

**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  
December 2012**

Cover graphic: Judy Fieth

Cover photos:

Foraging piping plover - Sidney Maddock

Piping plover in flight - Melissa Bimbi, USFWS

Roosting piping plover - Patrick Leary

Sign - Melissa Bimbi, USFWS

**INTER-REGIONAL PIPING PLOVER TEAM  
U.S. FISH AND WILDLIFE SERVICE**

**Melissa Bimbi**

U.S. Fish and Wildlife Service  
Region 4, Charleston, South Carolina

**Robyn Cobb**

U.S. Fish and Wildlife Service  
Region 2, Corpus Christi, Texas

**Patty Kelly**

U.S. Fish and Wildlife Service  
Region 4, Panama City, Florida

**Carol Aron**

U.S. Fish and Wildlife  
Region 6, Bismarck, North Dakota

**Jack Dingledine/Vince Cavaliere**

U.S. Fish and Wildlife Service  
Region 3, East Lansing, Michigan

**Anne Hecht**

U.S. Fish and Wildlife Service  
Region 5, Sudbury, Massachusetts

Prepared by  
**Terwilliger Consulting, Inc.**

Karen Terwilliger, Harmony Jump, Tracy M. Rice, Stephanie Egger  
Amy V. Mallette, David Bearinger, Robert K. Rose, and Haydon Rochester, Jr.



## **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.

**NOTICE OF COPYRIGHTED MATERIAL:** Permission to use copyrighted images in this document has been granted by the copyright holders. These images are not placed in the public domain by their appearance herein. They may not be copied or otherwise reproduced, except in their printed context within this document, without the written consent of the copyright holder.

Recommended citation:

U.S. Fish and Wildlife Service. 2012. Comprehensive Conservation Strategy for the Piping Plover (*Charadrius melodus*) in its Coastal Migration and Wintering Range in the Continental United States. East Lansing, Michigan.

An electronic copy of this document is available at: <http://www.fws.gov/midwest/EastLansing/>

# TABLE OF CONTENTS

PURPOSE AND GEOGRAPHIC SCOPE OF THIS STRATEGY .....	i
RELATIONSHIP OF THIS STRATEGY TO RECOVERY PLANS.....	i
ACKNOWLEDGMENTS .....	ii
DISCLAIMER .....	ii
NOTICE OF COPYRIGHTED MATERIAL.....	ii
TABLE OF CONTENTS.....	iii
PART I: INTRODUCTION.....	1
BIOLOGY, ECOLOGY, AND HABITAT PREFERENCES OF NONBREEDING PIPING PLOVERS .....	4
Description .....	4
Temporal and Spatial Distribution .....	4
Survival .....	7
Habitat Use.....	9
Winter Site Fidelity .....	11
Intra- and Inter-specific Interactions .....	12
KEY THREATS TO PIPING PLOVERS IN THEIR COASTAL MIGRATION AND WINTERING RANGE.....	13
Loss, Modification, and Degradation of Habitat .....	13
Development and Construction .....	13
Dredging and Sand Mining .....	16
Inlet Stabilization and Relocation .....	19
Groins .....	21
Seawalls and Revetments .....	22
Sand Placement Projects.....	23
Loss of Macroinvertebrate Prey Base due to Shoreline Stabilization .....	25
Invasive Vegetation.....	27
Wrack Removal and Beach Cleaning.....	28
Accelerating Sea Level Rise and other Climate Change Impacts.....	29
Weather events.....	31
Storm Events .....	31
Severe Cold Weather.....	33
Disturbance from Recreation Activities .....	33
Oil Spills and Other Contaminants .....	35
Oil Spills.....	35
Pesticides and Other Contaminants.....	37
Energy Development .....	38
Land-based Oil and Gas Exploration and Development .....	38
Wind Turbines.....	38
Predation.....	39
Military Operations.....	39
Disease.....	40
Summary and Synthesis of Threats .....	40
CURRENT CONSERVATION EFFORTS .....	41
International Treaties .....	41
Federal Regulatory Protections.....	41
Federal Lands.....	43
State Protections.....	44
Non-regulatory Activities.....	45

Conservation Efforts Outside the Continental United States .....	46
PART II: PRINCIPLES FOR CONSERVATION OF PIPING PLOVERS IN THEIR NONBREEDING RANGE .....	49
PART III: CONSERVATION STRATEGY – RECOMMENDATIONS FOR ADDRESSING THREATS AND RECOVERY NEEDS .....	51
1 Maintain natural coastal processes that perpetuate wintering and coastal migration habitat.....	53
2 Protect wintering and migrating piping plovers and their habitat from human disturbance. ....	60
3 Monitor nonbreeding plovers and their habitat. ....	67
4 Protect nonbreeding plovers and their habitats from contamination and degradation from oil or other chemical contaminants.....	71
5 Assess predation as a potential limiting factor for piping plovers on wintering and migration sites.....	74
6 Improve application of regulatory tools. ....	75
7 Develop mechanisms to provide long-term protection of nonbreeding plovers and their habitat....	80
8 Conduct scientific investigations to refine knowledge and inform conservation of migrating and wintering piping plovers.....	83
9 Coordinate, review, and refine recovery efforts. ....	87
LITERATURE CITED .....	89

## LIST OF FIGURES

Figure 1. Distribution and range of <i>C. m. melodus</i> , Great Lakes distinct population segments (DPS) of <i>C. m. circumcinctus</i> , and Northern Great Plains DPS of <i>C. m. circumcinctus</i> as delineated in the USFWS 2009 5-Year Review.....	2
Figure 2. Adult breeding plumage and nonbreeding plumage.....	4
Figure 3. The winter distribution in the continental U.S. of piping plovers from four breeding locations .	8
Figure 4. Number of sand placement events per decade in Florida between 1959-1999, and 2000-2006..	25

## LIST OF TABLES

Table 1. Results of the 1991, 1996, 2001, and 2006 international piping plover winter censuses and preliminary 2011 results. ....	6
Table 2. The lengths and percentages of sandy oceanfront beach in each state that are developed, undeveloped, and preserved as of December 2011 ( .....	15
Table 3. The number of open tidal inlets, inlet modifications, and artificially closed inlets in each state as of December 2011.....	17
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. ....	24
Table 5. The piping plover’s status and legal protection under state laws.....	44
Table 6. Conservation action outline. ....	52



## LIST OF 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*)
- 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*)

### APPENDIX 2: PIPING PLOVER MONITORING AND MANAGEMENT RECOMMENDATIONS AND EXAMPLES

- Appendix 2a. Recommendations for Stewardship and for Monitoring Sites for Piping Plovers in their Continental U.S. Coastal Migration and Winter Range
- Appendix 2b. How to Resight and Report Banded Piping Plovers
- Appendix 2c. Examples of Data Collection Forms
- Appendix 2d. Example of a State Atlas
- Appendix 2e. Examples of Effective Signs for Migrating and Wintering Piping Plover Conservation

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



## 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<sup>1</sup>; 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<sup>2</sup> 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).

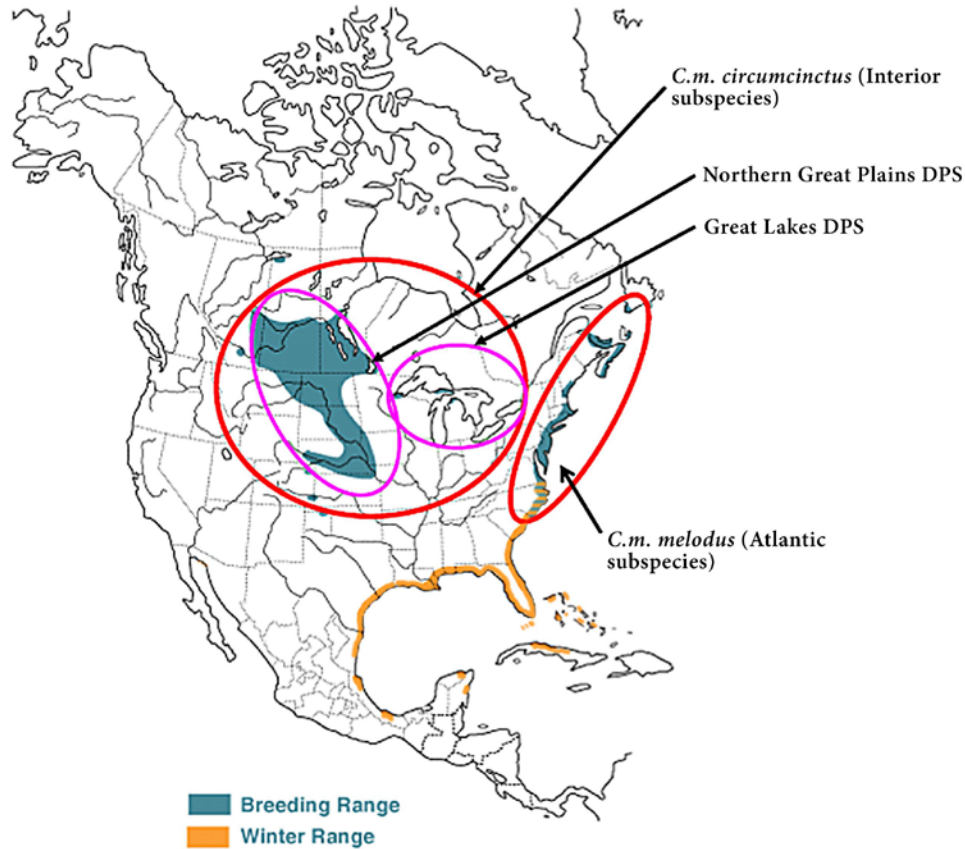
In 2001, critical habitat was designated for the breeding population in the U.S. Great Lakes region (USFWS 2001a), while a separate rule determined critical habitat for the U.S. portion of the Northern Great Plains breeding population in 2002 (USFWS 2002a). No critical habitat has been proposed or

---

<sup>1</sup> The 1957 checklist provides the American Ornithologists’ Union’s most recent treatment of subspecies.

<sup>2</sup> 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<sup>3</sup> 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.

<sup>3</sup> 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<sup>4</sup> (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).

---

<sup>4</sup> 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 <sup>a</sup>	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
<b>U.S. Total</b>	<b>3,384</b>	<b>2,416</b>	<b>2,299</b>	<b>3,355</b>	<b>2,858</b>
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
<b>GRAND TOTAL</b>	<b>3,451</b>	<b>2,515</b>	<b>2,389</b>	<b>3,884</b>	<b>3,975</b>

<sup>a</sup>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.

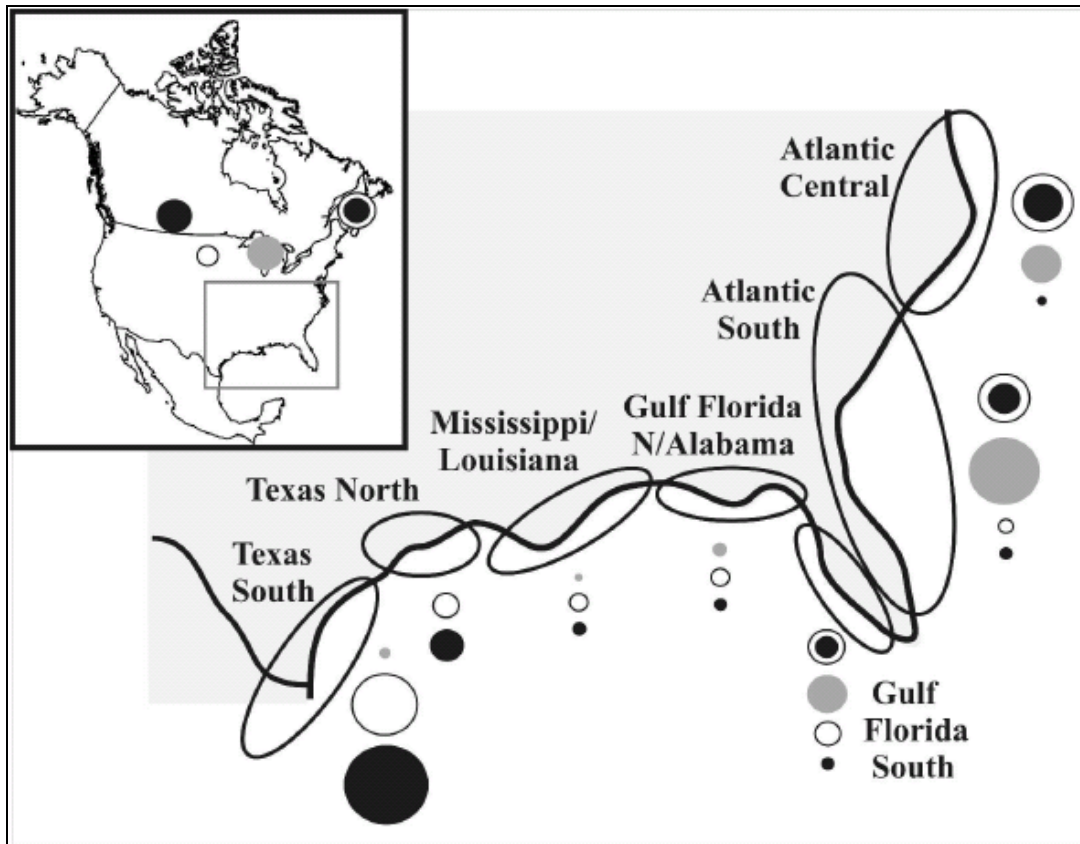
Abundance estimates for nonbreeding piping plovers may also be affected by the number of surveyor visits to the site. A preliminary analysis found 87% detection during the mid-winter period at South Carolina sites surveyed three times a month during fall and spring and one time per month during winter, 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<sup>5</sup> (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<sup>6</sup> 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

---

<sup>5</sup> 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).

<sup>6</sup> “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<sup>7</sup>. 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

---

<sup>7</sup> 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 Oeonidae 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<sup>2</sup>; the mean core area was 2.9 km<sup>2</sup>; 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<sup>2</sup> 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<sup>2</sup> 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) <sup>a</sup>	Approximate Miles of Beach Preserved (percent of total shoreline length) <sup>b</sup>
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 <sup>c</sup>	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%)
<b>TOTAL</b>	<b>2,119</b>	<b>856 (40%)</b>	<b>1,264 (60%)</b>	<b>901.5 (43%)</b>

<sup>a</sup> Beaches classified as “undeveloped” occasionally include a few scattered structures.

<sup>b</sup> 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.

<sup>c</sup> 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<sup>8</sup>.

### ***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<sup>th</sup> 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).

---

<sup>8</sup> 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 <sup>a</sup>	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
<b>TOTAL</b>	221	119 (54%)	89 (40%)	97 (44%)	8 (4%)	20 (9%)	30 (14%)	64 (N/A)

<sup>a</sup> Structures include jetties, terminal groins, groin fields, rock or sandbag revetments, seawalls, and offshore breakwaters.

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<sup>th</sup> 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).

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 19<sup>th</sup> 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<sup>9</sup>. 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<sup>10</sup>. 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<sup>11</sup> 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

---

<sup>9</sup> See page 19 for references describing these stabilization structures.

<sup>10</sup> 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.

<sup>11</sup> 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<sup>12</sup>.

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,

---

<sup>12</sup> 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.

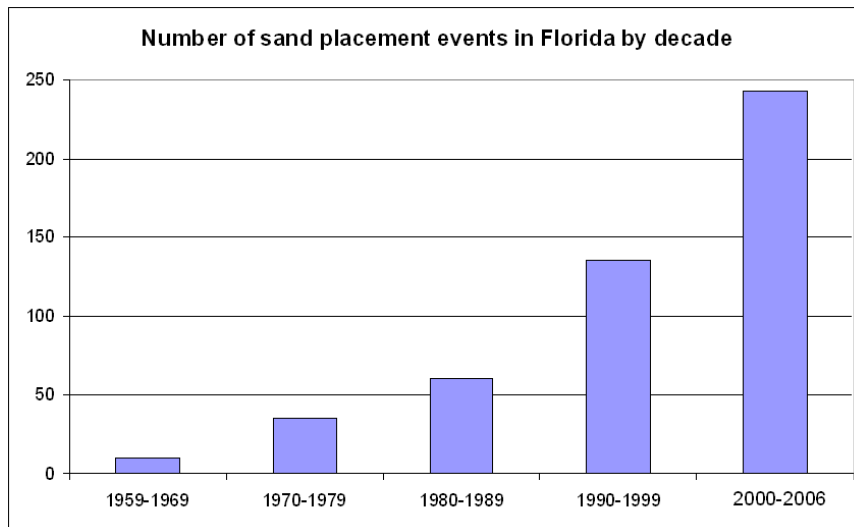
The beaches along the mainland coast of Mississippi are the most modified by sand placement activities with at least 85% affected (Table 4). Of the oceanfront beaches, the Atlantic coast of Florida has had the highest proportion (at least 51%) of beaches modified by sand placement activities. Approximately 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).**

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

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<sup>13</sup> 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<sup>14</sup> (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.

---

<sup>13</sup> 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).

<sup>14</sup> 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. Cavaliere, 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<sup>15</sup>. 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.

---

<sup>15</sup> 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<sup>16</sup> (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

---

<sup>16</sup> 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<sup>17</sup> (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).

---

<sup>17</sup> 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, Fors (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](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<sup>18</sup>. 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

---

<sup>18</sup> 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](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 ongoing 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.



## LITERATURE CITED

- Addison, L. 2012. Use of southeastern North Carolina inlets by migrating and wintering piping plovers (*Charadrius melodus*). Audubon North Carolina, Wilmington, North Carolina. Poster presentation at January 2012 Atlantic Coast piping plover and least tern workshop in Shepherdstown, West Virginia.
- American Bird Conservancy. 2007. Pesticide profile – fenthion. Accessed on 27 February 2009 at <http://www.abcbirds.org/abcprograms/policy/pesticides/Profiles/fenthion.html> 2007.
- American Ornithologists' Union [AOU]. 1945. Twentieth supplement to the checklist of North American birds. *Auk* 62:436-449.
- AOU. 1957. Checklist of North American birds. 5th edition. Baltimore, Maryland. 691 pp.
- Amirault, D. L., F. Shaffer, K. Baker, A. Boyne, A. Calvert, J. McKnight, and P. Thomas. 2005. Preliminary results of a five year banding study in eastern Canada: support for expanding conservation efforts to non-breeding sites? Unpublished Canadian Wildlife Service report. Accessed 14 October 2008 at [http://www.fws.gov/nc-es/birds/Amirault\\_Article.pdf](http://www.fws.gov/nc-es/birds/Amirault_Article.pdf).
- Amirault-Langlais, D. L., P. W. Thomas, and J. McKnight. 2007. Oiled piping plovers (*Charadrius melodus melodus*) in eastern Canada. *Waterbirds* 30(2):271-274.
- Arvin, J. 2008. A survey of upper Texas coast critical habitats for migratory and wintering piping plover and associated resident “sand plovers”. Gulf Coast Bird Observatory’s interim report to Texas Parks and Wildlife Department. Grant No. TX E-95-R.
- Arvin, J. C. 2009. Hurricane shifts plover populations. Gulf Coast Bird Observatory’s Gulf Crossings. Vol. 13, No.1.
- Association of Fish and Wildlife Agencies. 2009. Voluntary guidance for states to incorporate climate change into state wildlife action plans and other management plans. November 2009.
- Baker, A. J., P. M. Gonzalez, T. Piersma, L. J. Niles, I. de Lima Serrano do Nascimento, P. W. Atkinson, N. A. Clark, C. D. T. Minton, M. K. Peck, and G. Aarts. 2004. Rapid population decline in red knots: fitness consequences of decreased refueling rates and late arrival in Delaware Bay. *Proceedings of the Royal Society B: Biological Sciences* 271:875-882.
- Banda, A. 2009. 2006 Censo Internacional de Chorlo Pico Corto en Mexico. Pages 98-103 *in* Data from the 2006 International Piping Plover Census: U.S. Geological Survey Data Series 426.
- Beck, T. M. and P. Wang. 2009. Influences of channel dredging on flow and sedimentation patterns at microtidal inlets, west-central Florida, USA. *Proceedings of Coastal Dynamics 2009: Impacts of Human Activities on Coastal Processes*, Paper No. 98. Tokyo, Japan. 15 p.
- BirdLife International. 2012. Important bird area search for piping plovers in the Bahamas. Accessed November 4, 2012 at <http://www.birdlife.org/datazone/site/search>.
- Bishop, M. J., C. H. Peterson, H. C. Summerson, H. S. Lenihan, and J. H. Grabowski. 2006. Deposition and long-shore transport of dredge spoils to nourish beaches: impacts on benthic infauna of an ebb-tidal delta. *Journal of Coastal Research* 22(3):530-546.

- Blanco, P. 2006. Distribución y áreas de importancia para las aves del orden Charadriiformes en Cuba. Tesis en opción al grado científico de Doctor en Ciencias Biológicas, Instituto de Ecología y Sistemática, La Habana, Cuba. 102 pp.
- Blanco, P. 2012. *Charadrius melodus* Linnaeus, 1758 Frailecillo Blanco, piping plover. Libro rojo de los vertebrados de Cuba: 18:222-224.
- Brault, S. 2007. Population viability analysis for the New England population of the piping plover (*Charadrius melodus*). Report 5.3.2-4. Prepared for Cape Wind Associates, L.L.C., Boston, Massachusetts.
- Brown, A. C. and A. McLachlan. 2002. Sandy shore ecosystems and the threats facing them: some predictions for the year 2025. *Environmental Conservation* 29(1):62-77.
- Brown, S., C. Hickey, B. Harrington, and R. Gill. 2001. The U.S. Shorebird Conservation Plan, 2<sup>nd</sup> Edition. Manomet Center For Conservation Sciences, Manomet, Massachusetts, USA. 64 pp.
- Burger, J. 1991. Foraging behavior and the effect of human disturbance on the piping plover (*Charadrius melodus*). *Journal of Coastal Research*, 7(1):39-52.
- Burger, J. 1994. Foraging behavior and the effect of human disturbance on foraging behavior and habitat use in piping plover (*Charadrius melodus*). *Estuaries* 17:695-701.
- Burger, J., S. A. Carlucci, C. W. Jeitner, and L. Niles. 2007. Habitat choice, disturbance, and management of foraging shorebirds and gulls at migratory stopover. *Journal of Coastal Research*: 23 (5):1159-1166.
- Bush, D. M., O. H. Pilkey, Jr., and W. J. Neal. 1996. *Living by the rules of the sea*. Durham, North Carolina: Duke University Press. 179 p.
- Bush, D. M., N. L. Longo, W. J. Neal, L. S. Esteves, O. H. Pilkey, D. F. Pilkey, and C. A. Webb. 2001. *Living on the edge of the Gulf: the west Florida and Alabama coast*. Durham, North Carolina: Duke University Press. 340 p.
- Bush, D. M., W. J. Neal, N. J. Longo, K. C. Lindeman, D. F. Pilkey, L. Slomp Esteves, J. D. Congleton, and O. H. Pilkey. 2004. *Living with Florida's Atlantic beaches: coastal hazards from Amelia Island to Key West*. Durham, North Carolina: Duke University Press. 338 p.
- Calvert, A. M., D. L. Amirault, F. Shaffer, R. Elliot, A. Hanson, J. McKnight, and P. D. Taylor. 2006. Population assessment of an endangered shorebird: the piping plover (*Charadrius melodus melodus*) in eastern Canada. *Avian Conservation and Ecology* 1(3):4 Available at <http://www.ace-eco.org/vol1/iss3/art4/>.
- Cathcart, T. and P. Melby. 2009. Landscape management and native plantings to preserve the beach between Biloxi and Pass Christian, Mississippi. Mississippi-Alabama Sea Grant Consortium Publication MASGP-08-024. 32 p. Available at <http://www.masgc.org/pdf/masgp/08-024.pdf>.
- Catlin, D. H., J. D. Fraser, M. Stantial, J. H. Felio, K. Gierdes, and S. Karpanty. 2011. Chandeleur piping plover survey, January 18-19, 2011. Operations report to USFWS. Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 3 pp.

- Chapman, B. R. 1984. Seasonal abundance and habitat-use patterns of coastal bird populations on Padre and Mustang Island barrier beaches (following the Ixtoc I Oil Spill). Report prepared for U.S. Fish and Wildlife Service under Contract No. 14-16-0009-80-062.
- Cialone, M. A. and D. K. Stauble. 1998. Historical findings on ebb shoal mining. *Journal of Coastal Research* 14(2):537-563.
- City of Folly Beach. 2011. Code of Ordinances: 2011 S-10 Supplement contains local legislation current through Ord. 24-10, passed 10-26-10. City of Folly Beach, South Carolina. Available at [http://www.amlegal.com/nxt/gateway.dll/South%20Carolina/follybeach/follybeachsouthcarolinacodeofordinances?f=templates\\$fn=altmain-nf.htm\\$3.0&global=hitdoc\\_g &hitdoc\\_g\\_dt=altmain-nf.htm](http://www.amlegal.com/nxt/gateway.dll/South%20Carolina/follybeach/follybeachsouthcarolinacodeofordinances?f=templates$fn=altmain-nf.htm$3.0&global=hitdoc_g &hitdoc_g_dt=altmain-nf.htm). Accessed August 2, 2011.
- Cleary, W. J. and D. M. Fitzgerald. 2003. Tidal inlet response to natural sedimentation processes and dredging-induced tidal prism changes: Mason Inlet, North Carolina. *Journal of Coastal Research* 19(4):1018-1025.
- Cleary, W. J. and T. Marden. 1999. Shifting shorelines: a pictorial atlas of North Carolina inlets. North Carolina Sea Grant Publication UNC-SG-99-4. 51 p.
- Climate Change Science Program [CCSP]. 2008. Weather and climate extremes in a changing climate. Regions of focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Department of Commerce, NOAA's National Climatic Data Center, Washington, D.C.
- CCSP. 2009. Coastal sensitivity to sea-level rise: a focus on the Mid-Atlantic region. A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. J.G. Titus, coordinating lead author. Environmental Protection Agency, Washington, D.C. 320 p.
- Cobb, R. 2009. The 2006 International Piping Plover Winter Census in Texas: central Texas. Pages 79-81 *in* Data from the 2006 International Piping Plover Census: U.S. Geological Survey Data Series 426.
- Cohen, J. 2009. Feasibility and utility of survival modeling for detecting differences in piping plover survival across their breeding and wintering range. Report to U.S. Fish and Wildlife Service, Sudbury, Massachusetts. 10 pp.
- Cohen, J. B., J. D. Fraser, and D. H. Catlin. 2006. Survival and site fidelity of piping plovers on Long Island, New York. *Journal of Field Ornithology* 77:409-417.
- Cohen, J. B., S. M. Karpanty, D. H. Catlin, J. D. Fraser, and R. A. Fischer. 2008. Winter ecology of piping plovers at Oregon Inlet, North Carolina. *Waterbirds* 31:472-479.
- Colosio, F., M. Abbiati, and L. Airoidi. 2007. Effects of beach nourishment on sediments and benthic assemblages. *Marine Pollution Bulletin* 54(2007):1197-1206.
- Committee on the Status of Endangered Wildlife in Canada [COSEWIC]. 2001. Canadian species at risk, May 2001. Committee on the Status of Endangered Wildlife Species in Canada. Ottawa, Ontario, Canada.

- Dabees, M. A. and N. C. Kraus. 2008. Cumulative effects of channel and ebb shoal dredging on inlet evolution in southwest Florida, USA. Proceedings of the 31<sup>st</sup> International Conference on Coastal Engineering 2008, WS:2303-2315.
- Defeo O. and A. McLachlan. 2011. Coupling between macrofauna community structure and beach type: a deconstructive metaanalysis. Marine Ecology Progress Series 433:29-41.
- Defeo, O., A. McLachlan, D. S. Schoeman, T. A. Schlacher, J. Dugan, A. Jones, M. Lastra, and F. Scapini. 2009. Threats to sandy beach ecosystems: a review. Estuarine, Coastal and Shelf Science 81:1-12.
- Department of Justice Canada. 2002. Annual statutes of Canada 2002, Chapter 29. Species at Risk Act, Schedule 1, Part 2.
- Dickerson K., K. J. Nelson, and C. Zeeman. 2011. Characterizing contaminant exposure of mountain plovers on wintering grounds in California and breeding grounds in Colorado, Wyoming, and Montana. USFWS, Region 6. Contaminants Report Number R6&R8/725C/11. 164 pp.
- Dinsmore, S. J., J. A. Collazo, and J. R. Walters. 1998. Seasonal numbers and distribution of shorebirds on North Carolina's Outer Banks. Wilson Bulletin 110:171-181.
- Donnelly, C., N. Kraus, and M. Larson. 2006. State of knowledge on measurement and modeling of coastal overwash. Journal of Coastal Research 22(4):965-991.
- Douglas, B. C., M. Kearney, and S. Leatherman. 2001. Sea-level rise: history and consequences. Academic Press, Inc., New York, New York.
- Drake, K. L. 1999a. Time allocation and roosting habitat in sympatrically wintering piping and snowy plovers. M. S. Thesis. Texas A&M University-Kingsville, Kingsville, Texas. 59pp.
- Drake, K. R. 1999b. Movements, habitat use, and survival of wintering piping plovers. M.S. Thesis. Texas A&M University-Kingsville, Kingsville, Texas. 82 pp.
- Drake, K. R., J. E. Thompson, K. L. Drake, and C. Zonick. 2001. Movements, habitat use and survival of non-breeding piping plovers. Condor 103:259-267.
- Dugan, J. E. and D. M. Hubbard. 2006. Ecological responses to coastal armoring on exposed sandy beaches. Shore and Beach 74(1):10-16.
- Dugan, J. E. and D. M. Hubbard. 2010. Loss of coastal strand habitat in southern California: The role of beach grooming. Estuaries and Coasts 33:67-77.
- Dugan, J. E., D. M. Hubbard, M. McCrary, and M. Pierson. 2003. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. Estuarine and Coastal Shelf Science 58:25-40.
- Dugan, J. E. and D. M. Hubbard. 2010. Loss of coastal strand habitat in southern California: the role of beach grooming. Estuaries and Coasts (2010) 33:67-77.

- Ecological Associates, Inc. 2009. Dune restoration project at Bathtub Beach Park on Hutchinson Island St. Lucie Inlet, Martin County, Florida: piping plover surveys, January - May 2009. Jensen Beach, Florida.
- Ecological Associates, Inc. 2011. Volusia County Habitat Conservation Plan, Draft 4. Jensen Beach, Florida. 280 pp.
- Elliott, L. F. and T. Teas. 1996. Effects of human disturbance on threatened wintering shorebirds. Final report to USFWS. 12 pp.
- Elliott-Smith, E. and S. M. Haig. 2004. Piping plover (*Charadrius melodus*), in The birds of North America online (A. Poole, ed). Ithaca: Cornell Lab of Ornithology. Available at <http://bna.birds.cornell.edu/bna/species/002/articles/introduction>, accessed August 2011.
- Elliott-Smith, E., S. M. Haig, and B. M. Powers. 2009. Data from the 2006 International Piping Plover Census: U.S. Geological Survey Data Series 426. 332 pp.
- Emanuel, K. 2005. Increasing destructiveness of tropical cyclones over the past 30 years. *Nature* 436(4):686-688.
- Environment Canada. 2006. Recovery strategy for the piping plover (*Charadrius melodus circumcinctus*) in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa.
- Environment Canada. 2007. Addendum to the final recovery strategy for the piping plover (*Charadrius melodus circumcinctus*) in Canada RE: identification of critical habitat. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa.
- Environment Canada. 2012. Recovery strategy for the piping plover (*Charadrius melodus melodus*) in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa.
- Environmental Protection Agency [EPA]. 2009. Coastal zones and sea level rise. Accessed on 29 January 2009 at <http://www.epa.gov/climatechange/effects/coastal/index/html>.
- Erickson, K. M., N. C. Kraus, and E. E. Carr. 2003. Circulation change and ebb shoal development following relocation of Mason Inlet, North Carolina. Proceedings Coastal Sediments '03, World Scientific Publishing Corp. and East Meets West Productions, Corpus Christi, Texas. 13 pp.
- Eubanks, T. 1992. The piping plover in Texas: winter survey guidelines. Draft report for Great Lakes/Northern Great Plains piping plover recovery team. 17 pp.
- Fish, M. R., I. M. Côté, J. A. Horrocks, B. Mulligan, A. R. Watkinson, and A. P. Jones. 2008. Construction setback regulations and sea-level rise: mitigating sea turtle nesting beach loss. *Ocean and Coastal Management* 51(2008):330-341.
- Florida Department of Environmental Protection. 2012. Florida Beaches Habitat Conservation Plan: goals, objectives, and implications for management of Florida's sandy beaches, a primer. Accessed March 13, 2012 at <http://www.flbeacheshcp.com/docs/FLBHCP%20Primer.pdf>. 12 pp.

- Florida Exotic Pest Plant Council. 2009. List of invasive plant species. Florida Exotic Pest Plant Council. *Wildland Weeds* 12(4):13-16. Available online at <http://www.fleppc.org/list/List-WW-F09-final.pdf>, accessed August 2, 2011.
- Florida State Parks. 2012. Pet Policy. Accessed April 10, 2012 at <http://www.floridastateparks.org/thingstoknow/petpolicy.cfm>
- Forgues, K. 2010. The effects of off-road vehicles on migrating shorebirds at a barrier island in Maryland and Virginia. M.S. Thesis. Trent University, Peterborough, Ontario, Canada.
- Forys, B. 2011. An evaluation of existing shorebird management techniques' success at locations in Pinellas County /unpublished Final Report, Eckerd College, St. Petersburg, Florida. September 30, 2011. 6 pp.
- Foster, C. R., A. F. Amos, and L. A. Fuiman. 2009. Trends in abundance of coastal birds and human activity on a Texas barrier island over three decades. *Estuaries and Coasts* 32:1079-1089.
- Fraser, J., B. Hopkins, S. Karpanty, D. Catlin, J. Cohen, J. Felio, J. Schmerfeld, A. Secord, and C. M. Kane. 2010. Natural resource damage assessment work plan for determining injury to the piping plover (*Charadrius melodus*) from the Deepwater Horizon (MC 252) Oil Spill bird study #7. Virginia Tech, U.S. Fish and Wildlife Service.
- Frink, L., C. D. Jenkins, Jr., L. Niles, K. Clark, and E. A. Miller. 1996. Anitra Spill: responding to oiled shorebirds. Tri-State Bird Rescue and Research, Inc. and New Jersey Division of Fish, Game and Wildlife.
- Fussell, J. O. 1990. Census of piping plovers wintering on the North Carolina Coast - 1989-1990. Unpublished report to the North Carolina Wildlife Resources Commission. 54 pp.
- Galbraith, H., R. Jones, R. Park, J. Clough, S. Herrod-Julius, B. Harrington, and G. Page. 2002. Global climate changes and sea level rise: potential loss of intertidal habitat for shorebirds. *Waterbirds* 25:173-183.
- Gibson, M., C. W. Nathan, A. K. Killingsworth, C. Shankles, E. Coleman, S. Bridge, H. Juedes, W. Bone, and R. Shiplett. 2009. Observations and implications of the 2007 amalgamation of Sand-Pelican Island to Dauphin Island, Alabama. Geological Society of America. Paper No. 20-10, Southeastern Section - 58<sup>th</sup> Annual Meeting 41(1):52.
- Gilbertson, M., T. Kubiak, J. Ludwig, and G. Fox. 1991. Great Lakes embryo mortality, edema, and deformities syndrome (GLEMEDS) in colonial fish-eating birds: similarity to chick-edema disease. *Journal of Toxicology and Environmental Health* 33:455-520.
- Gill, F. 1995. *Ornithology*, 2<sup>nd</sup> Edition. W.H. Freeman. New York, New York.
- Gill, J.A., K. Norris, P. M. Potts, T. G. Gunnarsson, P. W. Atkinson, and W. J. Sutherland. 2001. The buffer effect and large-scale population regulation in migratory birds. *Nature* 412:436-438.
- Goldin, M. R. 1993. Piping plover (*Charadrius melodus*) management, reproductive ecology, and chick behavior at Goosewing and Briggs Beaches, Little Compton, Rhode Island, 1993. The Nature Conservancy, Providence, Rhode Island.



- Goss-Custard, J. D., R. T. Clarke, S. E. A. le V. dit Durell, R. W. G. Caldw, and B. J. Ens. 1996. Population consequences of winter habitat loss in migratory shorebird. II. Model predictions. *Journal of Applied Ecology* 32:337-351.
- Government Accountability Office. 2007. Coastal Barrier Resources System: status of development that has occurred and financial assistance provided by federal agencies. GAO-07-356. 72 pp.
- Gratto-Trevor, C. L. 2010. Marked piping plovers from the Bahamas. Environment Canada. Available at [www.fws.gov/northeast/pipingplover/pdf/BahamasBandReporting2010.pdf](http://www.fws.gov/northeast/pipingplover/pdf/BahamasBandReporting2010.pdf) accessed August 1, 2011.
- Gratto-Trevor, C., D. Amirault-Langlais, D. Catlin, F. Cuthbert, J. Fraser, S. Maddock, E. Roche, and F. Shaffer. 2012. Connectivity in piping plovers: do breeding populations have distinct winter distributions? *Journal of Wildlife Management* 76:348-355.
- Greene, K. 2002. Beach nourishment: a review of the biological and physical impacts. Atlantic States Marine Fisheries Commission. ASMFC Habitat Management Series #7. 78 pp.
- Grinsted, A., J. C. Moore, and S. Jevrejeva. 2010. Reconstructing sea level from paleo and projected temperatures 200 to 2100 AD. *Climate Dynamics* 34:461-472.
- Gutierrez, B. T., N. G. Plant, and E. R. Thieler. 2011. A Bayesian network to predict coastal vulnerability to sea level rise. *Journal of Geophysical Research* 116 (F02009) doi: 10.1029/2010JF001891.
- Haig, S. M. 1992. Piping plover. In A. Poole, P. Stettenheim, and F. Gill (eds), *The birds of North America*, No. 2. Philadelphia: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union.
- Haig, S. M. and J. H. Plissner. 1992. 1991 international piping plover census. Report to U.S. Fish and Wildlife Service Region 3, Endangered Species Division, Ft. Snelling, Minnesota. 148 pp.
- Haig, S. M., C. Ferland, F. J. Cuthbert, J. Dingleline, J. P. Goosen, A. Hecht, and N. McPhillips. 2005. A complete species census and evidence for regional declines in piping plovers. *Journal of Wildlife Management* 69:160-173.
- Hall, M. J. and O. H. Pilkey. 1991. Effects of hard stabilization on dry beach width for New Jersey. *Journal of Coastal Research* 7(3):771-785.
- Harrington, B. R. 2008. Coastal inlets as strategic habitat for shorebirds in the southeastern United States. DOER Technical Notes Collection. ERDC TN-DOER-E25. Vicksburg, Mississippi: U.S. Army Engineer Research and Development Center. Accessed at <http://el.erdc.usace.army.mil/dots/doer>.
- Helmets, D. L. 1992. Shorebird management manual. Western Hemisphere Shorebird Reserve Network. Manomet, Massachusetts. 58 pp.
- Herrington, T. O. 2003. Manual for coastal hazard mitigation. New Jersey Sea Grant College Program, Publication NJSG-03-0511. 108 p. Available at [http://www.state.nj.us/dep/cmp/coastal\\_hazard\\_manual.pdf](http://www.state.nj.us/dep/cmp/coastal_hazard_manual.pdf).

- Hoffman, D. J., C. P. Rice, and T. J. Kubiak. 1996. PCBs and dioxins in birds. Ch. 7, pp.165-207 *in*: W.N. Beyer, G.H. Heinz, and A.W. Redmon-Norwood (eds) Environmental contaminants in wildlife: interpreting tissue concentrations. CRC Press, Inc., New York, New York.
- Hoopes, E. A. 1993. Relationships between human recreation and piping plover foraging ecology and chick survival. M.S. Thesis. University of Massachusetts. 106 pp.
- Hopkinson, C. S., A. E. Lugo, M. Alber, A. P. Covich, and S. J. Van Bloem. 2008. Forecasting effects of sea-level rise and windstorms on coastal and inland ecosystems. *Frontiers in Ecology and Environment* 6:255-263.
- Houston Audubon Society. 2012. Bolivar Flats Shorebird Sanctuary. Accessed March 6, 2012 at <http://www.houstonaudubon.org/default.aspx/MenuItemID/862/MenuGroup/Bolivar.htm>.
- Hubbard, D. M. and J. E. Dugan. 2003. Shorebird use of an exposed sandy beach in southern California. *Estuarine Coastal Shelf Science* 58: 41-54.
- Intergovernmental Panel on Climate Change [IPCC]. 2007. Summary for policymakers *in* S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds) Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, New York, USA.
- Jekyll Island Authority. 2011. Jekyll Island Conservation Plan. Jekyll Island, Georgia. 82 pp. Available at <http://www.jekyllisland.com/Conservation.aspx>. Accessed September 12, 2011.
- Jevrejeva, S., J. C. Moore, and A. Grinsted. 2010. How will sea level respond to changes in natural and anthropogenic forcings by 2100? *Geophysical Research Letters* 37: L07703.
- Johnson, C. M. and G. A. Baldassarre. 1988. Aspects of the wintering ecology of piping plovers in coastal Alabama. *Wilson Bulletin* 100: 214-233.
- Kalejta, B. 1992. Time budgets and predatory impact of waders at the Berg River estuary, South Africa. *Ardea* 80:327-342.
- Karpanty, S. 2012. Effects of sea-level rise on piping plover habitat along the U.S. Atlantic Coast. January 26, 2012 presentation, U.S. Fish and Wildlife Service, Region 5 Science Seminar Series 2012. Accessed August 1, 2012 at <http://www.fws.gov/northeast/science/seminars/january2012.html>.
- Kim, K., H. Yoo, and N. Kobayashi. 2011. Mitigation of beach erosion after coastal road construction. *Journal of Coastal Research* 27(4):645-651.
- Kindinger, M. E. 1981. Impacts of the Ixtoc I oil spill on the community structure of the intertidal and subtidal infauna along South Texas beaches. M.S. Thesis. Division of Biology, Corpus Christi State University, Corpus Christi, Texas, viii + 91 pp.
- Klein, R. J. T., R. J. Nicholls, S. Ragoonaden, M. Capobianco, J. Aston, and E. N. Buckley. 2001. Technological options for adaptation to climate change in coastal zones. *Journal of Coastal Research* 17(3):531-543.

- Kluft, J. M. and H. S. Ginsberg. 2009. The effect of off-road vehicles on barrier island invertebrates at Cape Cod and Fire Island National Seashores. Technical Report NPS/NER/NRTR--209/138. National Park Service, Boston, Massachusetts.
- Kraus, N. C. 2007. Coastal inlets of Texas, USA. Proceedings Coastal Sediments '07:1475-1488. ASCE Press, Reston, Virginia. Available at <http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA481728>.
- Kraus, N. C., G. A. Zarillo, and J. F. Tavoraro. 2003. Hypothetical relocation of Fire Island Inlet, New York. Pages 10-14 in Proceedings Coastal Sediments '03. World Scientific Publishing Corp. and East Meets West Productions, Corpus Christi, Texas.
- Lafferty, K. D. 2001a. Birds at a southern California beach: seasonality, habitat use and disturbance by human activity. Biodiversity and Conservation 10:1949-1962.
- Lafferty, K. D. 2001b. Disturbance to wintering western snowy plovers. Biological Conservation 101:315-325.
- Lafferty, K., D. Goodman, and C. Sandoval. 2006. Restoration of breeding by snowy plovers following protection from disturbance. Biodiversity and Conservation 15:2217-2230.
- Larson, M. A., M. R. Ryan, and R. K. Murphy. 2002. Population viability of piping plovers: effects of predator exclusion. Journal of Wildlife Management 66:361-371.
- LeDee, O. E. 2008. Canaries on the coastline: estimating survival and evaluating the relationship between nonbreeding shorebirds, coastal development, and beach management policy. Ph.D. Dissertation. University of Minnesota, Twin Cities. 73 pp.
- LeDee, O. E., F. J. Cuthbert, and P. V. Bolstad. 2008. A remote sensing analysis of coastal habitat composition for a threatened shorebird, the piping plover (*Charadrius melodus*). Journal of Coastal Research 24:719-726.
- LeDee, O. E., K. C. Nelson, and F. J. Cuthbert. 2010a. The challenge of threatened and endangered species management in coastal areas. Coastal Management 38:337-353.
- LeDee, O. E., T. W. Arnold, E. A. Roche, and F. J. Cuthbert. 2010b. Use of breeding and nonbreeding encounters to estimate survival and breeding-site fidelity of the piping plover at the Great Lakes. Condor 112:637-643.
- Lord, A., J. R. Waas, J. Innes, M. J. Whittingham. 2001. Effects of human approaches to nests of northern New Zealand dotterels. Biological Conservation 98:233-240.
- Lott, C. A. 2009. The distribution and abundance of piping plovers (*Charadrius melodus*) and snowy plovers (*Charadrius alexandrinus*) on the west coast of Florida relative to beach nourishment and dune restoration before and after the 2004-2005 hurricane seasons. U.S. Army Corps of Engineers, Dredging Operations and Environmental Research Program, Engineer Research and Development Center, Technical Report.

- Lott, C. A., P. A. Durkee, W. A. Gierhart, and P. P. Kelly. 2009a. Florida coastal engineering and bird conservation geographic information system (GIS) manual. Technical Report ERDC/EL TR-09-15. U.S. Army Corps of Engineers, Dredging Operations and Environmental Research Program, Engineer Research and Development Center.
- Lott, C. A., C. S. Ewell, Jr., and K. L. Volansky. 2009b. Habitat associations of shoreline-dependent birds in barrier island ecosystems during fall migration in Lee County, Florida. Prepared for U.S. Army Corps of Engineers, Engineer Research and Development Center, Technical Report. 103 pp.
- Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority. 1998. Coast 2050: toward a sustainable coastal Louisiana. Louisiana Department of Natural Resources. Baton Rouge, La. Available at <http://www.coast2050.gov/2050reports.htm>.
- Lovejoy, T. E. and L. Hannah (eds). 2005. Climate change and biodiversity. Yale University Press. 418pp.
- Mabee, T. J., J. H. Plissner, S. M. Haig, and J. P. Goossen. 2001. Winter distribution of North American plovers in the Laguna Madre regions of Tamaulipas Mexico and Texas, U.S.A. Wader Study Group Bulletin 94:39-43.
- Maddock, S. B. 2008. Wintering piping plover surveys 2006-2007, East Grand Terre, Louisiana to Boca Chica, Texas, December 20, 2006-January 10, 2007, final report. Unpublished report prepared for the Canadian Wildlife Service, Environment Canada, Edmonton, Alberta. iv + 66 pp.
- Maddock, S. 2010. Band identification skills for piping plovers. Accessed July 26, 2012 at [http://www.fws.gov/charleston/pdf/PIPL\\_Band\\_Identification\\_Training.pdf](http://www.fws.gov/charleston/pdf/PIPL_Band_Identification_Training.pdf).
- Maddock, S., M. Bimbi, and W. Golder. 2009. South Carolina shorebird project, draft 2006-2008 piping plover summary report. Audubon North Carolina and U.S. Fish and Wildlife Service, Charleston, South Carolina. 135 pp.
- Mason, C. and R. M. Sorensen. 1971. Properties and stability of a Texas barrier beach inlet. Texas A&M University Sea Grant Program Publication No. TAMU-SG-71-217. 177 p. Available at <http://nsgl.gso.uri.edu/tamu/tamut71009.pdf>.
- Masterson, R. P., Jr., J. L. Machemehl, and V. V. Cavaroc. 1973. Sediment movement in Tubbs Inlet, North Carolina. University of North Carolina Sea Grant Report No. 73-2. 117 p. Available at <http://nsgl.gso.uri.edu/ncu/ncut73013.pdf>.
- Mawdsley, J. R., R. O'Malley, and D. S. Ojima. 2009. A review of climate change adaptation strategies for wildlife management and biodiversity conservation. Conservation Biology 23(5):1080-1089.
- McGowan, C. P. and M. R. Ryan. 2009. A quantitative framework to evaluate incidental take and endangered species population viability. Biological Conservation 142(12) 3128-3136.
- McLachlan, A. 1990. Dissipative beaches and macrofaunal communities on exposed intertidal sands. Journal of Coastal Research 6: 57-71.
- McLachlan, A. and A. C. Brown. 2006. The ecology of sandy shores. Academic Press, Burlington, Massachusetts. 373 pp.

- Melvin, S. M. and J. P. Gibbs. 1996. Viability analysis for the Atlantic Coast population of piping plovers. Pages 175-186 in *Piping plover (Charadrius melodus)*, Atlantic Coast population, revised recovery plan. U.S. Fish and Wildlife Service, Hadley, Massachusetts.
- Mercier, F. and R. McNeil. 1994. Seasonal variations in intertidal density of invertebrate prey in a tropical lagoon and effects of shorebird predation. *Canadian Journal of Zoology* 72: 1755–1763.
- Mierzykowski, S. E. 2009. Summary of existing information pertinent to environmental contaminants and oil spills on breeding Atlantic Coast piping plovers. USFWS. Spec. Proj. Rep. FY09-MEFO-7-EC. Maine Field Office. Old Town, Maine.
- Mierzykowski, S. E. 2010. Environmental contaminants in two composite samples of piping plover eggs from Delaware. USFWS. Special Project Report FY10-MEFO-2-EC. Maine Field Office. Orono, Maine.
- Mierzykowski, S. E. 2012. Environmental contaminants in piping plover eggs from Rachel Carson National Wildlife Refuge and Monomoy National Wildlife Refuge. USFWS. Special Project Report FY12-MEFO-1-EC. Maine Field Office. Orono, Maine.
- Miller, M. P., S. M. Haig, C. L. Gratto-Trevor, and T. D. Mullins. 2010. Subspecies status and population genetic structure in piping plover (*Charadrius melodus*). *Auk* 127:57-71.
- Morrier, A. and R. McNeil. 1991. Time-activity budget of Wilson's and semipalmated plovers in a tropical environment. *Wilson Bulletin* 103:598-620.
- Morris, F. W., IV, R. Walton, and B. A. Christensen. 1978. Hydrodynamic factors involved in Finger Canal and Borrow Lake Flushing in Florida's coastal zone. Volume I. Florida Sea Grant Publication FLSGP-T-78-003. Gainesville, Florida. 765 pp.
- Morrison, R. I. G. and K. A. Hobson. 2004. Use of body stores in shorebirds after arrival on high-arctic breeding grounds. *Auk* 121:333-344.
- Morton, R. A. 2008. Historical changes in the Mississippi-Alabama barrier-island chain and the roles of extreme storms, sea level, and human activities. *Journal of Coastal Research* 24(6):1587-1600.
- Morton, R., G. Tiling, and N. Ferina. 2003. Causes of hot-spot wetland loss in the Mississippi delta plain. *Environmental Geosciences* 10:71-80.
- National Park Service [NPS]. 2004. Abundance and distribution of non-nesting piping plovers (*Charadrius melodus*) at Cape Lookout National Seashore, North Carolina, 2000-2003. Harkers Island, North Carolina. 14 pp.
- NPS. 2007. Cape Hatteras National Seashore 2007 annual piping plover (*Charadrius melodus*) report. Cape Hatteras National Seashore, Manteo, North Carolina.
- NPS. 2010a. National Park Service Climate Change Response Strategy. National Park Service Climate Change Response Program, Fort Collins, Colorado. 36 p. Available at [http://www.nps.gov/climatechange/docs/NPS\\_CCRS.pdf](http://www.nps.gov/climatechange/docs/NPS_CCRS.pdf)

- NPS. 2010b. Piping plover (*Charadrius melodus*) monitoring at Cape Lookout National Seashore, 2010 summary report. Harkers Island, North Carolina. 27 pp.
- NPS. 2012. Gulf Islands National Seashore, plan your visit, Pets. Accessed March 27, 2012 at <http://www.nps.gov/guis/planyourvisit/pets.htm>.
- Neal, W. J., O. H. Pilkey, J. T. Kelley. 2007. Atlantic Coast beaches: a guide to ripples, dunes, and other natural features of the seashore. Mountain Press Publishing Company, Missoula, Montana. 250 pp.
- Nelson, D. A., K. Mauck, and J. Fletemeyer. 1987. Physical effects of beach nourishment on sea turtle nesting, Delray Beach, Florida. Technical Report EL-87-15. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi. 56 pp.
- New York Times. 2007. Newspaper article on cat predation in Texas dated December 1, 2007.
- Newstead, D. 2010. "Project 1101: Protecting important Texas shorebird habitats - using piping plovers (*Charadrius melodus*) as an indicator species" in Coastal Bend Bays and Estuaries Program FY 2011 Comprehensive Annual Work Plan. Corpus Christi, Texas. Available online at <http://www.cbbep.org/graphics/FY11CompWorkplan.pdf>
- Nicholls, J. L. 1989. Distribution and other ecological aspects of piping plovers (*Charadrius melodus*) wintering along the Atlantic and Gulf Coasts. M. S. Thesis. Auburn University, Auburn, Alabama. 150 pp.
- Nicholls, J. L. and G. A. Baldassarre. 1990a. Winter distribution of piping plovers along the Atlantic and Gulf Coasts of the United States. *Wilson Bulletin* 102:400-412.
- Nicholls, J. L. and G. A. Baldassarre. 1990b. Habitat selection and interspecific associations of piping plovers along the Atlantic and Gulf Coasts of the United States. *Wilson Bulletin* 102:581-590.
- Noel, B. L. and C. R. Chandler. 2005. Report on migrating and wintering piping plover activity on Little St. Simons Island, Georgia in 2003-2004 and 2004-2005. Report to U.S. Fish and Wildlife Service, Panama City, Florida. 38 pp.
- Noel, B. L. and C. R. Chandler. 2008. Spatial distribution and site fidelity of non-breeding piping plovers on the Georgia coast. *Waterbirds* 31:241-251.
- Noel, B. L., C. R. Chandler, and B. Winn. 2007. Seasonal abundance of nonbreeding piping plovers on a Georgia barrier island. *Journal of Field Ornithology* 78:420-427.
- Nordstrom, K. F. 2000. Beaches and dunes on developed coasts. Cambridge University Press, Cambridge, Massachusetts. 338 pp.
- Nudds, R. L. and D. M. Bryant. 2000. The energetic cost of short flight in birds. *Journal of Experimental Biology* 203:1561-1572.
- Otvos, E. G. 2006. Discussion of Froede, C.R., Jr., 2006. The impact that Hurricane Ivan (September 16, 2004) made across Dauphin Island, Alabama. *Journal of Coastal Research*, 22(2), 562-573. *Journal of Coastal Research* 22(6):1585-1588.

- Otvos, E. G. and G. A. Carter. 2008. Hurricane degradation – barrier development cycles, northeastern Gulf of Mexico: Landform evolution and island chain history. *Journal of Coastal Research* 24(2):463-478.
- Palmer, R. S. 1967. Piping plover. In Stout, G.D. (ed), *The shorebirds of North America*. Viking Press, New York. 270 pp.
- Penland, S. and K. Ramsey. 1990. Relative sea level rise in Louisiana and the Gulf of Mexico: 1908-1988. *Journal of Coastal Research* 6(2):323-342.
- Peterson, C. H. and M. J. Bishop. 2005. Assessing the environmental impacts of beach nourishment. *Bioscience* 55(10):887-896.
- Peterson, C. H., D. H. M. Hickerson, and G. G. Johnson. 2000. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of the sandy beach. *Journal of Coastal Research* 16(2):368-378.
- Peterson, C. H., M. J. Bishop, G. A. Johnson, L. M. D'Anna, and L. M. Manning. 2006. Exploiting beach filling as an unaffordable experiment: benthic intertidal impacts propagating upwards to shorebirds. *Journal of Experimental Marine Biology and Ecology* 338:205-221.
- Pfeffer, W. T., J. T. Harper, and S. O'Neel. 2008. Kinematic constraints on glacier contributions to 21<sup>st</sup> century sea level rise. *Science* 321:1340–1343.
- Pfister, C., B. A. Harrington, and M. Lavine. 1992. The impact of human disturbance on shorebirds at a migration staging area. *Biological Conservation* 60:115-126.
- Pilkey, O. H. and K. C. Pilkey. 2011. *Global climate change: a primer*. Duke University Press, Durham, North Carolina. 142 pp.
- Pilkey, O. H. and H. L. Wright III. 1988. Seawalls versus beaches. *Journal of Coastal Research* SI (4)41-64.
- Pilkey, O. H. and R. Young. 2009. *The rising sea*. Island Press, Washington. 203 pp.
- Pinellas County. 2012. Pinellas County, Florida, Parks & Preserves: Fort De Soto Park. Pinellas County, Florida. Bird Checklist and Park Map. Available at [http://www.pinellascounty.org/park/05\\_ft\\_desoto.htm](http://www.pinellascounty.org/park/05_ft_desoto.htm). Accessed April 1, 2012.
- Pinkston, J. 2004. Observations of wintering piping plovers using Gulf of Mexico barrier beaches along the Central Texas coast. Year One research summary report to USFWS Corpus Christi, Texas, Field Office. July 2004. One page + maps and tables.
- Pittman, C. 2001. Mosquito spray deadly to birds. *St. Petersburg Times* online Tampa Bay January 28, 2001. Accessed July 2, 2012, at [http://www.sptimes.com/News/012801/news\\_pf/TampaBay/Mosquito\\_spray\\_deadly.shtml](http://www.sptimes.com/News/012801/news_pf/TampaBay/Mosquito_spray_deadly.shtml).
- Plissner, J. H. and S. M. Haig. 2000. Viability of piping plover *Charadrius melodus* metapopulations. *Biological Conservation* 92:163-173.

- Program for the Study of Developed Shorelines [PSDS]. 2011. The U.S. beach nourishment experience including New England, east coast barrier islands, Pacific Coast, and Gulf of Mexico shorelines. Online database at <http://www.wcu.edu/1038.asp>, accessed August 28, 2011.
- Rahmstorf, S. 2007. A semi-empirical approach to projecting future sea-level rise. *Science* 315:368–370.
- Rahmstorf, S., A. Cazenave, J. U. Church, J. E. Hansen, R. F. Keeling, D. E. Parker, and R. C. J. Somerville. 2007. Recent climate observations compared to projections. *Science* 316:709.
- Rakocinski, C. F., R. W. Heard, S. E. LeCroy, J. A. McLelland, and T. Simons. 1996. Responses by macrobenthic assemblages to extensive beach restoration at Perdido Key, Florida, USA. *Journal of Coastal Research* 12(1):326-353.
- Rand, G. M. and S. R. Petrocelli. 1985. *Fundamentals of aquatic toxicology*. Hemisphere Publishing Corporation, Washington, D.C.
- Rattner, B. A. and B. K. Ackerson. 2008. Potential environmental contaminant risks to avian species at important bird areas in the northeastern United States. *Integrated Environmental Assessment and Management* 4(3):344-357.
- Rice, T. M. 2009. Best management practices for shoreline stabilization to avoid and minimize adverse environmental impacts. Prepared for USFWS, Panama City Ecological Services Field Office by Terwilliger Consulting, Inc., Locustville, Virginia.
- Rice, T. M. 2012a. Inventory of habitat modifications to tidal inlets in the continental U.S. coastal migration and wintering range of the piping plover (*Charadrius melodus*). Appendix 1b 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.
- Rice, T. M. 2012b. 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.
- Rich, T. D., C. J. Beardmore, H. Berlanga, P. J. Blancher, M. S. W. Bradstreet, G. S. Butcher, D. W. Demarest, E. H. Dunn, W. C. Hunter, E. E. Iñigo-Elias, J. A. Kennedy, A. M. Martell, A. O. Panjabi, D. N. Pashley, K. V. Rosenberg, C. M. Rustay, J. S. Wendt, and T. C. Will. 2004. *Partners in Flight North American landbird conservation plan*. Cornell Lab of Ornithology. Ithaca, New York. Accessed July 26, 2012 at [http://www.partnersinflight.org/cont\\_plan/](http://www.partnersinflight.org/cont_plan/).
- Roche, E. A., J. B. Cohen, D. H. Catlin, D. L. Amirault-Langlais, F. J. Cuthbert, C. L. Gratto-Trevor, J. Felio, and J. D. Fraser. 2010. Range-wide piping plover survival: correlated patterns and temporal declines. *Journal of Wildlife Management* 74:1784-1791.
- Ryan, M. R., B. G. Root, and P. M. Mayer. 1993. Status of piping plover in the Great Plains of North America: a demographic simulation model. *Conservation Biology* 7:581-585.



- Sallenger, A. H. Jr. 2010. An overview of extreme storms in the U.S. Gulf of Mexico and their coastal impacts. Search and Discovery Article #110143(2010), American Association of Petroleum Geologists (AAPG) / Datapages, Inc., [www.searchanddiscovery.com](http://www.searchanddiscovery.com), accessed August 27, 2011.
- Sallenger, A. H., Jr., C. W. Wright, P. Howd, K. Doran, and K. Guy. 2009. Chapter B. extreme coastal changes on the Chandeleur Islands, Louisiana, during and after Hurricane Katrina, in Lavoie, D., (ed) Sand resources, regional geology, and coastal processes of the Chandeleur Islands coastal system—an evaluation of the Breton National Wildlife Refuge: U.S. Geological Survey Scientific Investigations Report 2009–5252, p. 27–36. Available online at <http://pubs.usgs.gov/sir/2009/5252/>. Accessed February 13, 2012.
- Sax, D. F. and S. D. Gaines. 2008. Species invasions and extinction: the future of native biodiversity on islands. *Proceedings of the National Academy of Sciences USA* 105 (Supplement 1):11490-11497.
- Scavia, D., J. C. Field, D. F. Boesch, R. W. Buddemeier, V. Burkett, D. R. Cayan, M. Fogarty, M. A. Harwell, R. W. Howarth, C. Mason, D. J. Reed, T. C. Royer, A. H. Sallenger, and J. G. Titus. 2002. Climate change impacts on U.S. coastal and marine ecosystems. *Estuaries* 25:149-164.
- Schlacher, T. A. and L. Thompson. 2012. Beach recreation impacts benthic invertebrates on ocean-exposed sandy shores. *Biological Conservation* 147:123-132.
- Schlacher, T., D. Richardson, and I. McLean. 2008a. Impacts of off-road vehicles (ORVs) on macrobenthic assemblages on sandy beaches. *Environmental Management* 41:878-892.
- Schlacher, T., L. Thompson, and S. Walker. 2008b. Mortalities caused by off-road vehicles (ORVs) to a key member of sandy beach assemblages, the surf clam (*Donax deltoids*). *Hydrobiologia* 610:345-350.
- Schneider, S. H., and T. L. Root (eds). 2002. *Wildlife responses to climate change: North American case studies*. Island Press, Washington, D.C. 437 pp.
- Schoeman, D. S., A. McLachlan, and J. E. Dugan. 2000. Lessons from a disturbance experiment in the intertidal zone of an exposed sandy beach. *Estuarine, Coastal and Shelf Science* 50: 869-884.
- Smith, B. S. 2007. 2006-2007 nonbreeding shorebird survey, Franklin and Wakulla counties, Florida. Final report to the U.S. Fish and Wildlife Service in fulfillment of Grant # 40181-7-J008. Apalachicola Riverkeeper, Apalachicola, Florida. 32 pp.
- Smith, C. G., S. J. Culver, S. R. Riggs, D. Ames, D. R. Corbett, and D. Mallinson. 2008. Geospatial analysis of barrier island width of two segments of the Outer Banks, North Carolina, USA: Anthropogenic curtailment of natural self-sustaining processes. *Journal of Coastal Research* 24(1):70-83.
- South Carolina Department of Health and Environmental Control [SC DHEC]. 2010. Adapting to shoreline change: a foundation for improved management and planning in South Carolina. Final Report of the Shoreline Change Advisory Committee. Available online at [http://www.scdhec.gov/environment/ocrm/shoreline\\_change.htm](http://www.scdhec.gov/environment/ocrm/shoreline_change.htm)
- South Carolina Department of Natural Resources [SCDNR]. 2011. Kiawah Island East End Erosion and Beach Restoration Project: survey of changes in potential macroinvertebrate prey communities in piping lover foraging habitats. Final Report. 74 pp.

- Stibolt, G. 2011. Australian pine: one of Florida's least wanted. Florida Native Plant Society Blog, dated February 13, 211. Accessed July 18, 2012 at <http://fnpsblog.blogspot.com/2011/02/australian-pine-one-of-floridas-least.html>.
- Stillman, R. A. and J. D. Goss-Custard. 2010. Individual-based ecology of coastal birds. *Biological Reviews* 85:413-434.
- Stockdon, H. F., K. S. Doran, and K. A. Serafin. 2010. Coastal change on Gulf Islands National Seashore during Hurricane Gustav: West Ship, East Ship, Horn, and Petit Bois Islands. U.S. Geological Survey Open-File Report 2010-1090. 14 pp.
- Stolley, D. 2010. The climate change vulnerability assessment for shorebird habitat (CC-VASH). Western Hemisphere Shorebird Reserve Network. Available at <http://www.whsrn.org/tools/climate-change-tool>
- Stucker, J. H., F. J. Cuthbert, B. Winn, B. L. Noel, S. B. Maddock, P. R. Leary, J. Cordes, and L. C. Wemmer. 2010. Distribution of non-breeding Great Lakes piping plovers (*Charadrius melodus*) along Atlantic and Gulf of Mexico coastlines: ten years of band sightings. *Waterbirds*: 33:22-32.
- Tarr, N. M. 2008. Fall migration and vehicle disturbance of shorebirds at South Core Banks, North Carolina. M.S. Thesis. North Carolina State University, Raleigh, North Carolina.
- Tarr, J. G. and P. W. Tarr. 1987. Seasonal abundance and the distribution of coastal birds on the northern Skeleton Coast, South West Africa/Nimibia. *Madoqua* 15, 63-72.
- Thomas, K., R. G. Kvitek, and C. Bretz. 2003. Effects of human activity on the foraging behavior of sanderlings (*Calidris alba*). *Biological Conservation* 109:67-71.
- Thomas, R. C., K. B. Brown, and N. C. Kraus. 2011. Inlet stabilization: a case study at mouth of Colorado River, Texas. *Proceedings of Coastal Sediments 2011*(1):533-545. Miami, Florida..
- Thrush, S. F., R. B. Whitlatch, R. D. Pridmore, J. E. Hewitt, V. J. Cummings, and M. R. Wilkinson. 1996. Scale-dependent recolonization: the role of sediment stability in a dynamic sandflat habitat. *Ecology* 77: 2472–2487.
- Titus, J.G. 2011. Rolling easements. U.S. Environmental Protection Agency, Climate Ready Estuaries Program. Available at [www.epa.gov/cre/downloads/rollingeasementsprimer.pdf](http://www.epa.gov/cre/downloads/rollingeasementsprimer.pdf).
- Titus, J. G. and C. Richman. 2001. Maps of lands vulnerable to sea level rise: modeled elevations along the U.S. Atlantic and Gulf coasts. *Climatic Research* 18:205-228.
- Titus, J. G., D. E. Hudgens, D. L. Trescott, M. Craghan, W. H. Nuckols, C. H. Hershner, J. M. Kassakian, C. J. Linn, P. G. Merritt, T. M. McCue, J. F. O'Connell, J. Tanski, and J. Wang. 2009. State and local governments plan for development of most land vulnerable to rising sea level along the U.S. Atlantic coast. *Environmental Research Letters* 4 (044008) doi: 10.1088/1748-9326/4/4/044008.
- Trembanis, A. C., H. R. Valverde, and O. H. Pilkey, Jr. 1998. Comparison of beach nourishment along the U.S. Atlantic, Great Lakes, Gulf of Mexico, and New England shorelines. *Journal of Coastal Research* SI#26:246-251.

- Tremblay, T. A., J. S. Vincent, and T. R. Calnan. 2008. Status and trends of inland wetland and aquatic habitats in the Corpus Christi area. Final report under CBBEP Contract No. 0722 submitted to Coastal Bend Bays and Estuaries Program, Texas General Land Office, and National Oceanic and Atmospheric Administration.
- Truscott, A. M., C. Soulsby, S. C. F. Palmer, L. Newell, and P. E. Hulme. 2006. The dispersal characteristics of the invasive plant *Mimulus guttatus* and the ecological significance of increased occurrence of high-flow events. *Journal of Ecology* 94:1080–1091.
- Tsipoura, N. and J. Burger. 1999. Shorebird diet during spring migration stopover on Delaware Bay. *Condor* 101: 635-644.
- Tunnell, J. W., B. R. Chapman, M. E. Kindinger, and Q. R. Dokken. 1982. Environmental impact of Ixtoc I oil spill on south Texas sandy beaches: infauna and shorebirds. Simposio Internacional Ixtoc I, Mexico City. 2-5 June 1982. Available at <http://www.hartheresearchinstitute.org>.
- United Nations Environment Program [UNEP]. 2006. Migratory species and climate change: impacts of a changing environment on wild animals. United Nations Environment Program/Convention on Migratory Species Secretariat. Bonn, Germany. 68pp.
- U.S. Army Corps of Engineers [USACE]. 1992. Inlets along the Texas Gulf coast. Planning Assistance to States Program, Section 22 Report. U.S. Army Engineer District, Galveston, Southwestern Division. 56 p. Available at [http://cirp.usace.army.mil/pubs/archive/Inlets Along TX Gulf Coast.pdf](http://cirp.usace.army.mil/pubs/archive/Inlets_Alone_TX_Gulf_Coast.pdf).
- USACE. 2004. Bogue Inlet Channel Erosion Response Project, final environmental impact statement. Prepared for The Town of Emerald Isle by Coastal Planning & Engineering, Inc. Wilmington District, U.S. Army Corps of Engineers, Wilmington, North Carolina. Various paginations. Available at <http://www.saw.usace.army.mil/wetlands/Projects/BogueInlet/>.
- USACE. 2008. Beach fill design. Chapter 4 in Coastal Engineering Manual 1110-2-1100, Part V (Change 2). U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes). Available at <http://chl.ercd.usace.army.mil/chl.aspx?p=s&a=ARTICLES;101>.
- USACE. 2010. August 9, 2010, Biological assessment of the Louisiana coastal area – Terrebonne Basin Barrier Shoreline Restoration Project. U.S. Army Corps of Engineers, New Orleans District. 47 pp.
- USACE. 2011. Public notice, permit application SWG-2011-00511, issued 15 June 2011. Galveston District, Texas. 23 pp.
- U.S. Department of Agriculture [USDA]. Plant Profile: *Carex Kobomugi*. Available online at <http://plants.usda.gov/java/profile?symbol=CAKO2>. Accessed July 30, 2011.
- U.S. Fish and Wildlife Service [USFWS]. 1985. Determination of endangered and threatened status for the piping plover. *Federal Register* 50:50726-50734.
- USFWS. 1988a. Atlantic Coast piping plover recovery plan. Newton Corner, Massachusetts.
- USFWS. 1988b. Recovery plan for piping plovers (*Charadrius melodus*) of the Great Lakes and Northern Great Plains. U.S. Fish and Wildlife Service, South Dakota, and Twin Cities, Minnesota.

- USFWS. 1996. Piping plover (*Charadrius melodus*), Atlantic Coast population, revised recovery plan. Hadley, Massachusetts.
- USFWS. 2001a. Final determination of critical habitat for the Great Lakes breeding population of the piping plover. Federal Register 66:22938-22969.
- USFWS. 2001b. Final determination of critical habitat for wintering piping plovers. Federal Register 66:36037-36086.
- USFWS. 2002a. Final designation of critical habitat for the Northern Great Plains breeding population of the piping plover. Federal Register. 67:57637-57717.
- USFWS. 2002b. Southeastern coastal plains – Caribbean region report, U.S. Shorebird Conservation Plan. U.S. Fish and Wildlife Service, Atlanta, Georgia.
- USFWS. 2003. Recovery plan for the Great Lakes piping plover (*Charadrius melodus*). U.S. Fish and Wildlife Service, Fort Snelling, Minnesota.
- USFWS. 2006. Biological opinion on U.S. Army Corps of Engineers permit P/N 2005-1W-310P, Town of Kiawah Island beach renourishment and inlet relocation. Charleston Field Office, South Carolina.
- USFWS. 2007a. Informal consultation (draft BO) with Gulf Islands National Seashore. FWS Log No. 4-P-07-046, Reconstruction of J. Earle Bowden Way, Escambia County, Florida (May 16, 2007). Panama City Field Office, Florida.
- USFWS. 2007b. Biological opinion on U.S. Army Corps of Engineers permit SAJ-2006-4471 (IP-DEB) and FWS Log No. 4-P-07-056, St. Joseph Peninsula Beach Restoration, Gulf County, Florida (May 17, 2007). Panama City Field Office, Florida.
- USFWS. 2007c. Biological opinion on U.S. Army Corps of Engineers permit SAJ-2000-542 (IP-MBH) and FWS Log No. 4-P-06-250; 2007-F-0241, Naval Air Station Pensacola Navigation Channel dredging, Escambia County, Florida (October 31, 2007). Panama City Field Office, Florida.
- USFWS. 2008a. Biological opinion to Eglin Air Force Base, FWS Log No. 2008-F-0139, Beach and Dune Restoration, Santa Rosa Island, Okaloosa and Santa Rosa Counties, Florida (June 3, 2008). Panama City Field Office, Florida.
- USFWS. 2008b. Biological opinion to Federal Emergency Management Agency, FWS Log No. 2007-F-0430), Statewide along Florida's coastline, FEMA emergency berm repair and construction (April 3, 2008). Jacksonville, Vero Beach, and Panama City Field Offices, Florida.
- USFWS. 2008c. Biological opinion on U.S. Army Corps of Engineers permit SAJ-2007-764 (IP-MBH) and FWS Log No. 2008-F-0059, Perdido Key Beach Nourishment, Escambia County, Florida (June 9, 2008). Panama City Field Office, Florida.
- USFWS. 2008d. Biological opinion on U.S. Army Corps of Engineers permit SAJ-2007-5152 (IP-DEB) and FWS Log No. 2008-F-0060, Walton County Phase 2 Beach Nourishment, Walton County, Florida (October 2, 2008). Panama City Field Office, Florida.

- USFWS. 2008e. Biological and conference opinion on U.S. Corps of Engineers permit 24192, City of Corpus Christi (City) beach maintenance activities, Neuces County, Texas. Corpus Christi Field Office, Texas.
- USFWS. 2008f. Draft environmental assessment for the designation of revised critical habitat for the wintering population of piping plover in Texas. USFWS, Region 2, dated 4 December, 2008. 105 pp.
- USFWS. 2008g. Revised designation of critical habitat for the wintering population of the piping plover (*Charadrius melodus*) in North Carolina. Federal Register 73:62816-62841.
- USFWS. 2009a. Biological opinion on U.S. Army Corps of Engineers permit FP08-EP01-02 and FWS Log No. 2008-F-0295, East Pass Destin Navigation Project, Okaloosa County, Florida (April 21, 2009). Panama City Field Office, Florida.
- USFWS. 2009b. Biological opinion on U.S. Army Corps of Engineers permit SAJ-1995-7482 (IP-MJD) and FWS Log No. 2009-FA-0132, Matanzas Pass Reopening, Lee County, Florida (August 5, 2009). Jacksonville Field Office, Florida.
- USFWS. 2009c. Biological and conference opinion on U.S. Army Corps of Engineers permit SWG-2007-01847, City of Port Aransas (City) beach maintenance activities, Neuces County, Texas. Corpus Christi Field Office, Texas.
- USFWS. 2009d. Piping plover (*Charadrius melodus*) 5-year review: summary and evaluation. Northeast Region, Hadley, Massachusetts.
- USFWS. 2009e. Revised designation of critical habitat for the wintering population of the piping plover (*Charadrius melodus*) in Texas. Federal Register 74:23476-23524.
- USFWS. 2010a. Biological opinion on Louisiana Coastal Area Terrebonne Basin Barrier Shoreline Restoration Project and FWS Log 43440-2010-F-2769, Terrebonne Parish, Louisiana. Lafayette Field Office, Louisiana.
- USFWS. 2010b. Biological opinion on U.S. Army Corps of Engineers FWS Log No. 2010-F-0014, Town of Hilton Head Port Royal Sound Shoreline Restoration and Stabilization, Beaufort County, South Carolina. Charleston Field Office, South Carolina.
- USFWS. 2010c. Laguna Atascosa National Wildlife Refuge DRAFT Comprehensive Conservation Plan Laguna Atascosa National Wildlife Refuge.
- USFWS. 2010d. Rising to the urgent challenge: strategic plan for responding to accelerating climate change. Washington, D.C. 36 p. Available at <http://www.fws.gov/home/climatechange/pdf/CCStrategicPlan.pdf>.
- USFWS. 2010e. Biological opinion on U.S. Army Corps of Engineers permit for City of Bay St. Louis Recreational Harbor Project, FWS Log No. 43910-2010-F-0743 (October 19, 2010). Mississippi Field Office, Jackson, Mississippi.

- USFWS. 2010f. Adoption of conference opinion on wintering piping plover critical habitat as the biological opinion and project modifications on the Ocean Isle Beach portion of the Brunswick County Beaches Erosion Control and Hurricane Wave Protection Project (December 29, 2010). Raleigh Field Office, North Carolina.
- USFWS. 2011a. Florida Keys National Wildlife Refuges Complex Integrated Predator Management Plan: draft environmental assessment. Big Pine Key, Florida. 44pp.
- USFWS. 2011b. Great Plains wind energy environmental impact statement. Project fact sheet, volume 1, Summer 2011. 2 pp.
- USFWS. 2012a. Biological opinion on U.S. Army Corps of Engineers FWS Log No. 2011-F-0363R, Captain Sams Inlet Relocation Project, Charleston County, South Carolina. Charleston Field Office, South Carolina.
- USFWS. 2012b. Non-breeding piping plover conservation workshop proceedings, held Fernandina Beach, Florida, December 7-9, 2010. Compiled by USFWS South Carolina Field Office, January 2012. 32 pp.
- U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, and the Association of Fish and Wildlife Agencies. 2012. National fish, wildlife, and plants climate adaptation strategy. Available online at <http://www.wildlifeadaptationstrategy.gov/index.php>.
- U.S. Government. 2010. Joint Information Center news releases dated 28 July 2010, 2 August 2010, and 17 September 2010. Available at <http://www.restorethegulf.gov/release>.
- Verkuil Y., A. Dekinga, A. Koolhaas, J. van der Winden, T. van der Have, and I.I. Chernichko. 2006. Migrating broad-billed sandpipers achieve high fuelling rates by taking a multi-course meal. *Wader Study Group Bulletin* 110:15–20.
- Vermeer, M. and S. Rahmstorf. 2009. Global sea level linked to global temperature. *Proceedings of the Nation Academy of Sciences (PNAS)* 106(51):21527-21532. Available at <http://www.pnas.org/content/early/2009/12/04/0907765106.full.pdf>.
- Wamsley, T. V. and N. C. Kraus. 2005. Coastal barrier island breaching, part 2: mechanical breaching and breach closure. U.S. Army Corps of Engineers Technical Note ERDC/CHL CHETN-IV-65. 21p.
- Webster, P., G. Holland, J. Curry, and H. Chang. 2005. Changes in tropical cyclone number, duration, and intensity in a warming environment. *Science* (309):1844-1846.
- Wemmer, L. C., U. Ozesmi, and F. J. Cuthbert. 2001. A habitat-based population model for the Great Lakes population of the piping plover (*Charadrius melodus*). *Biological Conservation* 99:169-181.
- Westbrooks, R. G. and J. Madsen. 2006. Federal regulatory weed risk assessment beach vitex (*Vitex rotundifolia* L.f.) assessment summary. USGS Biological Research Division, Whiteville, North Carolina, and Mississippi State University, GeoResources Institute. 5pp.
- Wheeler, N. R. 1979. Effects of off-road vehicles on the infauna of Hatches Harbor, Cape Cod National Seashore. Unpublished report from the Environmental Institute, University of Massachusetts, Amherst, Massachusetts.

- Wilkinson, P. M. and M. Spinks. 1994. Winter distribution and habitat utilization of piping plovers in South Carolina. *Chat* 58: 33-37.
- Williams, T. 2001. Out of control. *Audubon Magazine* October 2001. Accessed on 26 February 2009, at <http://www.audubonmagazine.org/incite/incite0109.html>.
- Williams, S. J. and B. Gutierrez. 2009. Sea-level rise and coastal change: causes and implications for the future of coasts and low-lying regions. *Shore and Beach* 77(4):13-21.
- Winn, B., S. Brown, C. Spiegel, D. Reynolds, and S. Johnston. 2012. Atlantic flyway shorebird business strategy: a call to action. Unpublished document. Manomet Center for Conservation Sciences and U.S. Fish and Wildlife Service. Manomet and Hadley, Massachusetts.
- Yamalis, H. and H. Young. 2010. Long Island Sound Study: guidelines for habitat restoration grant applications. Long Island Sound Study, Stamford, Connecticut. Available online at [http://longislandsoundstudy.net/wp-content/uploads/2010/01/grantguidelines\\_finaldec20101.pdf](http://longislandsoundstudy.net/wp-content/uploads/2010/01/grantguidelines_finaldec20101.pdf), Accessed November 28, 2011.
- Zajac, R. N. and R. B. Whitlatch. 2003. Community and population-level responses to disturbance in a sandflat community. *Journal of Experimental Marine Biology and Ecology* 294:101-125.
- Zdravkovic, M. G. and M. M. Durkin. 2011. Abundance, distribution and habitat use of nonbreeding piping plovers and other imperiled coastal birds in the Lower Laguna Madre of Texas, submitted to U. S. Fish and Wildlife Service and National Fish and Wildlife Foundation by Coastal Bird Conservation/Conservian, Big Pine Key, Florida.
- Zivojnovich, M. and G. A. Baldassarre. 1987. Habitat selection, movements, and numbers of piping plovers wintering in coastal Alabama. Unpublished report to Alabama Department of Conservation and Natural Resources. 16 pp.
- Zonick, C. 1997. The use of Texas barrier island washover pass habitat by piping plovers and other coastal water birds. Report to the Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service.
- Zonick, C. A. 2000. The winter ecology of the piping plover (*Charadrius melodus*) along the Texas Gulf Coast. Ph.D. Dissertation. University of Missouri, Columbia, Missouri.
- Zonick, C. and M. Ryan. 1993. Ecology and conservation of wintering piping plovers and snowy plovers. Unpublished interim report. University of Missouri, Columbia, Missouri. 37 pp.
- Zonick, C. and M. Ryan. 1996. The ecology and conservation of piping plovers (*Charadrius melodus*) wintering along the Texas Gulf Coast. Department of Fisheries and Wildlife, University of Missouri, Columbia, Missouri 65211. 1995 Annual Report. 49 pp.
- Zonick, C., K. Drake, L. Elliott, and J. Thompson. 1998. The effects of dredged material on the ecology of the piping plover and the snowy plover. Report submitted to the U.S. Army Corps of Engineers.

### ***Correspondence, Electronic Communications, and Telephone Conversations***

- Acker, C. M. 2009. Electronic mail dated 10 February 2009 and phone conversations between Cathy Acker, Veterinary Records Supervisor, U.S. Geological Survey National Wildlife Health Center, Madison, Wisconsin and Richard Zane, USFWS Panama City Field Office, Florida regarding shorebird diagnostics data.
- Amos, A. 2009. Telephone conversation on 3 April 2009 between Tony Amos, University of Texas Marine Science Institute, and Robyn Cobb, USFWS Corpus Christi Field Office, Texas regarding injured and oiled piping plovers on the central Texas coast.
- Amos, A. 2010. PowerPoint presentation at December 2010 Nonbreeding piping plover conservation workshop in Fernandina Beach, Florida about three decades of wintering piping plover observations in South Texas.
- Amos, A. 2012. Telephone conversation on 9 April 2012 between Tony Amos, University of Texas Marine Science Institute, and Robyn Cobb, USFWS Corpus Christi Field Office, Texas regarding piping plovers that he observed during the Ixtoc oil spill.
- Banda, A. 2012. Electronic mail dated 24 April 2012 from Alfonso Banda, State Government of Tamaulipas, Mexico to Anne Hecht, USFWS Northeast Region regarding conservation of piping plovers in Mexico.
- Best, D. 1999. Page 26 in USFWS. 2003. Recovery plan for the Great Lakes piping plover (*Charadrius melodus*). U.S. Fish and Wildlife Service, Fort Snelling, Minnesota.
- Bimbi, M. 2011. Electronic mail from Melissa Bimbi, USFWS to Karen Terwilliger, Terwilliger Consulting, Inc. in regards to response protocols for oil spills.
- Brush, J. 2011. Electronic mail dated 2 May 2011 from Janell Brush, Florida Fish and Wildlife Conservation Commission to Karen Terwilliger, Terwilliger Consulting, Inc. providing information on piping plover conservation efforts and needs.
- Burkett, W. 2011. Electronic mail dated 16 May 2011 from Winnie Burkett, Sanctuary Manager, Houston Audubon to Karen Terwilliger, Terwilliger Consulting, Inc. providing information of conservation efforts for piping plover at Bolivar Flats.
- Caldwell, M. 2012. Electronic mail dated 5 April 2012 from Mark Caldwell, USFWS South Carolina Field Office to Melissa Bimbi, USFWS South Carolina Field Office regarding wind turbines.
- Carver, L. 2011. Electronic mail dated 11 January 2011 from Laura Ann Carver, Biologist-Oil-Spill Coordinator, Louisiana Department of Wildlife and Fisheries to Michael Seymour, Scientific Collecting Permits Coordinator Louisiana Department of Wildlife & Fisheries Louisiana Natural Heritage Program in regards to how many oil spills occur on average in a year in the Gulf.
- Catlin, D. 2012a. Electronic mail dated 25 June 2012 from Daniel H. Catlin, Virginia Polytechnic Institute and State University, Blacksburg, Virginia to Carol Aron, USFWS North Dakota Field Office regarding piping plovers banded in the Great Lakes and Northern Great Plains and resighted in the Bahamas.



- Catlin, D. 2012b. Electronic mail dated 20 March 2012 from Daniel H. Catlin, Virginia Polytechnic Institute and State University, Blacksburg, Virginia to Anne Hecht, USFWS Northeast Region regarding cold weather and plover weights.
- Cavalieri, V. 2011. Electronic mail dated 22 December 2011 from Vincent Cavalieri, USFWS Michigan Field Office to Anne Hecht, USFWS Northeast Region regarding detection of contaminants in piping plovers breeding in the Great Lakes.
- Clements, P. 2012. Electronic mail dated 2 April and 27 March 2012 from Pat Clements, USFWS Corpus Christi Field Office to Robyn Cobb, USFWS Corpus Christi Field Office regarding wind turbines.
- Cobb, R. 2011. Comments from Robyn Cobb, USFWS Corpus Christi Field Office to Karen Terwilliger, Terwilliger Consulting, Inc. regarding examples of essential habitat used by large numbers of piping plovers outside of designated critical habitat. 23 December 2011.
- Cobb, R. 2012a. Comments from Robyn Cobb, USFWS Corpus Christi Field Office to Anne Hecht, USFWS Northeast Region on plover use of dredged material islands in Texas. 21 June 2012.
- Cobb, R. 2012b. Note to file by Robyn Cobb, USFWS Corpus Christi Field Office regarding oiled piping plovers on southern Texas coast associated with 2009 “mystery spill.” Summarizes information from Clare Lee, Wade Steblein, and Steve Liptay.
- Cobb, R. 2012c. Electronic mail dated 9 November 2012 from Robyn Cobb, USFWS Corpus Christi Field Office to Anne Hecht, USFWS Northeast Region on piping plover conservation strategy questions.
- Cohen, J. 2009. Electronic mail dated 15 and 16 January 2009 from Jonathan Cohen, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, to Anne Hecht, USFWS Northeast Region regarding winter survival and detectability of banded piping plovers in South Carolina.
- Davis, C. 2012. PowerPoint presentation by Christina Davis, New Jersey Division of Fish and Wildlife at January 2012 Atlantic Coast piping plover and least tern workshop in Shepherdstown, West Virginia about New Jersey piping plover migration survey, 2008-2011.
- Elliott-Smith, E. 2012a. Electronic mail dated 14 February 2012 from Elise Elliott-Smith, U.S. Geological Survey Forest and Rangeland Ecosystem Science Center to Anne Hecht, USFWS Northeast Region regarding 2011 count of piping plovers in the Bahamas.
- Elliott-Smith, E. 2012b. Electronic mail dated 6 and 9 November 2012 from Elise Elliott-Smith, U.S. Geological Survey Forest and Rangeland Ecosystem Science Center to Anne Hecht, USFWS Northeast Region regarding 2011 winter census.
- Firmin, B. 2012. Electronic mail dated 24 April, 2012 from Brigitte Firmin, USFWS Louisiana Field Office to Anne Hecht, USFWS Northeast Region regarding threats to piping plovers from land-based oil and gas exploration and development.
- Gramling, J. 2011. Electronic mail dated 1 August 2011 from Joel M. Gramling, Ph.D., Department of Biology, The Citadel, Charleston, South Carolina to Stephanie Egger, Terwilliger Consulting, Inc. regarding the invasive *Carex kobomugi* on North Carolina beaches.

- Gratto-Trevor, C. 2012a. Electronic mail dated 21 May 2012 from Cheri Gratto-Trevor, Science and Technology Branch of Environment Canada to Anne Hecht, USFWS Northeast Region regarding preliminary results from Bahamas piping plover study.
- Gratto-Trevor, C. 2012b. Electronic mail dated 25 June 2012 from Cheri Gratto-Trevor, Science and Technology Branch of Environment Canada to Carol Aron, USFWS North Dakota Field Office regarding piping plovers banded in the Great Lakes and Northern Great Plains and resighted in the Bahamas.
- Gruver, B. 2012. October 2, 2012 letter from Bradley J. Gruver, Florida Fish and Wildlife Conservation Commission to Jack Dingleline, USFWS East Lansing Field Office providing comments on the Comprehensive Conservation Strategy.
- Hall, T. 2007. November 29, 2007 letter from Timothy N. Hall, USFWS South Carolina Field Office to Mr. A. E. Johnston responding to questions about feral cat colonies.
- Hammond, J. 2012. Electronic mail dated 23 March 2012 from John Hammond, USFWS Raleigh Field Office to Anne Hecht, USFWS Northeast Region regarding 2002 consultation with Camp Lejeune.
- Herod, H. 2012. Electronic mail dated 6 November 2012 from Holly Herod, USFWS Southeast Regional Office to Anne Hecht, USFWS Northeast Region regarding the Deepwater Horizon oil spill clean-up operations.
- Hines, M. K. 2009. Electronic mail dated 10 February 2009 from Megan Hines, Technical Manager, USGS, National Biological Information Infrastructure, Wildlife Disease Information Node, Madison, Wisconsin to Richard Zane, USFWS Panama City Field Office, Florida providing shorebird mortality database.
- Hunter, C. 2011a. Electronic mail dated 3 June 2011 from Chuck Hunter, Chief, Division of Planning and Resource Management, USFWS Atlanta, Georgia to Karen Terwilliger, Terwilliger Consulting, Inc. providing information about piping plover management on national wildlife refuges.
- Hunter, C. 2011b. Electronic mail dated 3 December 2011 from Chuck Hunter, Chief, Division of Planning and Resource Management, USFWS, Atlanta, Georgia to Karen Terwilliger, Terwilliger Consulting, Inc. providing information about piping plover management on national wildlife refuges.
- Isaacs, J. 2012. Electronic mail dated 8 March 2012 from Jackie Isaacs, USFWS Bon Secour National Wildlife Refuge to Anne Hecht, USFWS Northeast Region regarding piping plover protections.
- Johnston, S. 2012. Electronic mail dated 8 November 2012 from Scott Johnston, USFWS Northeast Region regarding Atlantic Shorebird Flyway Strategy Update.
- Keyes, K. 2011. Electronic mail dated 23 May 2011 from Kendal Keyes, Regional Natural Resources Coordinator, Texas Parks and Wildlife Department to Robyn Cobb, USFWS Corpus Christi Field Office, Texas in regards to current piping plover conservation efforts.
- Keyes, T. 2012. Electronic mail dated 15 March 2012 from Tim Keyes, Georgia Department of Natural Resources, Wildlife Resources Division to Anne Hecht, USFWS Northeast Region regarding management of public use.

- LeBlanc, D. 2009. Electronic mail dated 29 January 2009 from Darren LeBlanc, USFWS, Daphne, Alabama, Ecological Services Office to Patricia Kelly, USFWS, Panama City Field Office, Florida regarding habitat changes along Alabama coast from hurricanes.
- Lombard, C. 2010. Electronic mail dated 6 November 2010 from Claudia Lombard, USFWS Christiansted, Virgin Islands to Patricia Kelly, USFWS, Panama City Field Office, Florida regarding sightings of piping plover on St. Croix.
- Maddock, S. 2009. Telephone conversation dated April 3, 2009 between Sidney Maddock, Audubon, North Carolina, and Robyn Cobb, USFWS Corpus Christi Ecological Services Field Office, Texas regarding piping plover surveys along the Gulf coast, including Texas.
- Maddock, S. and M. Bimbi. Unpublished data. Piping plover winter and migration survey data collected in South Carolina from 2006-2008.
- Mierzykowski, S. 2012. Electronic mail dated 10 January 2012 from Steve Mierzykowski, USFWS Maine Field Office to Anne Hecht, USFWS Northeast Region regarding results of opportunistic tests of Atlantic Coast piping plover eggs for contaminants.
- Moore, P. and L. Gape. 2012. Summary of bird conservation by the Bahamas National Trust prepared by Predensa Moore and Lynn Gape, Bahamas National Trust and conveyed via electronic mail dated 29 February, 2012 from Matthew Jeffery, National Audubon Society to Anne Hecht, USFWS Northeast Region.
- Newstead, D. 2012a. June 20, 2012 telephone communication from David Newstead, Coastal Bend Bays and Estuaries Program to Robyn Cobb, USFWS Corpus Christi Field Office, about piping plover movements in the area of the Kennedy/Kleberg County wind farms. Documented in Note to File.
- Newstead, D. 2012b. Electronic mail dated 2 March and 10 September 2012 from David Newstead, Coastal Bend Bays and Estuaries Program to Anne Hecht, USFWS Northeast Region regarding plover mortalities in Laguna Madre/Padre Island study area.
- Nicholas, M. 2005. Electronic mail dated 8 March 2005 from Mark Nicholas, Gulf Islands National Seashore, Gulf Breeze, Florida to Patricia Kelly, USFWS, Panama City Field Office, Florida providing documentation of Great Lakes piping plover sightings post-hurricane.
- Pena, J. 2012. Electronic mail dated 17 April 2012 from Jaime Pena, Gladys Porter Zoo, Brownsville, Texas to Tom Shearer, USFWS Corpus Christi Field Office regarding piping plover conservation in Mexico.
- Rice, K. 2009. In-office conversation dated 13 March 2009, between Ken Rice, Contaminants specialist and Robyn Cobb, Endangered Species Recovery program, both of USFWS Corpus Christi Ecological Services Field Office, Texas regarding sources of oil spills that have affected the Texas Gulf coast.
- Roche, E. 2010. PowerPoint presentation at December 2010 Nonbreeding piping plover conservation workshop in Fernandina Beach, Florida about partitioning annual survival in Great Lakes piping plovers.
- Roche, E. 2012. Electronic mail dated 13 March 2012 from Erin Roche, University of Tulsa to Anne Hecht, USFWS Northeast Region regarding winter range temperature and spring survival of piping plovers.

- Schibley, L. 2011. Electronic mail dated 2 June 2011 from Lisa Schibley, Manomet Center for Conservation Science to Karen Terwilliger, Terwilliger Consulting, Inc. providing documentation of piping plover sightings in the Bahamas, Cuba, Nicaragua, St. Vincent and the Grenadines, Turks and Caicos Island.
- Seymour, M. 2011. Electronic mail dated 21 January 2011 from Michael Seymour, Louisiana Department of Wildlife and Fisheries, Louisiana Natural Heritage Program, Baton Rouge, Louisiana to Karen Terwilliger, Terwilliger Consulting, Inc. in response to Karen's November 1, 2010 request for information.
- Sipocz, A. 2011. Electronic mail dated 23 May 2011 from Andrew Sipocz, Natural Resources, Texas Parks and Wildlife Department to Robyn Cobb, USFWS Corpus Christi Field Office, Texas, in regards to current piping plover conservation efforts.
- Sternberg, M. and S. Perez. 2012. Electronic mail messages dated 9 March 2012 from Mitch Sternberg and Sonny Perez, USFWS South Texas Refuge Complex to Robyn Cobb, USFWS Corpus Christi Field Office regarding effects of off-road vehicle management.
- Teich, L. 2009. Electronic mail dated 6 February 2009 from Larry Teich, data base manager, Florida Department of Environmental Protection, Tallahassee, Florida transmitting spreadsheet regarding beach cleaning permits to Harold Mitchell, USFWS Panama City Field Office, Florida. Harold Mitchell forwarded the information via electronic mail to Patricia Kell, USFWS, Panama City Field Office, Florida.
- USFWS. 1996. December 18, 1996 letter from John M. Hefner, Raleigh Field Office to Glenn C. Woodward, Federal Emergency Management Agency, Raleigh, North Carolina regarding proposal to construct an emergency berm in CBRA Unit L06.
- USFWS. 2009a. May 27, 2009 letter from Gail A. Carmody, Panama City Field Office to Richard Meyers, Federal Emergency Management Agency, Lake Mary, Florida regarding St. Joseph Peninsula beach renourishment and dune installation.
- USFWS. 2009b. November 5, 2009 letter from Paul Souza, South Florida Ecological Services Office to Eric P. Summa, U.S. Army Corps of Engineers, Jacksonville, Florida regarding proposal to renourish beach in CBRA Unit P11.
- USFWS. 2009c. July 15, 2009 letter from Paul Souza, South Florida Ecological Services Office to Heather D. Batson, U.S. Department of Homeland Security, Lake Mary, Florida regarding proposal to place sand in CBRA Unit P21/P21P.
- USFWS. 2010. February 22, 2010 letter from Donald W. Imm, Panama City Field Office to Kenneth P. Bradley, U.S. Army Corps of Engineers, Mobile, Alabama regarding Walton County Beach renourishment.
- Weaver, F. 2012. Electronic mail dated 26 July 2012 from Frank Weaver, USFWS Corpus Christi Field Office to Robyn Cobb, USFWS Corpus Christi Field Office regarding ownership of the piping plover critical habitat in Texas.

Westbrooks, R. 2011. Phone conversation on 1 August 2011 from Randy G. Westbrooks, Ph.D., Invasive Species Prevention Specialist, USGS, Whiteville, North Carolina to Stephanie Egger, Terwilliger Consulting, Inc. regarding the invasive *Carex kobomugi* on North Carolina beaches.

Winstead, N. 2012. Electronic mail dated 10 March 2012 from Nick Winstead, Mississippi Department of Wildlife, Fisheries, and Parks to Anne Hecht, USFWS, Northeast Region regarding piping plovers surveys on Mississippi mainland beaches.

Woodrow, J.O. 2012. Two electronic mail messages dated 9 March 2012 from Woody Woodrow, USFWS Houston Field Office to Robyn Cobb, USFWS Corpus Christi Field Office regarding Bolivar Flats.