typically are found throughout the rest of the range (and as described in Figure 1); nevertheless, these delta-influenced and sediment-starved inlets often provide valuable shorebird and waterbird habitat.

Of the 34 passes open in 2011, 7 (21%) have been stabilized with hard structures along at least one shoreline. Of these, 7 have jetties (2 inlets with 1 jetty and 5 inlets with dual jetties), 1 has a groin, and 1 has a rock revetment or seawall (Table 9). At least 9 (26%) sandy passes in Louisiana that have been dredged for navigation or other purposes: Calcasieu Pass, Mermentau River, Freshwater Bayou, Belle Pass (Bayou Lafourche), Barataria Pass, Pass La Mer, Chaland Pass, Fontanelle Pass, and South Pass of the Mississippi River; Southwest Pass of the Mississippi River is also federally maintained with dredging, but as of 2011 does not have sandy shorelines adjacent to the distributary channel and thus was not included in this analysis. One inlet channel (Bayou Lafourche) was relocated in 1968, with artificial closure of the existing navigational channel and the opening of a new channel 300 feet to the west (Sargent and Bottin 1989a). No new inlets have been cut artificially (not including oil and gas industry canals).

Breaches cut by Hurricane Andrew (1992) on Raccoon Island were closed artificially (Louisiana Department of Wildlife and Fisheries, http://www.wlf.louisiana.gov/refuge/terrebonne-barrier-islands-refuge). Several projects funded under the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) have artificially closed inlets while restoring Louisiana's coast, with 3 breaches having been closed on the Chaland headland in 2006 (CWPPRA Project BA-38), approximately 8 breaches on East Timbalier Island in 1999-2000 (CWPPRA Projects TE-25 and TE-30), 3 breaches on Trinity Island in 1998 (CWPPRA Project TE-24), and the Coupe Nouvelle breach on Whiskey Island in 1998 (CWPPRA Project TE-27) (Louisiana Office of Coastal Protection and Restoration, http://www.lacoast.gov). Approximately 29 inlets were closed in response to the Deepwater Horizon oil spill, including 2 on Elmer's Island in Jefferson Parish, approximately 11 in the Chandeleur Island chain, approximately 6 on Scofield Island, approximately 6 on Pelican Island, and approximately 4 on Shell Island as part of Louisiana's sand berms building project (National Commission 2011, Google Earth 2012, Louisiana Office of Coastal Protection and Restoration (http://coastal.louisiana.gov/index.cfm?md=pagebuilder&tmp=home&pid=131 and http://www.lacoast.gov). In addition, any of the 7 breaches on the West Belle Pass barrier headland that are open at the time of construction will be closed as part of a barrier island restoration project funded by the National Oceanic and Atmospheric Administration in October 2011 (NOAA, http://www.habitat.noaa.gov/hlbarrierislandrestoration.html). Altogether at least 46 inlets (including those on the Chandeleur Island chain) have been closed artificially in Louisiana in recent years and 7 more likely to be closed in 2012.

Hurricanes Katrina, Rita and others created several dozen new inlets and breaches along the Louisiana coast, most notably within the Chandeleur Island chain of Breton National Wildlife Refuge, where the island was segmented into 45 islets and 44 inlets/breaches following Hurricane Katrina (Stockdon et al. 2007, Sallenger et al. 2009). An unknown number of inlets have closed as a result of natural coastal processes but the number is likely small as the natural closure of storm breaches during poststorm recovery periods is limited by a restricted supply of sandy sediments in coastal Louisiana and the relatively short period between storms in recent years. At least 2 inlet shoal complexes have been mined to supply sediment for beach nourishment projects (Pass La Mer in 2009 and Chaland Pass in 2009).

Table 9. Open tidal inlets from west to east along the Louisiana coast as of December 2011 with actual (X) habitat modification(s) at each. Note that an X in the Jetties column indicates one jetty is present and a D indicates two (dual) jetties. Also note that the Chandeleur Island complex is listed here as one entry due to its recent disintegration into dozens of islets, closure of numerous inlets during Deepwater Horizon oil spill response efforts, and uncertain stability.

Inlet	Type of Habitat Modification							
	Artificially created	Jetties	Terminal groins / groin field	Seawalls / revetments	Breakwaters	Dredging	Relocation of channel or inlet	Mined for beach fill
Unnamed breach in sandbar/spit adjacent to eastern jetty at Sabine Pass								
Calcasieu Pass		D				X		
Mermentau River Navigation Channel		D				X		
Beach Prong (west of the western boundary of Rockefeller Refuge)								
Joseph Harbor Bayou								
Little Constance Bayou								
Pigeon Bayou								
East Little Constance Bayou								
Rollover Bayou								
Freshwater Bayou Canal						X		
Mosquito Bayou								
Oyster Bayou								
Goreau River								
Bayou de West								
Jack Stout Bayou								
Fish Bayou								
Turtle Bayou								
Whiskey Pass								
Small inlet complex at eastern end of East Timbalier Island								
West Belle Pass barrier headland breaches†								
Belle Pass (i.e., Bayou Lafourche)		D				X	X	
Caminada Pass		X						
Barataria Pass		X		X		X		
Pass Abel								
Bayou Quatre Pass								
Pass Ronquille								
Unnamed breach two west of Pass La Mer								
Unnamed breach immediately west of Pass La Mer								
Pass La Mer						X		X
Chaland Pass						X		X
Fontanelle Pass (i.e., Empire Waterway)		D	X			X		
Scofield Bayou								
South Pass		D				X		
Chandeleur Island complex								

† Any breaches open along the West Belle Pass barrier headland are proposed to be closed in 2012 as part of a federally-funded restoration project (NOAA, http://www.habitat.noaa.gov/hlbarrierislandrestoration.html).

Texas

Eighteen tidal inlets currently are open in Texas, of which 10 (56%) have been stabilized with hard structures along at least one shoulder (Table 10). Of the latter, 9 have dual jetties, one has groins and one has sheet pile revetments. At least 13 (72%) inlets have been or continue to be dredged periodically for navigation or other purposes; 8 inlets are federally maintained as navigation channels and 4 have been dredged only once (Sargent and Bottin 1989b, USACE 1992, Kraus 2007). [Corpus Christi Pass, now closed and therefore not included in the above count of 13, was dredged in 1928 and 1938 before its 1943 closure (the inlet opens and closes intermittently due to storms; USACE 1992)]. The mouth of the Brazos River was relocated 5 miles to the south in 1929 for flood control purposes, but the old river mouth was not closed and currently exists as the Freeport Ship Channel (Sargent and Bottin 1989b, Kraus 2007). The San Bernard River mouth and Bolivar Roads (Galveston Bay) inlets have been relocated (Woody Woodrow, USFWS, pers. Communication 3/6/12). New inlets have been cut artificially in 11 locations for fish passage, flood relief and other purposes in Texas: the Brazos River (Diversion Channel) in 1929, the Colorado River Navigation Channel in 1934, Yarbrough Pass in 1952, Mansfield Pass in 1957 and 1962, Rollover Fish Pass in 1954-55, Matagorda Ship Channel in the 1962, Mustang Island Fish Pass in 1972, McCabe Cut in 1983, Cedar Bayou most recently in 1988 (also in 1939 and 1959), Mitchell's Cut in 1989, and Packery Channel in 2003-06. Four of the artificially created inlets have jetties today. The artificial cuts at both Mustang Island Fish Pass and Yarborough Pass were unsuccessful and both passages have closed naturally, although jetties still exist on the Gulf beach side of Mustang Island Fish Pass (Sargent and Bottin 1989b, USACE 1992, Wamsley and Kraus 2005, Kraus 2007, Williams et al. 2007, Thomas et al. 2011).

Table 10. Open tidal inlets from west (south) to east (north) along the Texas coast as of December 2011 with actual (X) and proposed (P) habitat modification(s) at each. Note that an X in the Jetties column indicates one jetty is present and a D indicates two (dual) jetties.

Inlet	Type of Habitat Modification							
	Artificially created	Jetties	Terminal groins / groin field	Seawalls / revetments	Breakwaters	Dredging	Relocation of channel or inlet	Mined for beach fill
Rio Grande River Mouth								
Brazos-Santiago Pass		D	X			X		
Mansfield Pass	X	D				X		
Packery Channel	X	D				X		
Aransas Pass		D				X		
Pass Cavallo						X		
Matagorda Ship Channel	X	D				X		
Colorado River Mouth	X	D				X		
Mitchell's Cut	X					X		
San Bernard River Mouth						X	X	
Brazos River Diversion Channel	X							
Bryan Beach Cut								
Quintana Beach Cut								

Inlet	Type of Habitat Modification							
	Artificially created	Jetties	Terminal groins / groin field	Seawalls / revetments	Breakwaters	Dredging	Relocation of channel or inlet	Mined for beach fill
Freeport Ship Channel		**D**				**X**		
San Luis Pass								**P**
Bolivar Roads (Galveston Bay)		**D**				**X**	**X**	**X**
Rollover Pass	**X**			**X**		**X**		**X**
Sabine Pass		**D**				**X**		

Three inlets have been closed artificially: Boca Chica Pass in 1868, Cedar Bayou in 1979 as part of IXTOC oil spill response efforts, and McCabe Cut in 1989 after Mitchell's Cut was opened nearby (USACE 1992). At least 14 inlets have been allowed to close as a result of natural coastal processes: Bryan Beach Cut 2, Wolf Island Cut, Cedar Lakes Pass, Matagorda Peninsula Cut, Brown Cedar Cut, 3-mile Cut, Greens Bayou, Cedar Bayou, Mustang Island Fish Pass, Corpus Christi Pass, Newport Pass, Yarborough Pass, Mansfield Pass and Boca Chica Pass (Sargent and Bottin 1989b, USACE 1992, Bates 2004, Kraus 2007, Google Earth 2012, Jennifer Wilson, USFWS, pers. Communication 3/7/12). A permit has been issued to reopen Cedar Bayou artificially as a fish pass, but the project has not been constructed yet (Robyn Cobb, USFWS, pers. Communication 3/7/12). At least 5 inlets are hurricane overwash channels that open and close naturally in response to storms, including Brown Cedar Cut, Greens Bayou, Cedar Bayou, Corpus Christi Pass and Newport Pass (USACE 1992, 2003); Cedar Lakes Pass is also a hurricane overwash channel that is influenced by river flows from the San Bernard River but is currently closed (Woody Woodrow, USFWS, pers. communication 3/7/12). Hurricane Allen reportedly cut 42 breaches across South Padre Island in 1980 (St. John 1991), Hurricane Bret opened a dozen breaches on Padre Island in 1999, and Hurricane Camille opened numerous breaches on Matagorda Island in 1969 (Robyn Cobb, USFWS, pers. Communication 3/7/12). Several overwash breaches appear in Google Earth imagery from 2011 on southern North Padre, South Padre and Brazos Islands from more recent storm events.

Bolivar Roads (Galveston Bay) has been mined to supply sediment for beach nourishment projects and the flood tidal delta of San Luis Pass has been proposed for mining as a source for a beach restoration project (Woody Woodrow, USFWS, pers. communication 3/6/12; Robyn Cobb, USFWS, pers. communication 3/7/12). The USACE (1992) reported that 6 of the 8 federally maintained navigation channels contained suitable material for mining as a source for beach fill.

DISCUSSION

Over half (54%) of the sandy tidal inlet habitats within the U.S. continental migration and wintering range of the piping plover that existed in 2010-2011 has been modified within the last century or so by human actions, such as the construction of hard stabilization structures, dredging activities, sediment mining, and the artificial relocation, opening and closing of inlets. The Atlantic coast of Florida has the most contiguously modified habitat; by contrast, significant sections of the South Carolina, Georgia and Louisiana coasts have remained unmodified. Two-thirds or more of the inlets of North Carolina, eastern Florida, Alabama, Mississippi and Texas have been modified (Table 1).

The adverse direct and indirect impacts of hard stabilization structures, dredging, inlet relocations and mining can be significant. The impacts that jetties have on inlet and adjacent shoreline habitat have been described by Cleary and Marden (1999), Bush et al. (1996, 2001, 2004), Wamsley and Kraus (2005), Thomas et al. (2011) and many others. The maintenance of navigation channels by dredging, especially deep ship channels such as those in Alabama and Mississippi, can significantly alter the natural coastal processes on adjacent inlet shorelines, as described by Otvos (2006), Morton (2008), Otvos and Carter (2008), Beck and Wang (2009), and Stockdon et al. (2010). The relocation of inlets or the creation of new inlets often leads to immediate widening of the new inlet cut and loss of adjacent habitat, amongst other impacts; these responses have been described by Mason and Sorenson (1971), Masterson et al. (1973), USACE (1992), Cleary and Marden (1999), Cleary and Fitzgerald (2003), Erickson et al. (2003), Kraus et al. (2003), Wamsley and Kraus (2005) and Kraus (2007). Cialone and Stauble (1998) describe the impacts of mining ebb shoals within inlets as a source of beach fill material at 8 locations and provide a recommended monitoring protocol for future mining events; Dabees and Kraus (2008) also describe the impacts of ebb shoal mining. In brief, mining of ebb shoals disrupts the dynamic equilibrium of the inlet and its natural processes and can alter tidal currents and circulation, increase erosion of adjacent shorelines, expose adjacent shorelines to higher wave energy, modify the longshore sediment transport system, impair sediment bypassing across the inlet, and result in the migration of tidal channels and shoals (Cialone and Stauble 1998, Dabees and Kraus 2008).

The cumulative effects of the habitat modifications to sandy tidal inlets within the migration and wintering range of the piping plover are appreciable and significant. The cumulative effects catalogued herein are regional, covering all eight states of the U.S. continental mainland range of the wintering piping plover. Range-wide, over half (54%) of the inlets and their associated habitats have been modified. The cumulative environmental consequences are adverse, major and long-term.

The artificial opening and closing of inlets modifies this type of habitat in the most extreme manner, resulting in the artificial conversion of habitat types and alteration of their abundance and distribution. A high number of inlets (30) have been artificially created within the migration and wintering range of the piping plover, including 10 of the 21 inlets along the eastern Florida coast (Table 1). These artificially created inlets tend to need hard structures to remain open or stable, with 20 of the 30 (67%) of them having hard structures at present. An even higher number of inlets (64) have been artificially closed, the majority in Louisiana; artificial closure of inlets results in complete loss of inlet habitat. One inlet in Texas was closed in response to the IXTOC oil spill in 1979, and 32 others in 2010-2011 because of the Deepwater Horizon oil spill. Of the latter, 29 are located in Louisiana, 2 in Alabama and 1 in Florida. To date only one of these inlets, West (Little Lagoon) Pass in Gulf Shores, Alabama, has been reopened, and the rest remain closed with no current plans for them to be reopened. The other inlets that have been artificially closed in Louisiana tend to be barrier island restoration projects because many of the state's barrier islands are disintegrating (Otvos 2006, Morton 2008, Otvos and Carter 2008).

The dredging of navigation channels or to relocate inlet channels for erosion control purposes also contributes to the cumulative effects by removing or redistributing the local and regional sediment supply; the maintenance dredging of deep ship channels can convert a natural inlet that normally bypasses sediment from one shoreline to the other into a sediment sink in which sediment no longer bypasses the inlet. Of the dredged inlets included in this analysis, dredging efforts began as early as the 1800s and continue to the present, generating long-term and even permanent effects on inlet habitat; at least 11 inlets have been dredged since the 19th Century, with the Cape Fear River (NC) having been dredged as early as 1826 and Mobile Pass (AL) since 1857. Dredging conducted every year or every 2 to 3 years results in continual perturbations and modifications to inlet and adjacent shoreline habitat. The volumes of sediment removed can be major, with 2.2 million cubic yards of sediment being removed on average every 1.9 years from the Galveston Bay Entrance (TX) and 3.6 million cubic yards of sediment removed from Sabine Pass (TX) on average every 1.4 years (USACE 1992). The mining of inlet shoals also removes massive amounts of sediment, with 1.98 million cubic yards mined for beach fill from Longboat Pass (FL) in 1998, 1.7 million cubic yards from Shallotte Inlet (NC) in 2001 and 1.6 million cubic yards from Redfish Pass (FL) in 1988 (Cialone and Stauble 1998, USACE 2004). This 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. All of these dredging and mining impacts are range-wide and are being conducted in every state.

The hard stabilization of inlets is another contributor to the appreciable cumulative adverse effects to inlet habitat along the southeastern Atlantic and Gulf coasts. The construction of jetties, groins, seawalls and revetments leads to habitat loss and both direct and indirect impacts to adjacent shorelines. Habitat modifications resulting from the construction of hard structures are long-term and permanent; at least 13 inlets across 6 of the 8 states containing have hard structures dating from the 19th Century. These effects are on-going, cumulative, and increasing in intensity, as hard structures continue to be built as recently as 2011 and others proposed for 2012. With sea level rising and global climate change altering storm dynamics, the pressure to modify the remaining half of sandy tidal inlets will only increase. Thus, the adaptation management strategies recommended by the USFWS climate change strategy (USFWS 2010), CCSP (2009), Williams and Gutierrez (2009), Pilkey and Young (2009), and many others will increasingly be difficult to implement.

Indeed, Otvos (2006, p. 1587) found that "[a]ccelerating trends of island destruction have brought delta-fringing Louisiana islands to the verge of extinction." A typical cycle along much of the coast of the migration and wintering range of the piping plover is for storms to open a new inlet or breach in a barrier island; then the inlet closes naturally as littoral drift slowly fills the breach within a small number of years. In this way islands are alternately segmented and joined as inlets naturally open and close (Davis and Gibeaut 1990, Otvos and Carter 2008, Stockdon et al. 2010). But many sections of coast are disintegrating and in some cases face extinction due to insufficient sediment in the system to support the natural post-storm reconstruction (sometimes due to dredging of nearby channels that act as sediment sinks), more intense and/or frequent storms due to climate change, and a rising sea level, all of which perturb the natural cycle of inlet opening and closing. This pattern is being observed along the North Carolina Outer Banks (Riggs and Ames 2003, Mallinson et al. 2008, Smith et al. 2008), western Dauphin Island in Alabama (Otvos 2006, Morton 2008), the Mississippi barrier islands of Gulf Islands National Seashore (Morton 2008, Stockdon et al. 2010), and much of the Louisiana coast (Otvos 2006, Morton 2008, Otvos and Carter 2008).

The cumulative effects of the existing habitat modifications to 119 of the 221 inlets, as described in this assessment, should be addressed in current and future proposals that would affect sandy tidal inlets within the U.S. continental wintering range of the piping plover. Rising sea level and climate change are likely to continue to increase the number of inlets in the near future. Whether these new inlets will provide additional favorable habitat to the piping plover and other wildlife, however, will depend on the human responses to their formation and whether decisions will be made to close or modify an inlet or allow natural processes to operate. The NC DOT and its partners, for example, are currently evaluating long-term solutions to the transportation corridors along the Outer Banks and whether to bridge, stabilize or close new inlets such as the ones opened in 2011 by Hurricane Irene. Large-scale plans to restore the Louisiana (Coast 2050 plan) and Mississippi (MsCIP Project) coasts also have been proposed. Although these plans would eliminate a significant number of current inlets, they would restore local sediment supplies to maintain beach and inlet habitats and improve their resilience to climate change and rising sea level (Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority 1998, USACE 2009). Finally, opportunities exist to restore and/or mitigate adverse impacts to existing inlets through the removal of hard structures, elimination of dredging and mining activities, reducing the frequency of dredging cycles, and the beneficial use of dredged material.

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Appendix 1c. The Status of Sandy Oceanfront Beach Habitat in the Continental U.S. Coastal Migration and Wintering Range of the Piping Plover (*Charadrius melodus*)[1]

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The 5-Year Review of the U.S. Fish and Wildlife Service (USFWS) for the piping plover (*Charadrius melodus*) recommends developing a state-by-state atlas for wintering and migration habitat for the overlapping coastal migration and wintering ranges of the federally listed (endangered) Great Lakes, (threatened) Atlantic Coast and Northern Great Plains piping plover populations (USFWS 2009). The atlas should include data on the abundance, distribution and condition of currently existing habitat. This assessment addresses this recommendation by providing information for one habitat type – namely, sandy oceanfront beaches within the migration and wintering range of the southeastern continental United States (U.S.). Sandy beaches are a valuable habitat for piping plovers, other shorebirds and waterbirds for foraging, loafing, and roosting.

METHODS

In order to evaluate the status of sandy oceanfront beaches along the coastlines of North Carolina (NC), South Carolina (SC), Georgia (GA), Florida (FL), Alabama (AL), Mississippi (MS), Louisiana (LA) and Texas (TX), several methods were used. Non-sandy oceanfront areas were excluded because they do not currently provide this habitat. These excluded areas occur along marshy sections of coast in Louisiana, the Big Bend Marsh coast of northwest Florida, the Ten Thousand Island Mangrove coast of southwest Florida, and the Florida Keys. The status of sandy oceanfront beaches was evaluated through an estimation of the length and proportions of shoreline that were developed, undeveloped, preserved, armored or with beach fill or dredge spoil placement. Mainland beaches, with the exception of those in Mississippi, were not included unless no barrier islands were located offshore and thus the mainland beaches were located directly on the Atlantic Ocean or Gulf of Mexico (e.g., Holly Beach, Louisiana).

The lengths of developed versus undeveloped sandy oceanfront beach were assessed primarily by using published reports such as the United States Geological Survey's (USGS's) *Coastal Classification Atlas* that was recently completed for most of the Gulf of Mexico coast. Existing data were thus located for the coasts of North Carolina, South Carolina, the Gulf coast of Florida, Alabama, Mississippi, and significant portions of Texas and Louisiana (sources are listed under the State-specific Results section). Data gaps were then identified where no existing data assessed these parameters. Google Earth was then used to calculate the lengths of sandy oceanfront beaches within the geographic data gaps as well as to distinguish the lengths that were developed versus undeveloped (see Table 1 for a list of the data gaps from Google Earth). A Microsoft Excel database of all data was created, with the data organized by geographic area. Wherever possible, data were compiled on a county-by-county or shoreline segment basis to facilitate updates and replication of the data.

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Rice, T. M. 2012. The Status of Sandy, Oceanfront Beach Habitat in the Continental U.S. Coastal Migration and Wintering Range of the Piping Plover (*Charadrius melodus*). Appendix 1c *in* Comprehensive Conservation Strategy for the Piping Plover (*Charadrius melodus*) in its Coastal Migration and Wintering Range in the Continental United States, U.S. Fish and Wildlife Service, East Lansing, Michigan.

For geographic areas where Google Earth was utilized to calculate the approximate lengths of beach shoreline that were developed versus undeveloped, no distinction was made as to the level of development. The USGS *Coastal Classification Atlas* categorized developed areas into low, medium, and high density development, but this assessment consolidated those categories into one developed category (for more detailed information on a particular area, consult the individual reports or topographic quadrangles produced by the Coastal Classification Mapping Project at http://coastal.er.usgs.gov/coastal-classification/). Undeveloped areas were those where no structures existed adjacent to the beach and that appeared natural in the Google Earth aerial imagery. Vacant lots that were surrounded by a high number of buildings were not counted as undeveloped areas unless they were of a sufficient size to measure (e.g., greater than 0.1 mile in oceanfront length). Golf courses adjacent to the beach were considered developed areas because the beach habitat has been modified or protected by armoring (e.g., Sea Island, GA) or inlet relocation and beach fill activities (e.g., Kiawah Island, SC). Parking lots and roads were not considered as developed areas developed on the landward side of the road and the road was close to the beach, preventing the sandy beach from migrating with rising sea level. Length measurements were made in miles using the "ruler" tool of Google Earth. The individual dates of Google Earth imagery and eye altitude from which measurements were made were recorded; the latter was typically 5,300-5,800 feet above ground level.

The shoreline lengths used in this report are approximations for several reasons. First, each state used its own methodology and a number of sources in determining the proportions of developed-to-undeveloped beaches. Also, some states conducted their estimates in 2001 but others in 2011, years of rapid development in some places but not others (Table 1). Furthermore, the imagery used by Google Earth was made between 2006 and 2011, creating further potential problems with estimations. The data sources for each geographic area are listed in Table 1.

The second reason why the shoreline lengths in this assessment are approximations is the dynamic nature of the habitat. Sandy oceanfront beaches shift in space over time and may grow (accrete) or recede (erode) on a daily, weekly, seasonal or annual basis. Thus, the measured lengths are snapshots in time and are not necessarily the same lengths that would be measured today or tomorrow. Third, only the ocean-facing segments of the inlet shorelines were included, and the demarcation lines were based on professional judgment. Finally, the measurements are approximations due to mathematical rounding to the nearest mile for statewide figures and nearest tenth of a mile for data within individual states.

The amount of preserved sandy oceanfront beach (protected to some degree from development) provides an approximation of how much of this habitat may be available as sea level continues to rise and climate changes. If an area is preserved then it is assumed that the habitat retains the potential to migrate inland with rising sea level and to continue to provide habitat for the piping plover and other shorebirds and waterbirds over time. Where sandy oceanfront beaches are developed, it is assumed that the habitat is highly susceptible to being lost or significantly degraded as sea level rises (through erosion or shoreline armoring), and thus of diminishing value to the piping plover. Currently undeveloped and unpreserved sandy oceanfront beaches were assumed to be developable.

Preserved lands in this assessment include the public lands of National Wildlife Refuges (NWRs) owned by the USFWS; National Seashores (NSs) owned by the National Park Service (NPS); National Estuarine Research Reserves (NERRs) owned by the National Oceanic and Atmospheric Administration (NOAA); lands owned by the Bureau of Land Management (BLM); state, county and local parks; state Wildlife Management Areas (WMAs); state wildlife refuges and heritage preserves, state recreation areas; and sometimes military bases (if landward areas are undeveloped). Sandy oceanfront beaches that have been protected by non-governmental conservation organizations, such as Audubon sanctuaries, or that are a part of research preserves such as the University of South Carolina (Beaufort)'s Pritchards Island, were also included. Finally, areas with known conservation easements (e.g., Dewees Island, SC) were included as preserved beaches. Properties that have habitat conservation plans were not included because these properties typically have some level of development and are not preserved, undeveloped spaces like refuges or parks. Data on the name, location, approximate shoreline length, and type of preserved land (e.g., wildlife refuge, park) were added to the Excel database. Shoreline lengths were obtained from published sources or websites of the individual lands wherever possible, and from Google Earth using the aforementioned methodology for measuring developed versus undeveloped areas. Preserved lands in Florida were measured using the State Parks, Conservation Lands, and Public Land data layers of the Florida Department of Environmental Protection (FL DEP) Beaches and Coastal Systems GIS database (http://ca.dep.state.fl.us/mapdirect/?focus=beaches); parcel lengths were measured at 1:12,000 scale and rounded to the nearest tenth of a mile. Due to their diminished habitat value from surrounding development, some preserved lands with less than one-tenth of a mile in beach length were excluded when they were not near other preserved parcels. Preserved lands that were included may also have diminished habitat value due to disturbance from recreational and other activities that can occur in parks, seashores, recreation areas, military bases, etc.

Table 1. Data sources used to determine the lengths of sandy oceanfront beach for each state of the wintering and migration range of the piping plover.

State	Shoreline segment	Data Sources
NC	Entire state	NC DENR (2011)
SC	Entire state	SC DHEC (2010)
GA	Entire state	Clayton et al. (1992), Google Earth (2010 imagery)
FL Atlantic Coast	Entire state	Bush et al. (2004), Google Earth (2010 and 2011 imagery)
FL Gulf Coast	Perdido Pass (AL) to St. Andrew Bay Entrance	Morton et al. (2004)
	St. Andrew Bay Entrance to Lighthouse Point	Morton and Peterson (2004)
	Anclote Key to Venice Inlet	Morton and Peterson (2003a)
	Venice Inlet to Cape Romano	Morton and Peterson (2003b)
AL	Entire state	Bush et al. (2001), Morton and Peterson (2005a), Google Earth (2008 imagery)
MS	Entire state	Morton and Peterson (2005a), Google Earth (2003, 2006 and 2007 imagery)
LA	Chandeleur Sound to Pass Abel	Google Earth (2010 imagery)
	Pass Abel to East Timbalier Island	Morton and Peterson (2005b)
	East Timbalier Island to Mermentau River Navigation Channel	Google Earth (2009 and 2010 imagery)
	Mermentau River Navigation Channel to Sabine Pass	Morton et al. (2005)
TX	Sabine Pass to Colorado River mouth	Morton and Peterson (2005c)
	Colorado River mouth to Aransas Pass	Google Earth (2011 imagery)
	Aransas Pass to Mansfield Channel	Morton and Peterson (2006a)
	Mansfield Channel to Rio Grande River mouth	Morton and Peterson (2006b)

Where readily available information existed, notations about habitat modifications within the preserved lands were noted in the database. These habitat modifications could include:

- the presence of jetties, groins or other shoreline armoring in or adjacent to the preserved land;
- dredging activities at an inlet in or near the preserved land;
- beach nourishment or dredge disposal activities on beaches in the preserved land;

- the presence of off-road vehicle (ORV) or recreational vehicle usage;
- campgrounds, recreational facilities, and/or camping allowed on the beach;
- the maintenance and protection of coastal highways (e.g., North Carolina Highway 12 in Cape Hatteras National Seashore or Texas Highway 87 within Sea Rim State Park);
- the artificial creation and/or maintenance of dunes;
- artificial opening or closure of inlets, including inlet relocations;
- vegetation plantings;
- the presence of feral horses, hogs or other animals that can damage vegetation and dunes;
- waterfowl impoundments;
- the presence of private inholdings or retained rights agreements that preclude some management options; and
- the presence of historic sites or structures (e.g., historic forts on the Fort Morgan peninsula in Alabama, Egmont Key NWR in Florida, or Fort Massachusetts in the Mississippi portion of Gulf Islands NS).

An assessment to estimate the length of each state's sandy oceanfront beach that has been armored with hard structures was conducted using data derived from published sources. Armoring structures are shore-parallel seawalls, revetments, riprap, geotubes and sandbags, but also may include groins, offshore breakwaters, and jetties. A description of the different types of stabilization structures typically constructed at or adjacent to sandy oceanfront beaches can be found in Appendix 1a (Rice 2009) as well in the *Manual for Coastal Hazard Mitigation* (Herrington 2003, online at http://www.state.nj.us/dep/cmp/coastal_hazard_manual.pdf) and in *Living by the Rules of the Sea* (Bush et al. 1996). The lengths of shoreline affected by armoring included in this report should be considered a minimum because the published sources are not necessarily current and short structures may protect only individual houses or buildings. Furthermore, Google Earth could not be readily used to update or fill data gaps due to the difficulty in identifying structures that may be hidden by vegetation, dunes, or beach fill. For example, the entire length of Miami Beach is armored with a seawall that is not readily visible due to a large-scale beach nourishment project that replaced the beach in front of the seawall (Bush et al. 2004).

An estimate of the length of sandy oceanfront beaches that have received or continue to receive beach fill or dredge spoil placement was also compiled. This information serves two purposes: 1) a basis for cumulative effects to sandy oceanfront beaches resulting from soft stabilization and dredge disposal activities, and 2) an assessment of the length of coastline where sandy beaches will attempt to be "held in place" as sea level rises. The latter increases the risk of further degrading habitat quality over time as the adverse impacts of these activities continue, perhaps in perpetuity (for a discussion of the potential adverse ecological impacts of beach nourishment and dredge disposal activities, for which "there is little to no difference" (Bush et al. 2004, p. 90), see Peterson et al. 2000, Peterson and Bishop 2005, Defeo et al. 2009, and Rice 2009). Again, published sources were used to compile the lengths of shoreline affected by beach nourishment and dredge disposal placement activities in each state (e.g., Lott et al. 2009, FL DEP 2011). For the coast of Florida, the GIS database of Lott et al. (2009) was used for lengths of individual projects; where adjacent projects overlapped, their individual lengths were trimmed to eliminate overlapping areas. Where readily available published sources were absent for a geographic area, the beach nourishment database of the Program for the Study of Developed Shorelines (at http://www.wcu.edu/1038.asp) was consulted and an inventory of projects in that region was added to the Excel database.

RESULTS

At present, approximately 2,119 miles of sandy oceanfront beach lie within the U.S. continental wintering range of the piping plover (Table 2). Florida has the highest number of miles of this habitat and the

Mississippi mainland and Florida coasts have the highest proportion of sandy oceanfront beaches that are currently developed (80% and 57%, respectively). By contrast, the barrier island coast of Mississippi (0%), Louisiana (6%), Texas (14%) and Georgia (17%) are the least developed. Altogether, 856 of 2,119 miles (40%) of sandy oceanfront beaches in the continental wintering range of the piping plover are developed. A slightly higher amount (901.5 miles, 43%) has been preserved, with Georgia (76%) and the barrier islands of Mississippi (100%) having the highest proportions of sandy oceanfront beach in preservation.

Table 2. The lengths and percentages of sandy oceanfront beach in each state that are developed, undeveloped and preserved as of December 2011.

State	Approximate Shoreline Length (miles)	Approximate Miles of Beach Developed (percent of total shoreline length)	Approximate Miles of Beach Undeveloped (percent of total shoreline length)[a]	Approximate Miles of Beach Preserved (percent of total shoreline length)[b]
NC	326	159 (49%)	167 (51%)	178.7 (55%)
SC	182	93 (51%)	89 (49%)	84 (46%)
GA	90	15 (17%)	75 (83%)	68.6 (76%)
FL	809	459 (57%)	351 (43%)	297.5 (37%)
- Atlantic	*372*	*236 (63%)*	*136 (37%)*	*132.4 (36%)*
- Gulf	*437*	*223 (51%)*	*215 (49%)*	*168 (38%)*
AL	46	25 (55%)	21 (45%)	11.2 (24%)
MS barrier island coast	27	0 (0%)	27 (100%)	27 (100%)
MS mainland coast	51[c]	41 (80%)	10 (20%)	12.6 (25%)
LA	218	13 (6%)	205 (94%)	66.3 (30%)
TX	370	51 (14%)	319 (86%)	152.7 (41%)
TOTAL	**2,119**	**856 (40%)**	**1,264 (60%)**	**901.5 (43%)**

[a] Beaches classified as "undeveloped" occasionally include a few scattered structures.
[b] Preserved beaches include public ownership, ownership by non-governmental conservation organizations, and conservation easements. The miles of shoreline that have been preserved generally overlap with the miles of undeveloped beach but may also include some areas (e.g., in North Carolina) that have been developed with recreational facilities or by private inholdings.
[c] The mainland Mississippi coast along Mississippi Sound includes 51.3 miles of sandy beach as of 2010-2011, out of 80.7 total shoreline miles (the remaining portion is non-sandy, either marsh or armored coastline with no sand). See the Mississippi state-specific results for details.

For nearly every state, data were located on the number of sandy oceanfront beaches that have been armored with hard erosion control structures (Table 3). The armoring data for North Carolina and South Carolina do not include shoreline length, but the total number of armoring structures is provided in their respective state summaries below. The length of armored shoreline on the Atlantic coast of Florida is uncertain, with only one county (Volusia) having complete data available. Therefore the total length of shoreline within the continental wintering range of the piping plover that has been armored is unknown but constitutes at least 230 miles (11% of the total shoreline length). Regardless of the missing data, the Florida coast has the greatest length of armored oceanfront beach.

At least 684.8 miles (32%) of sandy beach habitat in the continental wintering range of the piping plover have received artificial sand placement via dredge disposal activities, beach nourishment or restoration, dune restoration, emergency berms, inlet bypassing, inlet closure and relocation, and road reconstruction projects (Table 3). In some locations, such as in Louisiana, where sandy beach habitat has been lost due to erosion and sea level rise (see the Louisiana state-specific discussion below), “sediment placement projects are deemed environmental restoration projects by the USFWS, because without the sediment, many areas would erode below sea level” (USFWS 2009, p. 34). In most areas, however, sand placement projects are conducted in developed areas or adjacent to shoreline or inlet hard stabilization structures in order to address erosion, reduce storm damages, or ameliorate sediment deficits caused by inlet dredging and stabilization activities. The Atlantic coast of Florida has the highest proportion of sand placement activities on oceanfront beaches (at least 51%), but the mainland coast of Mississippi has had at least 85% of its sandy beaches modified with fill placement.

Table 3. Approximate shoreline miles of sandy beach that have been modified by armoring with hard erosion control structures and by sand placement activities for each state in the U.S. continental wintering range of the piping plover as of December 2011. Note that these totals are minimum numbers, given missing data for some areas.

State	Known Approximate Miles of Armored Beach	Known Approximate Miles of Beach Receiving Sand Placement
NC	Length Unknown (see state discussion below for numbers of structures)	91.3
SC	Length Unknown (see state discussion below for numbers of structures)	67.6
GA	10.5	5.5
FL Atlantic Coast*	58.1*	189.7
FL Gulf Coast	59.2	189.9
AL	4.7	7.5
MS barrier island coast	0	1.1
MS mainland coast	45.4	43.5
LA	15.9	60.4
TX	36.6	28.3
TOTAL	**230.4+**	**684.8+**

* The total lengths of coastal armoring for the Florida Atlantic coast are incomplete because no data are available from Brevard, Indian River, St. Lucie and Martin Counties. Only Volusia County has complete armoring data (Ecological Associates 2005); only partial data (Bush et al. 2004) are available from the remaining counties.

State-specific Results

North Carolina

Approximately 159 miles (49%) of the North Carolina sandy oceanfront beach are developed and 167 miles are undeveloped (NC DENR 2011). The beaches of Currituck and Brunswick Counties are the most developed, and those of Hyde and Carteret Counties are the least developed, due to the presence of Cape Hatteras and Cape Lookout National Seashores, respectively (Table 4).

Table 4. The approximate lengths of sandy oceanfront beach within each county of North Carolina and the proportions that are developed and undeveloped (NC DENR 2011).

County	Approximate shoreline length in miles	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Currituck	23	18 (78%)	5 (22%)
Dare	89	44 (49%)	45 (51%)
Hyde	17	3 (18%)	14 (82%)
Carteret	85	25 (29%)	60 (71%)
Onslow	27	14 (52%)	13 (48%)
Pender	14	9 (64%)	5 (36%)
New Hanover	31	16 (52%)	15 (48%)
Brunswick	40	30 (75%)	10 (25%)
TOTAL	**326**	**159 (49%)**	**167 (51%)**

Preserved sandy oceanfront beaches account for roughly 55% of the North Carolina coastline (Table 5). The longest of these is found in Cape Hatteras and Cape Lookout National Seashores, although the former has been extensively modified by the protection and maintenance of a coastal highway, several inholding communities, use by off road vehicles (ORVs), and the construction and maintenance of a continuous dune ridge. As a result of the inholding developed communities adjacent to the oceanfront in Cape Hatteras NS, the amount of land considered preserved in the state (55%) exceeds the amount undeveloped (51%).

The state of North Carolina prohibited the use of hardened erosion control structures on oceanfront beaches in 1985 but in 2011 authorized by legislation up to 4 terminal groins to be constructed (locations to be determined). However, sandbag revetments, constructed of very large geotextile bags several feet in length, are permitted for temporary protection of oceanfront property. The North Carolina Beach and Inlet Management Plan documents one jetty system in the state, 2 rock revetments, 2 sets of groins and 2 terminal groins. In addition approximately 350 sandbag revetments have been installed along the state’s sandy oceanfront beaches, each of which is supposed to only be in place for 2 to 5 years. But most have been in place for much longer and their fate is controversial (NC DENR 2011). The total length of these armoring structures is unknown.

Table 5. Preserved sandy oceanfront beaches in North Carolina, the county in which each is located, and approximate shoreline length of each.

Preserved Land	County Location	Approximate Length in Miles
Swan Island Unit, Currituck NWR	Currituck	2
Monkey Island Unit, Currituck NWR	Currituck	1
Pine Island Sanctuary	Currituck	0.3
Pea Island NWR	Dare	12
Cape Hatteras NS	Dare	68
Cape Lookout NS	Carteret	56
Fort Macon State Park	Carteret	1.4
Hammocks Beach State Park (Bear Island)	Onslow	4
Brown's Island, Camp Lejeune	Onslow	3.3
Onslow Beach, Camp Lejeune	Onslow	7.3
Lea-Hutaff Island	Pender	3.8
Mason Inlet Waterbird Management Area	New Hanover	0.4
Masonboro Island NERR and Masonboro Island State Natural Area	New Hanover	7.7
Freeman Park	New Hanover	1.3
Fort Fisher State Recreation Area	New Hanover	6
Smith Island, Bald Head Island State Natural Area	Brunswick and New Hanover	3
Cape Fear Point, Bald Head Island State Natural Area	Brunswick	0.3
Bird Island NC Coastal Reserve	Brunswick	0.9
TOTAL MILES		**178.7 (55% of state shoreline)**

As part of authorized beach nourishment or dredge disposal activities, approximately 28% (91.3 miles) of North Carolina's sandy oceanfront beaches have been or continue to receive beach fill, often multiple times (Table 6). The Wrightsville Beach beach fill project is one of the oldest in the country, beginning around 1939 and receiving renourishment approximately every 3 years.

Table 6. The approximate lengths of authorized constructed beach nourishment and dredge disposal placement projects on North Carolina beaches (from NC DENR 2011, PSDS 2012 and USFWS files).

Location	Project Length (miles)
Kitty Hawk	Unknown
Kill Devil Hills	Unknown
Nags Head	10.0
Pea Island	3.0
Hatteras Island	0.3
Hatteras Island, Isabel Inlet closure	0.3
Cape Hatteras	1.5
Ocracoke Island	0.6
Core Banks	2.0
Atlantic Beach / Fort Macon	7.4
Bogue Banks	16.8
Hammocks Beach State Park (Bear Island)	1.0

Location	Project Length (miles)
West Onslow Beach	1.6
Topsail Island	3.5
Figure Eight Island North	1.8
Figure Eight Island South (Mason Inlet)	2.8
Wrightsville Beach	3.0
Masonboro Island	2.5
North Carolina Beach (Carolina Beach Inlet dredge disposal)	0.8
Carolina Beach	3.0
Kure Beach	3.8
Bald Head Island	4.7
Oak Island	9.6
Long Beach Sea Turtle Habitat Restoration Project	2.3
Holden Beach	5.7
Ocean Isle Beach	3.3
TOTAL MILES	**91.3 (28% of state shoreline)**

South Carolina

The South Carolina *Adapting to Shoreline Change* report (SC DHEC 2010) found that 51% (93 miles) of the 182 miles of sandy oceanfront beach in the state has been developed. Approximately 89 miles (49%) are undeveloped, of which just over 13 miles are considered developable (SC DHEC 2010). No data are available comparing the level of development in individual counties or shoreline segments in South Carolina.

Preserved beaches account for 46% of the 182 miles of sandy oceanfront beach coastline in South Carolina (Table 7). The longest of these is found within Cape Romain NWR, which protects 22 miles of sandy oceanfront beaches.

In an inventory of armoring, SC DHEC (2010) found that 933 out of 3,850 (24%) habitable beachfront structures were fronted by erosion control structures constructed parallel to the shoreline. The lengths of these structures are unknown. Fripp Island had 100% and Folly Beach had 99% of its beachfront parcels armored. The Grand Strand area (North Myrtle Beach, Myrtle Beach, Surfside Beach and Garden City Beach) is also significantly armored. Dewees, Kiawah and Hunting Islands were the only developed areas without any shore parallel armoring structures, although the latter has shore perpendicular groins (SC DHEC 2010; Melissa Bimbi, USFWS, pers. communication, 4/20/12).

In addition to the 933 shore-parallel armoring structures (seawalls, revetments, etc.), in 2006 there were 165 oceanfront groins in South Carolina (SC DHEC 2010). Most (n = 125) are on Pawleys Island, Folly Beach, Edisto Beach and Hilton Head Island and six of them are terminal groins. Other armoring in South Carolina includes 6 jetty systems and one offshore breakwater. Finally, since 1985 111 Emergency Orders have been issued by the state and local governments, allowing sandbag revetments, beach scraping and minor nourishment projects using upland sand sources. SC DHEC (2010, p. 95) report that "the number of Emergency Orders has been increasing in recent years and may continue to increase if sea level continues to rise, storms become more frequent, and funding for renourishment becomes more intermittent."

Approximately 37% (67.6 miles) of South Carolina's sandy oceanfront beaches have been or continue to receive beach fill as part of authorized beach nourishment or dredge disposal activities, many of them multiple times (Table 8). For example, the Grand Strand has one of the longest lengths of beach nourishment in the country, with 26 miles of continuous beach fill modifying the sandy oceanfront beaches of the northern coast of the state.

Table 7. Preserved sandy oceanfront beaches in South Carolina, the county in which each is located, and approximate shoreline length of each (from Lennon et al. 1996, USFWS 2010a, and multiple online websites for individual preserved lands).

Preserved Land	County Location	Approximate Length in Miles
Waites Island	Horry	3.0
Briarcliffe Acres Conservation Area	Horry	0.7
SC Wildlife Sanctuary, Meher Spiritual Center	Horry	1.2
Myrtle Beach State Park	Horry	1.0
Huntington Beach State Park	Georgetown	3.0
Hobcaw Beach, Hobcaw Barony	Georgetown	2.3
North Island, Tom Yawkey Heritage Preserve	Georgetown	8.2
Sand and South Islands, Tom Yawkey Heritage Preserve	Georgetown	5.5
Cedar Island, Santee Coastal Reserve	Georgetown	3.0
Murphy Island, Santee Coastal Reserve	Charleston	6.0
Cape Romain NWR	Charleston	22.0
Capers Island Heritage Preserve	Charleston	3.3
Dewees Island, north end	Charleston	1.4
Isle of Palms County Park	Charleston	0.1
Morris Island	Charleston	4.0
Lighthouse Inlet Heritage Preserve	Charleston	0.4
Folly Beach County Park	Charleston	0.8
Bird Key Stono Seabird Sanctuary	Charleston	0.8
Kiawah Beachwalker Park	Charleston	1.2
Deveaux Bank Seabird Sanctuary	Charleston	2.3
Botany Bay Plantation WMA	Charleston	2.5
Edisto Beach State Park	Colleton	1.3
Hunting Island State Park	Beaufort	5.0
Pritchards Island	Beaufort	2.5
Turtle Island WMA	Jasper	2.5
	TOTAL MILES	**84.0 (46% of state shoreline)**

Table 8. The approximate lengths of authorized constructed beach nourishment and dredge disposal placement projects on South Carolina beaches (from SCCC 1992, USFWS 2006c, SC DHEC 2010, PSDS 2012, and USFWS files).

Location	Project Length (miles)
Grand Strand (North Myrtle Beach, Myrtle Beach, Surfside Beach and Garden City Beach)	26.0
Huntington Beach	1.9
Pawleys Island	2.8
Debidue (Debordieu) Island	1.8
Isle of Palms	2.7
Sullivans Island	0.5
Folly Beach	5.3
Folly Beach County Park and Bird Key	0.5
Kiawah Island	2.5
Captain Sam's Inlet Relocation	0.6
Seabrook Island	3.4
Edisto Beach	3.5
Hunting Island	3.8
Hilton Head Island	8.8
Daufuskie Island	3.5
TOTAL MILES	**67.6 (37% of state shoreline)**

Georgia

In Georgia, only 17% of approximately 90 miles of sandy oceanfront beach has been developed (Table 9). Nine of 13 barrier islands are "uninhabited places of coastal wilderness" that are completely undeveloped, but others, such as St. Simons and Sea Islands, are 100% developed (Clayton et al. 1992, p. 1). Approximately 76% (68.6 miles) of the sandy oceanfront beaches in the state have been preserved (Table 10). The longest of these is the Little Cumberland Island – Cumberland Island NS complex with nearly 20 miles of preserved beach. Little St. Simons Island is virtually undeveloped but unpreserved at present, although its private ownership maintains a "commitment to sustainable-use ecotourism" with a small resort on the backside of the island (http://www.littlestsimonsisland.com/greenpractices.html).

Clayton et al. (1992) found that approximately 10.5 miles of the sandy oceanfront beaches of Tybee, Sea, St. Simons and Jekyll Islands in Georgia had been armored. Two islands have been or continue to receive beach nourishment or dredge spoil placement and a third has been proposed (Table 11).

Table 9. The approximate lengths of sandy oceanfront beach in each county of Georgia and the proportions that are developed and undeveloped (from Clayton et al. 1992, Google Earth 2010 imagery).

County	Approximate shoreline length in miles	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Chatham	24.6	3.5 (14%)	21.1 (86%)
Liberty	10	0 (0%)	10 (100%)
McIntosh	15.2	0 (0%)	15.2 (100%)
Glynn	20.7	11.6 (56%)	9.1 (44%)
Camden	19.5	0 (0%)	19.5 (100%)
TOTAL	**90**	**15.1 (17%)**	**74.9 (83%)**

Table 10. Preserved sandy oceanfront beaches in Georgia, the county in which each is located, and approximate shoreline length of each.

Preserved Land	County Location	Approximate Length in Miles
Little Tybee Island Nature Preserve	Chatham	5.0
Williamson Island	Chatham	1.5
Wassaw Island NWR	Chatham	5.5
Ossabaw Island Heritage Preserve	Chatham	9.1
Saint Catherine's Island	Liberty	10.0
Blackbeard NWR	McIntosh	6.4
Richard J. Reynolds State Wildlife Refuge (Cabretta Island)	McIntosh	2.0
Sapelo Island NERR	McIntosh	3.8
Wolf Island NWR	McIntosh	3.0
Jekyll Island State Park	Glynn	2.4
Little Cumberland Island	Camden	2.4
Cumberland Island NS	Camden	17.5
	TOTAL MILES	**68.6 (76% of state shoreline)**

Table 11. The approximate lengths of authorized constructed beach nourishment and dredge disposal placement projects on Georgia beaches (from PSDS 2012).

Location	Project Length (miles)
Tybee Island	3.5
Sea Island	2.0
St. Simons Island	Proposed
TOTAL MILES	**5.5 (6% of state shoreline)**

Florida

Of the approximately 809 miles of sandy oceanfront beach in Florida, roughly 57% has been developed and 43% is undeveloped, with the Atlantic Coast more developed (63%) than the Gulf Coast (51%; Tables 12 and 13). The most developed counties on the Atlantic coast are Flagler, Palm Beach, Broward and St. Johns, where 79% or more of linear beach of each has been developed. Along the Gulf Coast, the central and southern coasts are considerably more developed than the Panhandle coastline.

Preserved beaches account for 37% (300.4 miles) of Florida's sandy oceanfront beaches (Tables 14 and 15). The Atlantic Coast accounts for over 132 miles of the preserved beaches and the Gulf Coast the remaining 168 miles. The longest of the preserved beaches are the Gulf Islands National Seashore (23.5 miles) and Tyndall Air Force Base (AFB) on the Gulf coast (16.5 miles) and the Cape Canaveral National Seashore – Cape Canaveral Air Force Station complex (43.4 miles) and the Archie Carr NWR Partnership (20.5 miles altogether) on the Atlantic Coast.

Table 12. The approximate lengths of sandy oceanfront beach in each county along the Atlantic Coast of Florida and the proportions that are developed and undeveloped (from Bush et al. 2004, Google Earth 2010 and 2011 imagery).

County	Approximate shoreline length in miles	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Nassau	15	9.5 (63%)	5.5 (37%)
Duval	15	9 (60%)	6 (40%)
St. Johns	40	31.6 (79%)	8.4 (21%)
Flagler	19	15.9 (84%)	3.1 (16%)
Volusia	51	32.6 (64%)	18.4 (36%)
Brevard	72	32.3 (45%)	39.8 (55%)
Indian River	28	17.2 (61%)	10.9 (39%)
St. Lucie	21	9.1 (43%)	11.9 (57%)
Martin	24	12.2 (51%)	11.8 (49%)

County	Approximate shoreline length in miles	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Palm Beach	42	34.7 (83%)	7.3 (17%)
Broward	24	19.3 (80%)	4.7 (20%)
Miami-Dade	21	12.9 (61%)	8.3 (39%)
TOTAL	**372**	**236 (63%)**	**136 (37%)**

Table 13. The approximate lengths of sandy oceanfront beach in each segment of the Gulf Coast of Florida and the proportions that are developed and undeveloped (from Morton et al. 2004, Morton and Peterson 2003a, 2003b, and 2004).

Shoreline Segment	Approximate shoreline length in miles	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Perdido Pass to St. Andrew Bay Entrance (Escambia, Santa Rosa, Okaloosa, Walton and Bay Counties)	113.7	53.6 (47%)	60.1 (53%)
St. Andrew Bay Entrance to Lighthouse Point (Bay, Gulf and Franklin Counties)	129.2	38.7 (30%)	90.5 (70%)
Anclote Key to Venice Inlet (Pinellas, Hillsborough, Manatee and Sarasota Counties)	84.5	59.2 (70%)	25.3 (30%)
Venice Inlet to Cape Romano (Sarasota, Charlotte, Lee and Collier Counties)	110.0	71.3 (65%)	38.6 (35%)
TOTAL	**437.4**	**222.8 (51%)**	**214.6 (49%)**

Table 14. Preserved sandy oceanfront beaches along the Atlantic coast of Florida, the county in which each is located, and approximate shoreline length of each. Note that only lands that exceed 1 mile in length are listed here by name, but the contribution of 41 additional preserved areas with lengths less than 1 mile to the overall length of preserved beaches is included in the total (therefore the total listed is greater than the sum of the individual parcels listed).

Preserved Land	County Location	Approximate Length in Miles
Little Talbot Island State Park	Duval	4.2
Huguenot Memorial Park	Duval	1.3
Kathryn Abbey Hanna Park	Duval	1.5
Guana Tolomato Matanzas NERR	St. Johns	13.1
Anastasia State Park	St. Johns	3.6
North Peninsula State Park	Volusia	2.8
Cape Canaveral NS	Volusia and Brevard	24.0
Cape Canaveral Air Force Station	Brevard	19.4
Archie Carr NWR Partnership	Brevard and Indian River	20.5

Preserved Land	County Location	Approximate Length in Miles
Sebastian Inlet State Park	Brevard and Indian River	2.8
Avalon State Park	St. Lucie	1.4
John Brooks Park	St. Lucie	1.7
Blind Creek Natural Area	St. Lucie	1.4
St. Lucie Inlet Preserve State Park	Martin	2.4
Jupiter Island Tract, Hobe Sound NWR	Martin	3.5
Blowing Rocks Preserve	Martin	1.0
John D. MacArthur State Recreation Area	Palm Beach	1.6
Red Reef Park & South Beach Park	Palm Beach	1.2
John H. Lloyd State Park	Broward	2.2
Haulover Beach Park	Miami-Dade	1.4
Crandon Park	Miami-Dade	1.9
Bill Baggs Cape Florida State Recreation Area	Miami-Dade	1.4
	TOTAL MILES	**132.4 (36% of state shoreline)**

Table 15. Preserved sandy oceanfront beaches along the Gulf coast of Florida, the county in which each is located, and approximate shoreline length of each. Note that only lands that exceed 1 mile in length are listed here by name, but their contribution of 16 additional preserved areas with lengths of less than 1 mile to the overall length of preserved beaches is included in the total (therefore the total listed is greater than the sum of the individual parcels listed).

Preserved Land	County Location	Approximate Length in Miles
Perdido Key State Park	Escambia	1.6
Perdido Key Area, Gulf Islands NS	Escambia	6.7
Fort Pickens Area, Gulf Islands NS	Escambia	7.5
Santa Rosa Island Area, Gulf Islands NS	Escambia	9.3
Eglin Air Force Base†	Santa Rosa	17.0
Henderson Beach State Park	Santa Rosa	1.3
Topsail Hill Preserve State Park	Walton	3.3
Grayton Beach State Park	Walton	1.8
St. Andrews State Park	Bay	4.6
Tyndall Air Force Base	Bay	16.5
St. Joseph Peninsula State Park	Gulf	9.9
Eglin Air Force Base, Cape San Blas Satellite Property	Gulf	1.5
St. Vincent NWR (St. Vincent Island)	Franklin	8.7
Cape St. George State Preserve (Little St. George Island)	Franklin	9.6
St. George Island State Park	Franklin	8.8
Jeff Lewis Wilderness Preserve	Franklin	4.0
John S. Phipps Preserve	Franklin	1.5
Bald Point State Park	Franklin	1.8
Anclote Keys State Preserve State Park	Pasco and Pinellas	5.7
Honeymoon Island State Park	Pinellas	2.9

Preserved Land	County Location	Approximate Length in Miles
Caladesi Island State Park	Pinellas	2.2
Shell Key Preserve	Pinellas	2.3
Fort DeSoto Park	Pinellas and Hillsborough	2.8
Egmont Key NWR	Hillsborough	1.8
Coquina Gulfside Park	Manatee	1.0
North Lido Public Beach	Sarasota	1.4
Brohard Park	Sarasota	1.3
Caspersen Beach County Park	Sarasota	2.0
Stump Pass Beach State Park	Charlotte	1.2
Don Pedro Island State Park	Charlotte	1.2
Cayo Costa State Park	Lee	9.3
Bowman's Beach Regional Park	Lee	1.7
Lovers Key State Park	Lee	1.7
Barefoot Beach Preserve County Park	Collier	1.4
Delnor-Wiggins Pass State Park	Collier	1.1
Clam Pass Park	Collier	1.5
Rookery Bay NERR (Kice Island / Cape Romano complex)	Collier	11.6
	TOTAL MILES	**168 (38% of state shoreline)**

† Note that Eglin Air Force Base (AFB) contains several segments of shoreline that have been armored or developed, which is likely to result in those segments not providing high quality habitat as sea level rises.

Approximately 59.2 miles (14%) of the sandy oceanfront beach between Perdido Pass near the Alabama-Florida state line and Cape Romano on the Gulf coast of Florida are armored (Morton et al. 2004, Morton and Peterson 2003a, 2003b, 2004). Data on the length of armoring along the Atlantic Florida coast are incomplete, with Volusia County the only county with complete data (see Table 3 footnote). Using outdated data from 1991, 145 miles of the entire Florida coast were armored as of two decades ago (NMFS 1991a and b as cited within Ecological Associates 2005). Some communities are 100% armored, such as Miami Beach (Bush et al. 2004).

More beach nourishment and dredge disposal activities have been conducted in Florida than in any other state in the continental wintering range of the piping plover. FL DEP (2011) states that over 218 miles of sandy beaches have been "restored" or "maintained" under the state Ecosystem Management and Restoration Trust Fund since 1998. For Fiscal Year 2011/2011, 81 projects requested state funding for feasibility, design and/or construction of beach nourishment projects and another 13 for inlet sand bypassing or inlet management plan activities (FL DEP 2011). Almost 51 contiguous miles from Boca Raton to Key Biscayne south of Miami Beach receive beach nourishment, by far the longest project area in the continental wintering range of the piping plover (FL DEP Beaches and Coastal System GIS Beach Nourishment Data Layer). Approximately 43% (over 189.9 miles) of the Gulf Coast in Florida has received beach nourishment or dredge spoil, and half (51% or at least 189.7 miles) of the Atlantic Coast has done so, many areas multiple times and with multiple types of projects (Tables 16 and 17).

These beach lengths with habitat modification are minimum distances, because other known sand placement projects do not have accurate location data (i.e., Florida R-Monuments) to be included without potentially overlapping with other project areas. The state of Florida utilizes a network of range monuments (R-Monuments) located along the entire coastline for survey, planning, and monitoring purposes; the monument numbers are sequential within each county, increasing in number from north to south, or west to east along the Panhandle. The distance between monuments varies. The lengths listed in Tables 16 and 17 are also minimum measurements because distances between R-Monuments did not include partial monuments but were calculated to the nearest R-Monument (e.g., if a project's start point was R-33.8, the measurement started at R-34; if its endpoint was R-101.5, the measurement ended at R-101).

Table 16. The approximate lengths of sand placement projects on Florida's Atlantic Coast beaches (from Lott et al. 2009, FL DEP 2011, PSDS 2012, USFWS files and the FL DEP Beaches and Coastal System GIS Beach Nourishment Data Layer). Projects are listed by county from north to south, and then by increasing R-Monument within each county. RM_Start refers to the known starting Florida R-Monument location and RM_End refers to the known endpoint R-Monument for the project; start and endpoints may have been trimmed to eliminate overlaps with immediately adjacent projects. Note that projects denoted with a P are currently proposed.

County	Project Name or Area	RM_Start	RM_End	Length (miles)
Nassau	Fernandina Harbor dredge disposal	R-1	R-9	1.52
Nassau	Nassau County (Amelia Island) Beach Erosion Control	R-9	R-34.5	4.30
Nassau	South Amelia Island Beach Restoration Project	R-50	R-80	3.40
Duval	Duval County Beach Erosion Control	R-31	R-80	8.99
Duval	Jacksonville Harbor Expansion	V-501	V-505	0.79 P
St. Johns	Vilano Beach and Summer Haven	R-109	R-117	1.61 P
St. Johns	St. Johns County Shore Protection Project at St. Augustine	R-132	R-152	3.80
St. Johns	Summer Haven	R-197	R-209	2.29
St. Johns	Anastasia State Park (St. Augustine Inlet dredge disposal)			3.79
Flagler	State Road AIA Shoreline Stabilization Project			unknown
Volusia	Volusia County	R-40	R-145	18.92
Volusia	Ponce de Leon Inlet dredge disposal	R-158	R-161	0.56
Volusia	Volusia County	R-161	R-208	8.50
Brevard	Brevard County Beach at Cape Canaveral	R-1	R-4	0.56
Brevard	Brevard County Shore Protection Project- (North Reach)	R-4	R-53	8.98
Brevard	Patrick Air Force Base	R-53	R-75	4.05
Brevard	Brevard County Shore Protection Project- (Mid Reach)	R-75	R-118	7.60
Brevard	Brevard County Shore Protection Project- (South Reach)	R-118	R-139	7.80
Indian River	Ambersand Beach (Indian River County Sectors 1 & 2)	R-3	R-17	2.63
Indian River	Indian River County, Sector 3 and Wabasso Beach	R-19	R-55	6.76

County	Project Name or Area	RM_Start	RM_End	Length (miles)
Indian River	Vero Beach	R-71	R-86	2.89
Indian River	South County Beach (Indian River County Sector 7)	R-97	R-115.7	3.40
St. Lucie	Avalon	R-1	R-10	1.69
St. Lucie	Fort Pierce Harbor Dredged Material Disposal	R-31	R-33	0.38
St. Lucie	Fort Pierce Shore Protection Project	R-33.8	R-46	2.27
St. Lucie	South St. Lucie County Beaches	R-88	R-90	0.38
St. Lucie	South St. Lucie County Beaches	R-97.7	R-115	3.18
Martin	Martin County Shore Protection Project - Hutchinson Island	R-1	R-25.6	4.20
Martin	Bathtub Beach Park	R-34.5	R-36	0.24
Martin	Sailfish Point Marina Channel dredging with beach placement	R-36	R-39	0.66
Martin	St. Lucie Inlet dredge disposal	R-59	R-69	1.69
Martin	Jupiter Island Beach Restoration Project	R-75	R-117	7.18
Palm Beach	Coral Cove Park	R-5	R-7.6	0.29
Palm Beach	Jupiter Inlet Bypassing	R-12	R-13	0.15
Palm Beach	Jupiter-Carlin Park Beach Nourishment Project	R-13	R-19	1.10
Palm Beach	Juno Beach Restoration Project	R-26	R-38	2.45
Palm Beach	Singer Island	R-60	R-69	1.91
Palm Beach	Palm Beach Harbor dredging with beach placement	R-76	R-79	0.65
Palm Beach	North End Palm Beach Restoration (Reach 2)	R-79	R-90	2.30 P
Palm Beach	Mid-Town Beach Restoration Project (Reaches 3 & 4)	R-90.4	R-101.4	2.40
Palm Beach	South of Mid-Town Beach Restoration Project	R-101.4	R-110	1.75 P
Palm Beach	Town of Palm Beach, Phipps Ocean Park and South End Palm Beach Reach 8	R-116	R-134	5.54
Palm Beach	Palm Beach County	R-135	R-138	0.68
Palm Beach	Palm Beach Harbor / South Lake Worth Inlet Bypassing	R-151	R-152	0.16
Palm Beach	Ocean Ridge Beach Restoration Project	R-152	R-160	1.58
Palm Beach	Delray Beach Restoration Project	R-175	R-188.5	2.71
Palm Beach	Boca Raton (North) Beach Restoration Project	R-205	R-212	1.42

County	Project Name or Area	RM_Start	RM_End	Length (miles)
Palm Beach	Boca Raton (Central) Beach Restoration Project	R-216	R-222.9	1.50
Palm Beach	South Boca Raton (South) Beach Restoration Project	R-223	R-227.9	1.00
Broward	Hillsboro Beach Restoration Project	R-6	R-12.5	1.40
Broward	Segment II Broward County Beach Erosion – Hillsboro Inlet to Port Everglades	R-25	R-72	8.87
Broward	Segment III Broward County Beach - John U. Lloyd SP, Dania Beach, Hollywood, and Hallandale Beach	R-86	R-128	8.11
Miami-Dade	Dade County Shore Protection Project - Sunny Isles	R-7	R-19	2.43
Miami-Dade	Dade County Shore Protection Project - Haulover Beach Park	R-19	R-26	1.35
Miami-Dade	Dade County Shore Protection Project - Bal Harbor	R-27	R-31	0.79
Miami-Dade	Dade County Shore Protection Project - Surfside	R-31	R-38	1.43
Miami-Dade	Dade County Shore Protection Project - Miami Beach	R-38	R-74	7.12
Miami-Dade	Fisher Island	R-75	R-78	0.52
Miami-Dade	Virginia Key Beach	R-79	R-88	1.75
Miami-Dade	Key Biscayne Beach Erosion Control	R-92.5	R-96	0.59
Miami-Dade	Key Biscayne Beach Erosion Control	R-99	R-101	0.38
Miami-Dade	Key Biscayne Shore Protection Project	R-101	R-113.7	2.32
			TOTAL	**189.7+**

Table 17. The approximate lengths of beach nourishment and dredge disposal placement projects on Florida's Gulf Coast beaches (from Lott et al. 2009, FL DEP 2011, PSDS 2012 and USFWS files). Projects are listed by county from west to east / north to south, and then by increasing R-Monument within each county. RM-Start refers to the known starting Florida R-Monument location and RM_End refers to the known endpoint R-Monument for the project; start and endpoints may have been trimmed to eliminate overlaps with immediately adjacent projects. Note that projects denoted with a P are currently proposed.

County	Project Name or Area	RM_Start	RM_End	Length (miles)
Escambia	Perdido Key	R-1	R-34	6.50
Escambia	Pensacola Navigation Channel (dredge disposal)	R-34	R-64	6.30
Escambia	Santa Rosa Island (dredge disposal)	R-85	R-107	4.19 P
Escambia	Pensacola Beach	R-107	R-151	8.20
Escambia	Navarre Beach	R-192.5	R-213.5	4.10
Santa Rosa/Okaloosa	Eglin Air Force Base	V-551	V-609 (selected sites)	5.00
Santa Rosa/Okaloosa	Eglin Air Force Base	V-608	V-512 (selected sites)	2.65
Okaloosa	Ft. Walton Beach	R-1	R-15	2.80
Okaloosa	Okaloosa County- Destin, Holiday Isle	R-17	R-32	3.06
Okaloosa/Walton	Destin - Walton County	R-39	R-49	2.13
Walton	Western Walton County- Beach Restoration	R-1	R-23	4.92
Walton	Walton County Beach Nourishment, Phase 2	R-41	R-67	5.20
Walton	Gulf Trace	R-67	R-68	0.21
Walton	Walton County- Beach Restoration	R-68	R-78	1.95 P
Walton	Walton County Beach Nourishment, Phase 2	R-78	R-98	3.86
Walton	Walton County- Beach Restoration	R-98	R-105	1.59 P
Walton	Walton County Beach Nourishment, Phase 2	R-105	R-127	3.86
Bay	Panama City Beaches	R-0.5	R-92	17.40
Bay	Panama City Harbor (dredge disposal)	R-92	R-97	0.85
Bay	Mexico Beach	R-127	R-138.2	2.45
Gulf	St. Joseph's Peninsula	R-67	R-105.5	7.50
Gulf	Stump Hole	R-105.5	R-112	1.56
Franklin	St. George Island State Park	R-106	R-128.5	4.26
Franklin	Alligator Point	R-210	R-225	0.47 P
Pinellas	Honeymoon Island	R-8	R-12	0.82
Pinellas	Sand Key - Bellair, Indian Shores, Redington Beach, N. Redington Beach	R-51	R-107	10.57
Pinellas	Treasure Island	R-126	R-143	9.50
Pinellas	Long Key	R-144	R-148	0.76
Pinellas	Mullet Key	R-173	R-179.5	1.16
Pinellas	Mullet Key (dredge disposal)	R-181	R-191	1.74

County	Project Name or Area	RM_Start	RM_End	Length (miles)
Hillsborough	Egmont Key	R-2	R-10	1.52
Manatee	North Anna Maria Island	R-1	R-2	0.11 P
Manatee	Anna Maria Island	R-2	R-41	4.20
Manatee/Sarasota	Longboat Key	R-44	R-29.5	9.92
Sarasota	Lido Key	R-31	R-44.2	2.31
Sarasota	North Siesta Key	R-46	R-48.4	0.36 P
Sarasota	South Siesta Key	R-64	R-77.2	2.46
Sarasota	Casey Key	R-81	R-96	2.93 P
Sarasota	Venice	R-116	R-133	3.30
Charlotte	Manasota Key	R-14.4	R-20	0.92
Charlotte	Charlotte County Shore Protection Project	R-22	R-25.5	0.46
Charlotte	Knight Island	R-27.5	R-40	2.20
Lee	Gasparilla Island	R-10	R-26A	3.20
Lee	North Captiva Island	R-81	R-81A (+208 ft)	0.23
Lee	Captiva Island	R-83	R-109	5.06
Lee	Northern Shore Sanibel Island	R-109	R-118	1.69
Lee	Gulf Pines, Sanibel Island	R-129	R-133	0.77
Lee	Sanibel Island	R-174A	Bay 1A	0.25
Lee	Estero Island	R-175	R-199	4.72
Lee	South Estero Island	R-208	R-210	0.41
Lee	Lover’s Key	R-214	R-222	1.54
Lee	Big Hickory Island	R-222.3	R-223.8	0.47
Lee	Little Hickory Island- Bonita Beach	R-225.5	R-230	0.80
Collier	Barefoot Beach (dredge disposal)	R-11.4	R-14.2	0.39 P
Collier	Delnor-Wiggins State Park	R-18	R-20.5	0.39 P
Collier	Vanderbilt Beach	R-21	R-37	3.12
Collier	Clam Bay (dredge disposal)	R-37	R-48	2.13
Collier	Park Shore	R-48	R-55	1.42
Collier	Naples	R-58	R-79	3.70
Collier	Naples (Gordon Pass dredge disposal)	R-79	R-83	0.83
Collier	Keewaydin Island (Gordon Pass dredge disposal)	R-90	R-93	0.76
Collier	Marco Island- Hideaway Beach (North)	R-135	R-139	0.83
Collier	Marco Island- Hideaway Beach (South)	R-143	R-148	0.90
			TOTAL	**189.9+**

Alabama

The approximately 46.3 miles of sandy oceanfront beach in Alabama is roughly 55% developed, with Dauphin Island (total shoreline in Mobile County) 42% developed and the Baldwin County shoreline of the Fort Morgan peninsula, Gulf Shores and Orange Beach 61% developed (Table 18). Dauphin Island was split into Dauphin Island West (0% developed) and Dauphin Island East (82% developed) by the Ivan/Katrina Cut, an inlet opened by Hurricane Ivan in 2004 and expanded to 2 kilometers wide by Hurricane Katrina in 2005. There are at least 4 preserved lands along the Alabama coast, totaling over 11 miles of sandy oceanfront beach (Table 19). The longest stretch of preserved sandy oceanfront beach is in Gulf State Park, although the park is partially developed with recreational facilities and public recreation appears to be the primary use of the land.

Table 18. The approximate lengths of sandy oceanfront beach within each county of Alabama and the proportions that are developed and undeveloped (Bush et al. 2001, Morton and Peterson 2005a, USFWS 2005a, Google Earth 2008 imagery).

County	Approximate shoreline length in miles	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Mobile	15.3	6.5 (52%)	8.8 (58%)
Baldwin	31	18.9 (61%)	12.1 (39%)
TOTAL	**46.3**	**25.4 (55%)**	**20.9 (45%)**

Table 19. Preserved sandy oceanfront beaches in Alabama, the county in which each is located, and the approximate shoreline length of each.

Preserved Land	County Location	Approximate Length in Miles
Dauphin Island Audubon Bird Sanctuary	Mobile	0.6
Fort Morgan State Historic Site / Bon Secour NWR, Fort Morgan Unit	Mobile	1.8
Perdue Unit, Bon Secour NWR	Baldwin	4
Gulf State Park	Baldwin	3.5
Bureau of Land Management	Baldwin	1.3
	TOTAL MILES	**11.2 (24% of state shoreline)**

Approximately 4.7 miles (10%) of the Alabama coast is armored with hard erosion control structures (Morton and Peterson 2005a). Dauphin Island, Gulf Shores, and Orange Beach have had beach nourishment projects, an unknown length of sandy oceanfront beaches near Perdido Pass have received dredge spoil, and up to 1,000 feet of littoral zone of adjacent beaches receive maintenance dredge spoil on an as-needed basis from Little Lagoon Pass (Table 20). Altogether at least 7.4 miles (16%) of Alabama's oceanfront coastline has received fill material, some areas multiple times.

Table 20. The approximate lengths of authorized constructed beach nourishment and dredge disposal placement projects on Alabama sandy oceanfront beaches (from Froede 2007, PSDS 2012, and USFWS files).

Location	Project Length (miles)
Dauphin Island	4
Gulf Shores	3.3
Perdido Pass area dredge disposal	Unknown
Little Lagoon Pass area dredge disposal	0.2
TOTAL MILES	**7.5 (16% of state shoreline)**

Mississippi

Barrier Island Shoreline

Mississippi's Gulf of Mexico shoreline consists of a series of offshore barrier islands that, with the exception of a dredge spoil island owned by the U.S. Army Corps of Engineers, are entirely within the Gulf Islands National Seashore. These islands currently have approximately 27.3 miles of sandy oceanfront beach, of which none is developed. Preserved beaches account for 100% of the barrier island coastline (Table 21). The longest of these (≈11.8 miles) is found on Horn Island in Gulf Islands National Seashore. The mainland coastline of Mississippi, landward of the barrier islands, includes many miles of sandy beaches that were assessed separately (see below) since these beaches include several critical habitat units and provide habitat for the piping plover; the mainland beaches front on Mississippi Sound and not the Gulf of Mexico, however, as they are located landward of the barrier islands.

Table 21. The approximate lengths of sandy oceanfront barrier island beach in each county of Mississippi and the proportions that are developed and undeveloped (from Morton and Peterson 2005a, Google Earth 2003, 2006, and 2007 imagery).

County	Approximate shoreline length in miles	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Harrison	8.1	0	8.1 (100%)
Jackson	19.2	0	19.2 (100%)
TOTAL	**27.3**	**0**	**27.3 (100%)**

Table 22. Preserved sandy oceanfront barrier island beaches in Mississippi, the county in which each is located, and approximate shoreline length of each. Note that private inholdings remain on some of the barrier islands, and therefore the NPS does not have full ownership of all the islands.

Preserved Land	County Location	Approximate Length in Miles
Petit Bois Island, Gulf Islands NS	Jackson	6.4
Sand Island	Jackson	1.0
Horn Island, Gulf Islands NS	Jackson	11.8
East and West Ship Islands, Gulf Islands NS	Harrison	4.5
Cat Island, Gulf Islands NS	Harrison	3.6
	TOTAL MILES	**27.3 (100% of state barrier island shoreline)**

There is no shoreline armoring of the barrier island beaches of Mississippi (Morton and Peterson 2005a). The Mississippi oceanfront coast has not received much beach nourishment or dredge spoil; only one small intermittent beach nourishment project to protect Fort Massachusetts on West Ship Island and dredge disposal activities on Sand Island has been reported. The Mississippi Coastal Improvements Program (MsCIP) Comprehensive Plan to protect and restore the Mississippi barrier island coast proposes to add fill material to East and West Ship Islands, to close the inlet that separates them, and to place nearshore fill deposits near the other islands of Gulf Shores NS (USACE 2009).

Table 23. The approximate lengths of authorized constructed beach nourishment and dredge disposal placement projects on Mississippi's sandy oceanfront barrier island beaches (from PSDS 2012).

Location	Project Length (miles)
Sand Island	0.9
West Ship Island	0.2
TOTAL MILES	**1.1 (4% of state barrier island shoreline)**

<u>Mainland Shoreline</u>

Approximately 51.3 miles of sandy, soundfront beaches are present along the 80.7 mile long mainland Mississippi coast (Table 24). USACE (2010a) states that there are 60 miles of sandy beach along the Mississippi Sound shoreline, but 2010 and 2011 Google Earth imagery records only 51.3 miles. The amount of sandy beach along the sound front, shoreline of mainland Mississippi fluctuates with the placement and subsequent erosion of beach fill and dredge disposal projects. Non-sandy shoreline segments were included in this area due to the presence of extensive shoreline armoring (i.e., seawalls, bulkheads and groins). Some of these shoreline segments currently have no sandy beaches in front of them, but beach fill and dredge disposal projects periodically recreate beaches in these locations. Highly irregular estuarine shorelines not directly facing Mississippi Sound were excluded in this assessment. With the exceptions of the approximately 6 miles of non-sandy shoreline in Hancock County Marshes Preserve and approximately 6.8 miles of non-sandy shoreline within Grand Bay NERR in Jackson County (Table 25), virtually the entire remaining 67.9 miles of soundfront coast could periodically have sandy beach habitat given the extensive degree of habitat modifications resulting from beach fill and dredge disposal activities (Table 26).

The soundfront shoreline is well developed in the communities of Waveland, Bay St. Louis, Pass Christian, Long Beach, Gulfport, Biloxi, Ocean Springs, Belle Fontaine, Gautier and Pascagoula. The precise shoreline length is difficult to calculate given the irregular shape of the non-sandy shorelines in the Hancock County Marshes Preserve and the Grand Bay NERR. When non-sandy and sandy shoreline segments are combined, 66% of the soundfront shoreline is developed and 34% is undeveloped (Table 24). Harrison County, stretching from Pass Christian to Biloxi, is the most developed (86%), with Deer Island just off the Biloxi shoreline the only undeveloped segment in the county. When just the sandy shoreline segments of the soundfront coast are considered, 80% of the sandy beaches are developed and 20% are undeveloped (Table 2).

Table 24. The approximate lengths of soundfront mainland shoreline in each county of Mississippi and the proportions that are developed and undeveloped (from Google Earth 2010 and 2011 imagery).

County	Approximate shoreline length in miles	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Hancock	15.0	7.0 (47%)	8.0 (53%)
Harrison	32.6	28.0 (86%)	4.6 (14%)
Jackson	33.2	18.2 (55%)	14.9 (45%)
TOTAL	**80.7**	**53.2 (66%)**	**27.5 (34%)**

Although several segments of the soundfront shoreline have been preserved, very little has sandy beaches, as of September 2010 (Table 25). Deer Island Coastal Preserve is a state-owned island near Biloxi that has been undergoing restoration using dredged material (Paul Necaise, USFWS, pers. communication, 4/17/12), and as of November 2011 4.6 miles of sandy beach habitat has been constructed. Grand Bay NERR has a few natural pocket beaches along its soundfront shoreline in Jackson County (Paul Necaise, USFWS, pers. communication, 4/17/12). The beneficial use of dredged material has been proposed to be added to create additional habitat to Round Island (Paul Necaise, USFWS, pers. communication, 4/17/12), and other areas are being proposed for preservation and ecosystem restoration under the MsCIP (USACE 2009). However, the amount of sandy beach habitat that would be constructed in those efforts is unknown.

Historically most of the shoreline of the Mississippi mainland had a narrow sandy strip, with freshwater inlets, grasses and trees along the water's edge (Cathcart and Melby 2009). Following a series of storms, the shoreline between Pass Christian and Biloxi was modified with a seawall constructed between 1923 and 1927, which later allowed the construction of U.S. Route 90 just landward of the seawall (Cathcart and Melby 2009). Altogether there are roughly 45.4 miles of armored shoreline along the soundfront coast, primarily consisting of seawalls and groins.

Table 25. Preserved sandy, soundfront beaches in mainland Mississippi, the county in which each is located, and approximate shoreline length of each. Note that the total of 25% is based upon the proportion of sandy beaches present in 2010 and 2011 Google Earth imagery (of 51.3 miles).

Preserved Land	County Location	Approximate Length in Miles
Hancock County Marshes Coastal Preserve	Hancock	0 (no sand)
Buccaneer State Park / Grand Bayou Coastal Preserve	Hancock	1.1[1]
Deer Island Coastal Preserve	Harrison	4.6[2]
Davis Bayou Coastal Preserve	Jackson	2.1[3]
Bellefontaine Marsh Coastal Preserve	Jackson	1.7[3]
Graveline Bay Coastal Preserve	Jackson	0.8
Pascagoula River Marshes Coastal Preserve	Jackson	0 (no sand)
Round Island Coastal Preserve	Jackson	1.6
Grand Bay NERR	Jackson	0.7 (sandy portion)
	TOTAL MILES	**12.6 (25% of state mainland shoreline)**

[1] Buccaneer State Park had only 0.2 miles of sandy beach as of 2010 but was scheduled for a federal beach fill project that would restore all 1.1 miles of its shoreline.
[2] Deer Island recently has had its sandy beaches restored using dredged material.
[3] Sandy beaches along these shorelines typically are narrow strips of intermittent pocket beaches.

The majority of the present soundfront shoreline is manmade, with 26 miles of artificially created beach between Pass Christian and Biloxi alone (Douglass 2002, Cathcart and Melby 2009). Approximately 85% (43.5 of 51.3 miles) of the sandy, soundfront coast has been modified with beach nourishment and dredge disposal placement projects (Table 26). The Hancock County Beach Dunes Project in Waveland and Bay St. Louis currently is placing 6.0 miles of beach fill and restoring 19 acres of dunes along the shoreline of the western sound (USACE Mobile District, http://www.sam.usace.army.mil/mscip/Hancock_County_Beach_Dunes.htm). With the completion of the federal Hancock County Beach Dunes Project, virtually the entire soundfront shoreline of mainland Hancock County (apart from the Hancock County Marshes Coastal Preserve) will have received beach fill or dredge spoil. Similarly, the entire Harrison County soundfront shoreline has received beach fill.

The MsCIP has proposed to modify and restore many habitats along the mainland Mississippi shoreline, including on roughly 30 of 60 miles of beach and dune (USACE 2010a). The interim Pascagoula Beach Boulevard Restoration Project recently repaired a seawall, reconstructed 7,700 feet of geotubes, placed beach fill excavated from the Pascagoula federal navigation channel along 7,700 feet of Pascagoula shoreline, and installed riprap and vegetation to protect the beach fill and geotubes from erosion (USACE 2010b). However, the addition of the riprap and tidal marsh vegetation along the toe, or waterfront, edge of the beach fill limits its potential for becoming valuable sandy beach habitat.

Table 26. The approximate lengths of authorized constructed beach nourishment and dredge disposal placement projects on the soundfront shoreline of mainland Mississippi (from USACE 2010b, PSDS 2012, and the USACE Mobile District website).

Location	Project Length (miles)
Hancock County Beach Dunes Project[1]	6.0
City of Bay St. Louis[2]	2.7
Harrison County (Pass Christian to Biloxi)	26.0
Deer Island	4.6
Ocean Springs, Front Beach	1.1
Ocean Springs, East Beach	1.1
Pascagoula Beach Boulevard Restoration Project	1.5
Pascagoula, Front Beach	0.5
TOTAL MILES	**43.5 (85% of state mainland shoreline)**

[1] The federal Hancock County Beach Dunes Project overlaps with previous beach fill projects along Hancock County Beach and Waveland.
[2] A segment of the 6.0 mile long Bay St. Louis area previously receiving beach fill overlaps with the Hancock County Beach Dunes Project and has been subtracted to obtain the length listed here.

Louisiana

The Louisiana coast is a mix of sandy and non-sandy oceanfront beaches. There are currently roughly 217.5 miles of sandy beaches, but they are not continuous and large sections of coastline are characterized by a series of small pocket beaches interspersed with non-sandy and often marshy shoreline. Of the sandy beaches, only 6% are developed (Table 27), primarily the areas of Holly Beach, Constance Beach, and Grand Isle. Preserved sandy oceanfront beaches account for roughly 30% of the Louisiana coastline (Table 28). The longest is in the state-run Rockefeller Wildlife Refuge (26.5 miles).

Table 27. The approximate length of sandy oceanfront beach in each shoreline segment of Louisiana and the proportions that are developed and undeveloped (Morton et al. 2005, Morton and Peterson 2005b, Google Earth 2009 and 2010 imagery).

Shoreline Segment	Approximate shoreline length in miles	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Sabine Pass to Mermentau River Navigation Channel	51	6.9 (14%)	44.1 (86%)
Mermentau River Navigation Channel to Joseph Harbor Bayou	16.1	0	16.1 (100%)
Joseph Harbor Bayou to Flat Lake	12.1	0	12.1 (100%)
Flat Lake Entrance to Freshwater Bayou Canal	7.2	0	7.2 (100%)
Freshwater Bayou Canal to Vermilion Bay	10.1	0	10.1 (100%)

Shoreline Segment	Approximate shoreline length in miles	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Vermilion Bay to Atchafalaya Bay	2.4	0	2.4 (100%)
Atchafalaya Bay to Caillou Bay	18.6	0	18.6 (100%)
Caillou Bay to East Timbalier Island	23.7	0	23.7 (100%)
East Timbalier Island to Pass Abel	26.7	5.9 (22%)	20.8 (78%)
Pass Abel to Bay Coquette	19.5	0	19.5 (100%)
South West Pass to South Pass	14.6	0	14.6 (100%)
South Pass to Chandeleur Sound	15.6	0	15.6 (100%)
TOTAL	**217.5**	**12.8 (6%)**	**204.8 (94%)**

Approximately 15.9 miles (7%) of sandy oceanfront beach has been armored with hard structures (Morton et al. 2005, Morton and Peterson 2005b, Google Earth). Beach restoration projects are much more extensive than shoreline armoring, with at least 60.4 miles of sandy oceanfront beach receiving beach fill or dredge spoil (Table 29). Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) projects have restored sandy beaches that have eroded or been lost due to sediment starvation, local subsidence and sea level rise (see http://lacoast.gov/new/Projects/List.aspx for a list of projects and their details). Numerous other beach restoration (nourishment) projects are planned as part of the Louisiana Coast 2050 effort (see http://www.coast2050.gov/ for more information).

Table 28. Preserved sandy oceanfront beaches in Louisiana, the parish in which each is located, and approximate shoreline length of each.

Preserved Land	Parish Location	Approximate Length in Miles
Rockefeller Wildlife Refuge	Vermilion	26.5
Paul J. Rainey Wildlife Sanctuary	Vermilion	0 (no sand)
Marsh Island Refuge	St. Mary and Iberia	0 (no sand)
Terrebonne Barrier Islands Refuge	Terrebonne	13.9
Elmer's Island Wildlife Refuge	Jefferson	2.3
Grand Isle State Park	Jefferson	0.9
Pass A Loutre WMA	Plaquemines	7.1
Breton NWR	St. Bernard & Plaquemines	15.6
	TOTAL MILES	**66.3 (30% of state shoreline)**

Table 29. The approximate lengths of authorized constructed beach nourishment (restoration) and dredge disposal placement projects on Louisiana's sandy oceanfront beaches (from PSDS 2012, Google Earth imagery, CWPPRA project data, and USFWS files). Note that the Chandeleur Island Chain, Pelican Island, Scofield and Shell Island all received fill material during the Deepwater Horizon oil spill response efforts.

Location	Project Length (miles)
Bay Joe Wise (Pass Chaland to Grand Bayou Pass)	2.25
Chandeleur Island Chain	7.0
East Grand Terre Island	2.8
East Timbalier Island	2.5
Grand Isle	7.4
Grand Terre Island	4.5
Holly Beach	9.5
Pelican Island	2.4
Raccoon Island (Isles Dernieres)	1.0
Scofield	2.9
Shell Island	1.6
Timbalier Island	2.2
Trinity and East Islands (Isles Dernieres)	7.5
West Belle Pass Headland	3.1
Whiskey Island (Isles Dernieres)	3.8
TOTAL MILES	**60.4 (28% of state shoreline)**

Texas

Virtually the entire coast, except the inlets, comprises the approximately 370 miles of sandy oceanfront beach in Texas (Table 30). Roughly 14% of these beaches are developed and 86% are undeveloped. Although many long segments of barrier islands and peninsulas are preserved (Table 31), some long undeveloped beaches, such as those on San Jose Island and the west Matagorda peninsula, are privately owned with no public access, minimal structures, and private airstrips (Morton et al. 1983, Google Earth 2011 imagery). Padre Island National Seashore is reportedly the longest undeveloped barrier island in the world, with nearly 66 miles of preserved sandy oceanfront beach (NPS 2011). Altogether, preserved sandy oceanfront beaches account for approximately 152.7 miles (41%) of the Texas coastline (Table 31). Besides Padre Island National Seashore, the Matagorda Island NWR and State Natural Area also protect a substantial proportion of the coast (38 miles).

Table 30. The approximate lengths of sandy oceanfront beach in each shoreline segment of Texas and the proportions that are developed and undeveloped (Morton and Peterson 2005c, 2006a, and 2006b, Google Earth 2011 imagery).

Shoreline Segment	Approximate shoreline length in miles	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Sabine Pass to Colorado River	150.7	39.1 (26%)	111.6 (74%)
Colorado River Mouth to	23.7	0	23.7

Shoreline Segment	Approximate shoreline length in miles	Developed shoreline miles (% of total)	Undeveloped shoreline miles (% of total)
Matagorda Ship Channel			(100%)
Matagorda Ship Channel to Pass Cavallo	4.1	0	4.1 (100%)
Pass Cavallo to Aransas Pass	56	0	56.0 (100%)
Aransas Pass to Mansfield Channel	93	6.9 (7%)	86.1 (93%)
Mansfield Channel to Rio Grande River	42.4	4.7 (11%)	37.7 (89%)
TOTAL	**369.9**	**50.7 (14%)**	**319.2 (86%)**

Approximately 36.6 miles (10%) of Texas's sandy oceanfront beach has been armored (Morton and Peterson 2005c, 2006a, 2006b, Google Earth). At least 28 miles (8%) of sandy oceanfront beach has received beach nourishment or dredge disposal, some areas multiple times (Table 32). Galveston Island has the longest reaches of nourished beach, and the town of South Padre Island – Isla Blanca Park area has 30,000 feet of oceanfront beach that periodically receives dredged materials.

Table 31. Preserved sandy oceanfront beaches in Texas, the county in which each is located, and approximate shoreline length of each.

Preserved Land	County Location	Approximate Length in Miles
Sea Rim State Park	Jefferson	5.2
Bolivar Flats Shorebird Sanctuary	Galveston	2.3
East End Lagoon Park and Nature Preserve	Galveston	2.8
Galveston Island State Park	Galveston	1.5
Justin Hurst WMA	Brazoria	1.3
San Bernard NWR	Brazoria	5.8
Matagorda Bay Nature Park	Matagorda	2.0
Matagorda Island NWR and State Natural Area	Matagorda	38.0
I.B. Magee Beach Park	Nueces	0.7
Mustang Island State Park	Nueces	5.0
Padre Island NS, North Padre Island	Kleberg, Kenedy, & Willacy	65.5
Laguna Atascosa NWR, South Padre Island Unit	Willacy & Cameron	9.6
Andie Bowie County Park	Cameron	0.5
Isla Blanca Park	Cameron	1.0
Boca Chica Tract, Lower Rio Grande River NWR	Cameron	5.5
	TOTAL MILES	**152.7 (41% of state shoreline)**

Table 32. The approximate lengths of authorized constructed beach nourishment and dredge disposal placement projects on Texas's sandy oceanfront beaches (from PSDS 2012, Google Earth imagery, and Morton and Miller 2004).

Location	Project Length (miles)
Caplen Shores area west of Rollover Pass	1.1
Corpus Christi	1.4
Galveston Island	6.8
Galveston Island State Park	Unknown
Galveston Island west end subdivisions	6.3
Gilchrest Subdivision east of Rollover Pass	1.0
McFaddin NWR	1.0
North Padre Island	1.0
Quintana	1.0
Rollover Pass area shorelines	2.0
South Padre Island and Isla Blanca Park	5.7
Surfside Beach	1.0
Texas Point NWR	Unknown
TOTAL MILES	**28.3 (8% of state shoreline)**

DISCUSSION

A substantial proportion of the sandy oceanfront beaches within the U.S. continental wintering and migration range of the piping plover have been developed (40%), filled with sediment (at least 32%) and armored (at least 11%). These habitat modifications tend to occur in the same locations as each other, resulting in localized adverse cumulative effects. When combined with the habitat modifications to the tidal inlets within the continental wintering range (results of Rice 2012), significant cumulative loss and degradation of piping plover habitat has resulted, for example on areas such as the east coast of Florida where 90% of the inlets have been armored and/or dredged, 63% of the oceanfront beach has been developed, 51% has received sand placement, and at least 16% of the beach has been armored. The number of beach nourishment projects is increasing in virtually every state (Trembanis et al. 1998, Bush et al. 2004, USFWS 2009), resulting in an increasing magnitude of habitat modification. This assessment did not include other forms of habitat modification, such as dune building and maintenance, vegetation plantings, beach scraping (using bulldozers to push up artificial levees or "dunes" with sediment from the beach), the maintenance and protection of coastal roads, and the alterations caused by driving ORVs on beaches and dunes. However, all of these activities occur throughout the range and cumulatively they increase the adverse effects on habitats used by piping plovers and other wildlife that use beaches.

Over 811 miles of sandy oceanfront beaches in the continental migration and wintering range of the piping plover has been conserved and protected through preservation and easements. These preserved lands are not uniformly distributed throughout the range however. Federal lands have been especially important as preserved sandy oceanfront beach habitat. For example, the National Seashores – Cape Hatteras, Cape Lookout, Cumberland, Cape Canaveral, Gulf Islands, and Padre Island – contribute over 280 miles of protected sandy beaches. This protection does not equate to pristine, undisturbed, and unmodified habitat, however, because the seashores have been and continue to be modified by beach nourishment and placement of dredge disposal (Gulf Islands, Cape Hatteras), permitted ORV use (Cape Hatteras, Cape Lookout, Padre Island), protection and maintenance of coastal highways (Cape Hatteras, Gulf Islands), the potential for incompatible activities on private inholdings (Cape Hatteras, Cumberland), creation and maintenance of artificial dune ridges (Cape Hatteras, Gulf Islands), and closure of new inlets (Cape Hatteras). National Wildlife Refuges have also preserved sandy oceanfront beaches throughout the range, most notably on Pea Island (NC), Cape Romain (SC), Archie Carr (FL), Breton (LA), and Matagorda Island (TX). Other significant federal lands as important habitat for piping plovers include those of military bases (Camp Lejeune in NC, Eglin and Tyndall AFBs in FL) and the NERR system (Masonboro in NC, Apalachicola, Guana Tolomato Matanzas and Rookery Bay in FL). Although they are generally shorter in length than the federal lands, lands owned by state, county, local, and conservation organizations collectively make an important contribution to the total inventory of preserved lands.

This inventory of preserved lands can be used to identify geographic gaps where conservation efforts may be prioritized to maintain and increase habitat availability and quality as sea level rises and climate changes. The area with the least modified habitat, i.e., retaining the most constituent elements of the wintering critical habitat designation, appears to be in Texas. Long stretches of undeveloped barrier islands and peninsulas, with overwash passes and flats, discontinuous dunes, and sparse vegetation are common on the Texas coastline. The islands of the Gulf Islands National Seashore in Mississippi and the area of the Florida panhandle protected by the Gulf Islands National Seashore, Eglin AFB and Tyndall AFB provide similar habitat and opportunities for better conservation efforts to avoid higher levels of modification and disturbance as sea level rises. The beaches and islands of Cape Lookout NS and Cape Romain NWR constitute the only comparably analogous lands on the Atlantic Coast in terms of habitat features or elements. The undeveloped and preserved islands of Georgia provide a uniquely contiguous suite of inlets and sandy beach habitats. All of these areas are well-suited to allow habitat migration with rising sea level. Indeed, some are already showing signs of doing so.

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Appendix 2a. Recommendations for Stewardship and for Monitoring Sites for Piping Plovers in their Continental U.S. Coastal Migration and Wintering Range

1. Conduct a site assessment to determine the effectiveness of current site management for piping plovers and other shorebird species. For an example of a site assessment tool, go to http://www.whsrn.org/tools.

2. Protect piping plover habitat and areas with high concentrations of other shorebirds. Piping plovers are generally not present between 15 May and 15 July; however, other sensitive shorebirds (particularly nesting shorebirds) may benefit from year-round protection of roosts and restrictions on dogs, off-road vehicles, and wrack-removal.

   2.1. Seasonally close piping plover roosting areas and areas where other shorebirds concentrate.

      2.1.1. Post a 25-m buffer around roosting areas with closure signs connected by string from 15 July through 15 May. Maintain closures by re-posting toppled signs and replacing broken string throughout the season.

      2.1.2. Relocate or adjust closures as habitat conditions change between migration/winter seasons.

   2.2. Prohibit dogs at important piping plover sites (e.g., sites occupied by piping plovers and/or within 1.5 km (one mile) of an unstabilized inlet).

   2.3. Prohibit recreational off-road vehicles, including cars, trucks, 4-wheelers, all-terrain vehicles, and golf carts, at important piping plover sites (e.g., sites occupied by piping plovers or within 1.5 km (one mile) of an unstabilized inlet). Essential vehicles necessary to conduct shorebird surveys or sea turtle nesting surveys within these important sites should adhere to beach driving best management practices to protect nesting sea turtles, sea turtle hatchlings, breeding shorebirds and seabirds and their chicks. Contact your local USFWS Field Office for best management practices for driving on beaches.

   2.4. Do not remove wrack at important piping plover sites. Less restrictive practices protecting wrack within occupied plover habitat or within 1.5 km (one mile) of an inlet should only be considered if sufficient resources are available to detect shifts in shorebird locations. Trash may be removed by hand, but natural material should remain.

3. Conduct surveys to determine the distribution, abundance, and seasonality of piping plovers where data are lacking on site use.

   3.1. Recommended piping plover survey protocol:

      Piping plover abundance and distribution should be determined by conducting two to three intensive surveys per month for at least one full nonbreeding season in order to determine site use. Surveys should be conducted 10 days apart (weather and tide permitting; no surveys should be conducted if winds exceed 15 mph) beginning 15 July and ending 15 May. Surveys should be scheduled +/- 3 days of the 5th, 15th, and 25th of each month, consistent with the International Shorebird Survey protocol. Surveys should be conducted between mid and high tide when piping plovers are more concentrated. Resighting of bands will be easier a few hours before or after high tide when birds are no longer roosting.

If banded birds are observed during a survey, the band combinations should be recorded and band placement and color should be verified through a spotting scope, not with binoculars. Band combinations should be noted in the following order: Upper Left (UL), Lower Left (LL): Upper Right (UR), and Lower Right (LR). The following abbreviations should be used to record band color combinations:

X: metal	b: light blue	C: Atlantic Canada color metal
f: flag	G: dark green	T: other (describe)
R: red	g: light green	/: split band (1 band with 2 colors)
Y: yellow	L: black	//: triple split (1 band with 3 colors)
O: orange	W: white	N: no band seen (area not visible)
B: dark blue	A: gray	–: no band
P: pink	U: purple	

Example: A piping plover with: (UL) orange flag band, (LL) light blue band over a black over orange over black triple split band, (UR) metal band, (LR) light green band would be recorded as **Of,bL/O/L:X,g**. A comma separates the bands of the upper and lower leg and a colon separates the legs from each other.

For more information about resighting and reporting banded piping plovers, see Appendix 2b: How To Resight and Report Banded Piping Plovers.

3.2. Report band combinations to piping.plover@usace.army.mil. Please provide your local USFWS and State wildlife agency a copy of your datasheet(s) as soon after the sighting as possible in case more information about the sighting or the band combination is needed.

3.3. Although piping plovers are the target species for these surveys, any additional observations of other species, especially sensitive species such as red knots and snowy plovers, will help USFWS and State wildlife agencies to identify areas of shorebird concentration and facilitate their management.

3.4. Additional information such as date, location, time, weather conditions, observer name(s) should be collected during each survey (see Appendix 2c: Examples of Data Collection Forms).

3.5. It is equally important to record the absence of piping plovers as well as their presence. Indicate when and where you have surveyed and no birds were observed.

4. Post interpretive signs that inform site users about the importance of shorebird conservation, particularly for the piping plover.

4.1. Interpretive signs should be designed to relay the message to the general public. Photos or graphics should be used wherever possible to convey the message. Text should be succinct and written in non-technical terms (see examples in Appendix 2e: Examples of Effective Signs for Migrating and Wintering Piping Plover Conservation).

4.2. Interpretive signs should depict and explain any signs that site users may observe on the beach. For example, if an area has seasonal closures, visitors will be more likely to recognize the closure signs and understand why the area is closed.

5. Provide outreach programs and materials to promote shorebird conservation with emphasis on the piping plover.

    5.1. Create a site steward program and have staff or volunteers set up a spotting scope outside of closures to allow people to see the birds while learning about shorebird conservation.

    5.2. Offer guided birding trips that observe appropriate buffer distances to avoid disturbance to shorebirds.

    5.3. Provide shorebird identification classes and educational workshops.

    5.4. Develop site-specific outreach materials about shorebird conservation.

Appendix 2b. How to Resight and Report Banded Piping Plovers

Be careful not to disturb the bird. A slow, quiet approach avoids harassment and allows the observer to carefully scan the band combination. The use of a spotting scope facilitates accurate observations from a distance.

Please record:

1. Location where the bird was seen (GPS coordinates are helpful).
2. Date when the bird was seen.
3. Any observations of the bird's behavior (e.g., roosting, foraging).
4. Band combination:
    a. Band combinations should be recorded in the following sequence: upper left (UL; above the "knee"), lower left (LL; below the "knee"), upper right (UR), lower right (LR). "Right" and "left" are from the bird's perspective, not the observer's (just like a person's right and left legs).
    b. Band types include flags (band with tab sticking out), metal, and color bands.
    c. Some bands may have alpha-numeric codes printed on the band or the flag (e.g., A1). The code and the color and location of the band or flag should be documented. Both the color of the band and the code (e.g., white writing on a green band) should be noted.
    d. Some bands are split (a single band with two colors; e.g., orange/blue) or triple split (a single band with three colors; e.g., blue/orange/blue).
    e. Sometimes two bands of the same color are placed over each other, appearing like one very tall band.
    f. Some piping plovers are banded on the upper legs only, and bands can be stacked (one above the other) on the upper leg.
    g. Record leg positions where bands are absent as well as where they are present.
    h. Note if the color or type of any of the bands is uncertain or if some parts of a leg were not seen clearly.
    i. Recognize that band colors can fade over time.

Left Figure: The band combination below would be recorded as: metal (UL), dark blue (LL), black flag (UR), red over black (LR). The abbreviated band combination (refer to Appendix 2a) would be recorded as: X,BB:Lf,RL. Right Figure: Example in yellow circle shows use of an alpha-numeric code on a color band.

Please send this information with the observer's contact information to piping.plover@usace.army.mil.

For more information about resighting bands, please consult http://www.fws.gov/charleston/pdf/PIPL_Band_Identification_Training.pdf.

To download an example spreadsheet for recording banded piping plovers, go to http://www.fws.gov/charleston/pdf/PIPL/example_usfws_pipl_survey_spreadsheet.xlsx.

Appendix 2c. Examples of Data Collection Forms

Below is a Florida example of a field sheet to collect appropriate data on piping plovers or other shorebirds.

Non-breeding Shorebirds & Seabirds Monitoring

Pg. 1 of 1

Location: Little Talbot **Date:** 1/11/11 **Start/End time:** 8:30-14:45

Observer(s): Bob Smith, Sue Paper **%Cloud cover:** 20 **Wind:** 3 **Visibility:** E

Tide: high, falling **Surf:** calm **Precipitation:** None

Wrack: Yes-(S)parse ■ Yes-(A)bundant □ No □ **Beach Raking:** Y ■ N □

Direct Disturbance:

- □ Avian predator (RAPT)
- □ Powered water craft (PWC)
- □ Aircraft (AIR)
- □ Kite surfers (KITE)
- □ Non-powered water craft (NPWC)
- □ Dogs off-leash (DOG)
- ■ Vehicle present (VEH)
- ■ Walkers/runners/dog on leash/cyclists (WALK)

Comments: Walkers flushed flock 1, birds returned and continued foraging

***All birds not associated with a flock are recorded as Flock # 0**

****Roost/loaf & Forage- put X in box for appropriate behavior(s)**

Flock No.	Time flock sighted	Lat/Long	Species	Roost	Forage	# of Banded Birds	# of Bands Read	Total #
1	900	30.433,-81.406	REKN	N	Y	6	5	23
2	945	30.437,-81.406	PIPL	Y	Y	1	1	3
2	945	30.437,-81.406	SEPL	Y	N	0	0	24
2	945	30.437,-81.406	DUNL	Y	Y	0	0	47
2	945	30.437,-81.406	SAND	N	Y	0	0	4
0			SAND	N	Y	0	0	34
0			RUTU	Y	Y	1	1	9
0			WILL	N	Y	0	0	12
0			BBPL	Y	N	0	0	5

Resighting

Pg. 1 of 1

Location: Little Talbot **Date:** 1/11/11 **Observer(s):** Bob Smith, Sue Paper

ULU- Upper left top, ULL- Upper left bottom, LLU- Lower left top, LLL- Lower left bottom, URU- Upper right top, URL- Upper right bottom, LRU- Lower right top, LRL- Lower right bottom

Flock No.	Species	Flag Code (REKN/AMOY)	Flag Color	ULU	ULL	LLU	LLL	URU	URL	LRU	LRL	Confirmed	Comments
1	REKN	AL9	FL		Y				FL		S	Y	flag faded
1	REKN	UU1	FL						FL		S	Y	
1	REKN	H1P	FL		B				FL		S	Y	
1	REKN	NA7	FL		B				FL		S	Y	
1	REKN	LA7	FL						FL		S	Y	
2	PIPL		FG			R	W		FG	R	Y	Y	
0	RUTU	XA9	FL						FL		S	Y	

Blank Forms

Non-breeding Shorebirds & Seabirds Monitoring

Pg. ___ of ___

Location: ____________ **Date:** ____________ **Start/End time:** ________________________

Observer(s): ____________________ **%Cloud cover:** ______ **Wind:** _______ **Visibility:** __________

Tide: __________ **Surf:** __________ **Precipitation:** ______________

Wrack: Yes-(S)parse ☐ Yes-(A)bundant ☐ No ☐ **Beach Raking:** Y ☐N ☐

Direct Disturbance:

☐ Avian predator (RAPT)
☐ Powered water craft (PWC)
☐ Aircraft (AIR)
☐ Kite surfers (KITE)
☐ Non-powered water craft (NPWC)
☐ Dogs off-leash (DOG)
☐ Vehicle present (VEH)
☐ Walkers/runners/dog on leash/cyclists (WALK)

Comments:

*All birds not associated with a flock are recorded as Flock # 0
**Roost/loaf & Forage- put X in box for appropriate behavior(s)

Flock No.	Time flock sighted	Lat/Long	Species	Roost	Forage	# of Banded Birds	# of Bands Read	Total #

Resighting

Pg. ___of ___

Location: ______________ **Date:** _________ **Observer(s):** ____________

ULU- Upper Left Upper/(top), ULL- Upper Left Lower/(bottom), LLU- Lower Left Upper/(top), LLL- Lower Left Lower/(bottom), URU- Upper Right Upper/(top), URL- Upper Right Lower/(bottom), LRU- Lower Right Upper/(top), LRL- Lower Right Lower/(bottom)

Flock No.	Species	Flag Code (REKN/AMOY)	Flag Color	ULU	ULL	LLU	LLL	URU	URL	LRU	LRL	Confirmed	Comments

Red Knot	REKN	American Oystercatcher	AMOY	Sanderling	SAND
Least Tern	LETE	Piping plover	PIPL	Snowy Plover	SNPL

South Carolina example of a piping plover survey datasheet.

To download a PDF, go to http://www.fws.gov/charleston/pdf/PIPL/usfws_pipl_survey_datasheet.pdf.
To download an Excel version, go to
http://www.fws.gov/charleston/pdf/PIPL/example_usfws_pipl_survey_spreadsheet.xlsx.

SC Nonbreeding PIPL Survey Data Sheet

Date:_____ Location:_____ Observer(s):_____

Start Time:_____AM/PM End Time:_____AM/PM **General weather** (circle one): Sunny Partly cloudy Cloudy Rain Fog Other (describe)

Temp:___°F **Wind Direction** (circle one): N NE E SE S SW W NW **Wind Speed** (circle one): 0-5 6-10 11-15 16-20 >21 MPH

Tidal stage(s): Low Mid High (Rising/Falling)

Disturbance (#): Pedestrian(s)____ Boat(s)____ Bicycle(s)____ ATV(s)____ ORV(s)____ Dog(s) On____ Dog(s) Off____

PIPL #	Left Upper	Left Lower	Right Upper	Right Lower	Latitude	Longitude	Habitat	Behavior	Notes

Habitat:
1: intertidal zone
2: fresh wrack
3: backshore
4: old wrack
5: dune
6: ephemeral pool
7: washover/blowout
8: dense vegetation
9: other (describe)
10: unknown

Behavior:
1: foraging
2: roosting
3: preening
4: bathing
5: flying
6: aggression
7: walking

Bands:
X: metal band
f: flag
R: red
Y: yellow
O: orange
B: dark blue
b: light blue
W: white
A: gray
G: dark green
g: light green
L: black
S: silver
-: no band
N: no band seen
/: split band
//: triple split band
T: other (describe)
P: pink
U: purple

Total PIPL:_____

Appendix 2d. Example of a State Atlas

The South Carolina Shorebird Project (SCSP) was created and funded in 2006. The project objectives were to: 1) Determine the abundance and distribution of piping plovers within designated critical habitat units in South Carolina, 2) Determine the abundance and distribution of other shorebird species of concern, such as the Wilson's plover, American oystercatcher, red knot, and marbled godwit, within these critical habitat units, 3) Create partnerships to achieve shorebird conservation, and 4) Increase awareness about shorebird conservation through outreach and education. The project includes partners from county, state, and federal agencies, NGOs, and private citizens. Shorebird surveys documented the importance of South Carolina for nonbreeding piping plovers, particularly for the Great Lakes population, and fostered conservation efforts for Wilson's plovers and red knots. The project has also increased awareness and prompted interest in posting seabird colonies at additional sites in the state that were not previously protected. This excerpt is from the SCSP Report for objectives 1 and 2 and represents one of many sites surveyed in South Carolina.

Little Capers Island

County: Beaufort

Survey Area: All sandy inlet beaches, ocean beach, and bay beach at the south end.

Critical Habitat Designation: Unit SC-14, Capers Island.

Habitat conditions: The three sections of the island are accessible only by boat. The northern section has several houses, the central section has a single house, and the southern section is undeveloped. The north and central sections have relatively narrow beaches at high tide with limited roosting habitat except at those inlets with open sandy areas; the southern section of beach is wider with multiple overwash fans and a moderate size open sandy area at the southern end. The beach is relatively flat in slope so there are large intertidal feeding areas, with the inlets providing areas of mud/sand substrate and the beach with sand substrate. All three sections have overwash fans that provide low energy feeding habitat in the fan area, which extends into the marsh.

Habitat Modifications: None observed except on the northern island, which has sand fencing.

Management Measures: None observed.

Comments:

- One of the better locations in the state for Piping Plovers (PIPL), and an important location for birds from the Great Lakes population**.**
- ATV tracks were observed on the northern section. The island is difficult to survey due to the two inlets that bisect the island.
- Although the northern and southern sections can be accessed from interior channels, the middle section is accessible by boat only when the ocean is calm and at mid/high tide, or by wading across the southern inlet at low tide.
- At times, disturbance may be a concern on both the southern and northern sections.
- Movements of individual piping plovers among the three sections of Little Capers Island were documented based on band observations.
- Little Capers Island is one of the top locations in the state for Wilson's Plovers (WIPL).
- American Oystercatchers (AMOY), and Marbled Godwits (MAGO); Red Knots (REKN) were also noted during piping plover surveys.

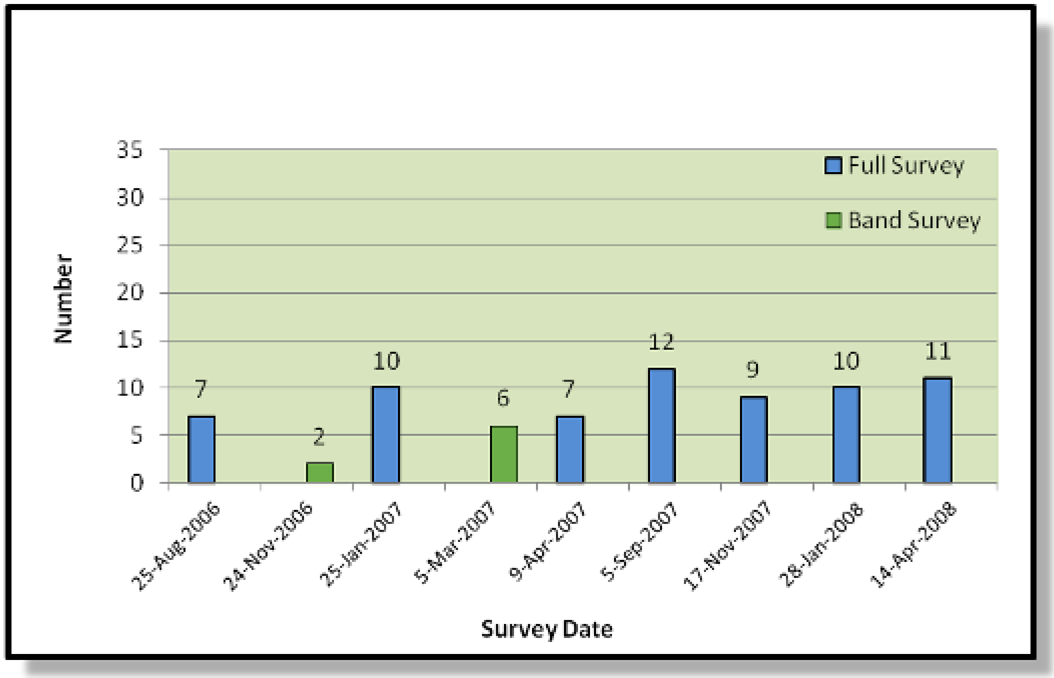

Figure 1. Numbers of piping plovers observed in different seasons and years on Little Capers Island, South Carolina.

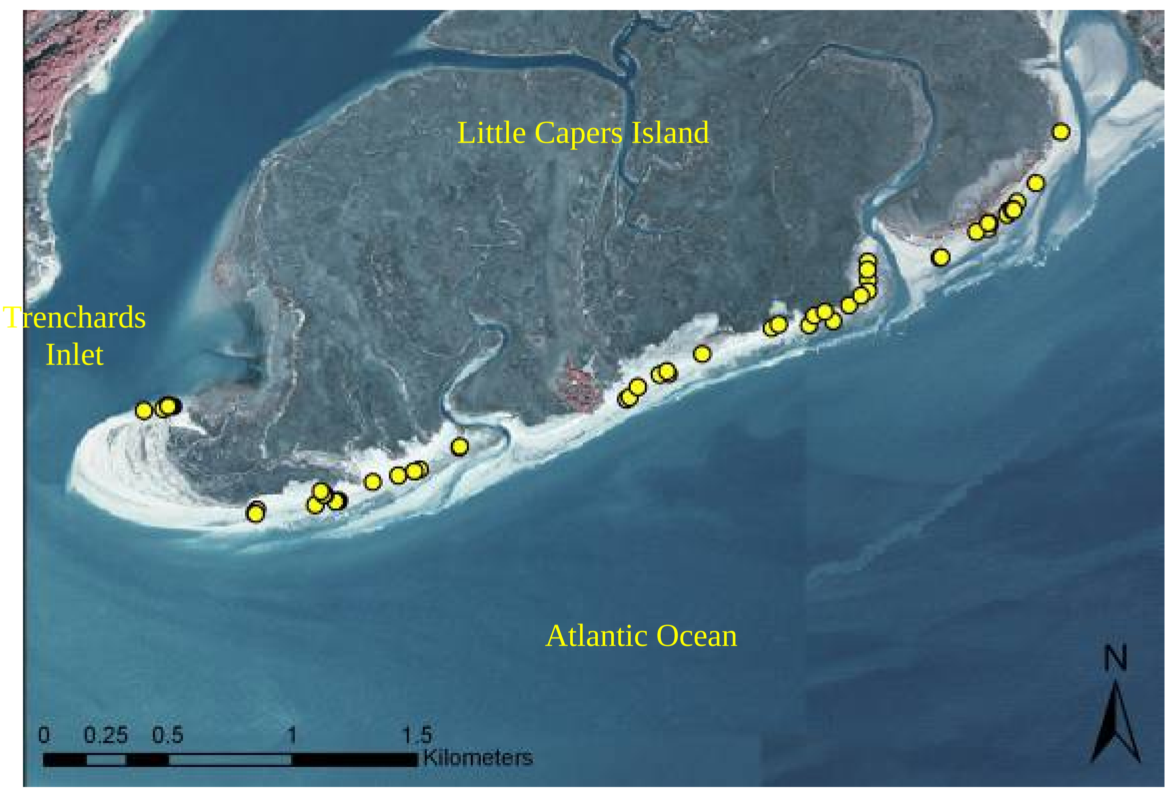

Figure 2. Locations (yellow dots) on Little Capers Island where piping plovers were observed during 2006 to 2008.

Table 1. Band combinations observed on Piping Plovers on Little Capers Island, South Carolina.

PIPL #	Date	Bands[1]	Band #	M or W[2]	Pop[3]	Comments
1	25-Aug-2006	-,X:-,C		M	At C	At C double size metal band, completely faded
2	25-Aug-2006	X,L:-,YO		M	GL US	
3	24-Nov-2006	-,-:X,g		W	GL US	
4	25-Jan-2007	-,-:X,g		W	GL US	
5	25-Jan-2007	O,-:X,O/R		W	GL US	band faded
6	25-Jan-2007	X,Y:-,Ob		W	GL US	
7	25-Jan-2007	X,Y:Wf,Yg		W	GP C	
8	5-Mar-2007	-,-:X,g	ends in 312	W	GL US	1951-26312
9	5-Mar-2007	X,Y:-,Ob		W	GL US	
10	9-Apr-2007	O,-:X,O/R		W	GL US	
11	9-Apr-2007	X,b:O,-		M	GL US	Matches brood marker for adult banded bird seen in 2007-8
12	9-Apr-2007	X,Y:-,Ob		W	GL US	
13	9-Apr-2007	X,Y:Wf,Yg		W	GP C	Central island
14	5-Sep-2007	-,-:X,g		W	GL US	second season at same location
15	5-Sep-2007	O,-:X,-		W	UK	This would match GL bird from 06-7 same location if the split fell off (spit worn first season)
16	5-Sep-2007	Of,BR:X,R		W	GL US	seen at middle island also
17	5-Sep-2007	X,b:Of,LO		W	GL US	previously banded X,b:O,- (matches a bird seen in spring previous year)
18	5-Sep-2007	X,Y:Wf,Yg		W	GP C	
19	17-Nov-2007	-,-:X,g	[]951-[]6312	W	GL US	
20	17-Nov-2007	Of,BR:X,R		W	GL US	
21	17-Nov-2007	X,Y:-,Ob		W	GL US	bird moved across S inlet to N side (middle island)
22	28-Jan-2008	O,-:X,-		W	UK	This would match GL bird from 06-7 same location if the split fell off (spit worn first season)
23	28-Jan-2008	Of,BR:X,R		W	GL US	
24	28-Jan-2008	X,b:Of,LO		W	GL US	
25	28-Jan-2008	X,Y:-,Ob		W	GL US	
26	28-Jan-2008	X,[Y]:Wf,Yg		W	GP C	Y band missing
27	14-Apr-2008	-,-:X,g		W	GL US	
28	14-Apr-2008	Of,BR:X,R		W	GL US	

PIPL #	Date	Bands[1]	Band #	M or W[2]	Pop[3]	Comments
29	14-Apr-2008	X,b:Of,LO		W	GL US	
30	14-Apr-2008	X,[Y]:Wf,Y g		W	GP C	Y band missing

[1] Abbreviations of band combinations are noted in the following order: Upper Left (UL), Lower Left (LL): Upper Right (UR), and Lower Right (LR). A comma separates the upper and lower leg and a colon separates the legs from each other.

X: metal	b: light blue	C: Atlantic Canada color metal
f: flag	G: dark green	T: other (describe)
R: red	g: light green	/: split band (1 band with 2 colors)
Y: yellow	L: black	//: triple split (1 band with 3 colors)
O: orange	W: white	N: no band seen (area not visible)
B: dark blue	A: gray	–: no band
P: pink	U: purple	

[2]M=migrant bird, W=winter bird. A winter bird is a bird that has been documented at a site between December 1 and January 31. A migrant bird is a bird that has not been documented at a site between December 1 and January 31.

[3]Pop=population based on band combination. UK=unknown, ATL US=Atlantic US, ATL C=Atlantic Canada, GL US=Great Lakes US, GL C=Great Lakes Canada, GP US=Great Plains US, GP C=Great Plains Canada.

Table 2. Observations of other shorebirds on Little Capers Island during piping plover surveys.

Date	Tide St.[1]	Tide Dir.[2]	WIPL	AMOY	REKN	MAGO
25-Aug-2006	H	R	66	10	340	3
25-Jan-2007	H	F	0	6	0	0
9-Apr-2007	M	R	73	7	73	0
5-Sep-2007	M	R	18	14	116	2
17-Nov-2007	M	R	1	2	25	13
28-Jan-2008	H	F	0	11	13	2
14-Apr-2008	H	F	50	12	107	0

[1]Tidal Stage. H=High, M=Mid, L=Low.
[2]Tide Direction. R=Rising, F=Falling.

Appendix 2e. Examples of Effective Signs for Migrating and Wintering Piping Plover Conservation


ALCOHOL
CAMPING
DOGS
PROHIBITED
ON ISLAND


CRITICAL
WILDLIFE AREA
CLOSED
TO PUBLIC ACCESS
No vehicles
No entry
No dogs
Pedestrians, vehicles, vessels or dogs are prohibited from entering this area. The take of fish or wildlife within this area is prohibited.
Engaging in any of these activity is a violation of State Law, Chapter 68A-19.005 F.A.C., and violators may be subject to criminal penalties. To report violations, call 888-404-3922.
Funds for this sign provided by the Wildlife Foundation of Florida
Florida Fish and Wildlife Conservation Commission
MyFWC.com


IMPORTANT SHOREBIRD AREA
Migratory shorebirds roost here between October and April
Resident shorebirds nest here on the dry sand between Sept and April
Please enjoy beaches, and by following these simple guidelines, you can help protect our shorebirds too.
Avoid the far ends of the beach during high tide
Please keep your dog under control
Walk and drive below the high tide mark to avoid crushing nests and scaring birds
WWF
Natural Heritage Trust


Save Shorebirds, Share the Beach
Loaf or Die!
Like you, many shorebirds come to the beach to rest and take a break from hectic schedules. For shorebirds, loafing is not lazy. It's life or death. They rest and feed to replenish fat and relax flight muscles before continuing migration. Disturbing these birds just a few times can diminish their chances of survival.
To Share the Beach with Shorebirds:
Keep dogs leashed. Dogs chase exhausted shorebirds and stress nesting birds.
Stay out of areas in or near dunes so you will not accidentally step on chicks or eggs.
Walk or bike around large flocks of birds on the beach, not through them.
Avoid feeding gulls or leaving trash on the beach. Gulls and other predators can be lured to shorebird areas where they eat chicks and eggs.
Shallow Scrapes are Precarious Cradles
Some shorebirds, like Wilson's Plovers, nest on this beach. The plover's nest is a difficult-to-see depression in the sand. The futures of parent plovers and their chicks depend on you. To help, avoid dunes and berms (small sand piles between dunes and beach) where they raise their families. Chicks explore the beach as they mature, so be careful where you step.
Spotting Shorebirds
Stay aware so you can give them space.
Can you find the nesting shorebird in this picture?

Appendix 3. Agencies, Organizations, and Unaffiliated Individuals Involved in Conservation of Migrating and Wintering Piping Plovers

Federal Agencies	State and Local Government	Private Entities and Individuals
CONTINENTAL UNITED STATES		
Alabama		
U.S. Fish and Wildlife Service Alabama Field Office, Daphne (Dianne Ingram) Bon Secour National Wildlife Refuge (Jackie Isaacs)	Alabama Department of Conservation and Natural Resources (Roger Clay)	
Florida		
U.S. Fish and Wildlife Service North Florida Field Office, Jacksonville (John Milio, Billy Brooks) South Florida Field Office, Vero Beach (Jeff Howe, Marilyn Knight) Panama City Field Office (Patty Kelly) Tallahassee Migratory Bird Field Office (Cindy Fury) Hobe Sound National Wildlife Refuge (Richard Brust) Chassahowitzka National Wildlife Refuge Complex (Joyce Kleen) St. Vincent National Wildlife Refuge (Brad Smith) National Park Service Gulf Island National Seashore (Mark Nicholas) Department of Defense: Eglin Air Force Base (Kelley Anderson, Kelly Knight, Dustin Varble, Bruce Hagedorn, Kathy Gualt) Tyndall Air Force Base (Wendy Jones)	Florida Fish and Wildlife Conservation Commission (John Himes, Robin Boughton, Janell Brush, Bobbi Carpenter, Laura DiGruttolo, Nancy Douglass) Florida Department of Environmental Protection (Raya Pruner, Marvin Friel, Sally Braem, Daniel Larremore, Kristin Ebersole, Mike Simmons) Volusia County Environmental Management (Stacey Bell, Jennifer Winters) Escambia County (Tim Day)	Audubon Florida (Julie Wraithmell, Ann Hodgson, Monique Borboen-Abrams, Alan Knothe) Barbara Eells Coastal Eco-Group, Inc. (Cheryl Miller) Eckerd College (Beth Forys) Ecological Associates, Inc.(Amber Bridges) Pat and Doris Leary Sustainable Ecosystems International (Greg Braun)

Federal Agencies	State and Local Government	Private Entities and Individuals
Georgia		
U.S. Fish and Wildlife Service Coastal Georgia Field Office (Chris Coppola) National Park Service Cumberland Island National Seashore (Doug Hoffman) U.S. Army Corps of Engineers (Ellie Covington)	Georgia Department of Natural Resources (Tim Keyes)	Little St. Simons Island (Scott Coleman)
Louisiana		
U.S. Fish and Wildlife Service Louisiana Field Office (Deborah Fuller, Brigette Firmin) Southeast Louisiana National Wildlife Refuges Complex (James Harris) U.S. Army Corps of Engineers (Ed Creef)	Louisiana Department of Wildlife and Fisheries (Mike Seymour, Mike Carloss, Todd Baker, Cassidy Lejeune) Louisiana Department. of Natural Resources (Greg DuCote)	Barataria-Terrebonne National Estuary Program (Richard DeMay) The Nature Conservancy (Keith Ouchley) National Audubon (Paul Kemp) Louisiana State University Museum of Natural Science Louisiana Bird Resource Center (Richard Gibbons)
Mississippi		
U.S. Fish and Wildlife Service Mississippi Field Office (Paul Necaise) National Park Service Gulf Island National Seashore (Gary Hopkins)	Mississippi Department of Wildlife, Fisheries and Parks (Nick Winstead)	
North Carolina		
U.S. Fish and Wildlife Service Raleigh Field Office (Pete Benjamin) Columbia Migratory Bird Field Office (John Stanton) National Park Service Cape Hatteras National Seashore (Britta Muiznieks, Thayer Broili) Cape Lookout National Seashore (Jon	North Carolina Wildlife Resources Commission (Sara Schweitzer)	Audubon North Carolina (Walker Golder, Lindsay Addison)

Federal Agencies	State and Local Government	Private Entities and Individuals
Altman, Michael Rikard)		
South Carolina		
U.S. Fish and Wildlife Service South Carolina Field Office (Melissa Bimbi) Cape Romain National Wildlife Refuge (Sarah Dawsey and Dan Ashworth) U.S. Army Corps of Engineers Charleston District (Greg Wahl and Mark Messersmith)	South Carolina Department of Natural Resources (Felicia Sanders) South Carolina Department of Parks, Recreation, and Tourism (Mike Walker) Charleston County Park and Recreation Commission (Julie Hensley, Mark Madden, Keith McCullough) Town of Hilton Head Island (Sally Krebs) Town of Kiawah Island (Aaron Given, Jim Jordan)	Audubon South Carolina (Norm Brunswig) Cape Romain Bird Observatory (Nathan Dias)
Texas		
U.S. Fish and Wildlife Service Corpus Christi Field Office (Robyn Cobb, Mary Orms, Beau Hardegree, Pat Clements, Frank Weaver) Clear Lake Field Office (Donna Anderson, Woody Woodrow) South Texas National Wildlife Refuge Complex (Mitch Sternberg, Sonny Perez, Leo Gustafson, Bryan Winton, Scott Edler) Texas Mid-coast National Wildlife Refuge Complex (Jennifer Wilson) Aransas National Wildlife Refuge (Brad Strobel) San Bernard National Wildlife Refuge (Shane Kasson) Texas Chenier Plains NWR Complex (Tim Cooper, Patrick Walther)National Park Service Padre Island National Seashore (Wade Stablein)	Texas Parks and Wildlife Department (Brent Ortego, Kendal Keyes, Andy Sipocz, Paul Eubank, Damon Reeves) Texas General Land Office (Amy Nunez, Jennifer Stephens, Ray Newby)	Coastal Bend Bays and Estuaries Program (David Newstead) Coastal Bird Conservation Program (Margo Zdravkovic) Gulf Coast Bird Observatory (Cecilia Riley, Susan Heath) University of Texas Marine Science Institute (Tony Amos) Houston Audubon Society (Marc Reid) Winnie Burkett University of Houston-Clear Lake (George Guillen, Kristen Vale) Texas A & M University-Corpus Christi (Kim Withers)

Federal Agencies	State and Local Government	Private Entities and Individuals
U.S. National and Regional		
U.S. Fish and Wildlife Service Atlantic Coast Joint Venture (Craig Watson) Inter-regional Piping Plover Team (Melissa Bimbi, Patricia Kelly, Robyn Cobb, Vince Cavalieri, Jack Dingledine, Carol Aron, Anne Hecht) Gulf Coast Joint Venture (William Vermillion) Migratory Bird Program, Northeast Region (Caleb Spiegel) Migratory Bird Program, Southwest Region (Bill Howe) Shorebird Conservation Coordinator (Brad Andres) Southeast Region National Wildlife Refuge System Planning (Chuck Hunter) National Park Service Southeast Coast Inventory and Monitoring Program (Mike Byrne) U.S. Geological Survey Biological Resources Division (Elise Elliott-Smith, Susan Haig) Coastal Geology (Ben Gutierrez)		American Bird Conservancy (Casey Lott) Audubon International Programs (Matt Jeffery) Audubon Important Bird Area Program (Connie Sanchez) National Audubon, Gulf of Mexico Conservation and Restoration (Chris Canfield, Melanie Driscoll) Sidney Maddock State University of New York, Syracuse (Jonathan Cohen) University of Wisconsin (Olivia LeDee) University of Tulsa (Erin Roche) University of Minnesota (Francesca Cuthbert) Virginia Tech Department of Fisheries and Wildlife Sciences (Jim Fraser, Sarah Karpanty, Dan Catlin) Western Hemispheric Shorebird Reserve Network

Federal Agencies	State and Local Government	Private Entities and Individuals
OUTSIDE CONTINENTAL UNITED STATES		
Anguilla		
Anguilla National Trust (Farah Mukhida)		
Bahamas		
Bahamas National Trust (Predensa Moore, Lynn Gape, Eric Carey)		Andros Conservancy and Trust Friends of the Environment in Abaco
British Virgin Islands		
		Jost Van Dykes Preservation Society (Susan Zaluski)
Canada		
Canadian Wildlife Service (Andrew Boyne, Julie McKnight, Jen Rock, Francois Shaffer) Environment Canada, Science and Technology Branch (Cheri Gratto-Trevor)		Bird Studies Canada (Sue Abbott)
Cayman Islands		
National Trust for the Cayman Islands (Patricia Bradley)		
Cuba		
		Instituto de Ecologia y Stistematica (Pedro Blanco Rodriguez) University of Havana (Antonio Rodrigues Suarez)
Dominica		
Forestry, Wildlife, and Parks Division (Bertrand Jno Baptiste)		

Federal Agencies	State and Local Government	Private Entities and Individuals
Dominican Republic		
		Sociedad Ornitológica de la Hispaniola (Kate Wallace)
Mexico		
	State of Tamaulipas (Alfonso Banda)	Pronatura Noreste
Puerto Rico		
U.S. Fish and Wildlife Service Boqueron Field Office (Marelisa Rivera)		Sociedad Ornitologica Puertorriguena (Sindiali Acosta-Malaret, Alcides Morales) University of Puerto Rico (Allen Lewis)
St. Lucia		
Ministry of Agriculture, Lands, Forestry and Fisheries (Alwin Dornelly)		
St. Vincent and the Grenadines		
		AvianEyes Birding Group (Lystra Culzac-Wilson)
Trinidad and Tobago		
Department of Natural Resources & the Environment (Angela Ramsey)		
Turks and Caicos Islands		
Turks and Caicos Ministry of Environment (Rhodriques Ewing) Turks and Caicos National Trust (Jonathan Sayao, Ethlyn Gibbs)		
U.S. Virgin Islands		
U.S. Fish and Wildlife Service Sandy Point National Wildlife Refuge (Claudia Lombard)		St. Croix Environmental Association (Carol Cramer-Burke)