

**Deepwater Horizon Early Restoration  
North Breton Island Restoration Project  
Plaquemines Parish, Louisiana**

**04EL1000-2014-F-0200  
Biological Opinion  
Conference Opinion  
May 9, 2014**

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## Acronyms

Act	Endangered Species Act
ATV	All-terrain vehicle
BA	Biological Assessment
BO	Biological Opinion
CCSP	Climate Change Science Program
CEM	Coastal Engineering Manual
CWPPRA	Coastal Wetlands Planning, Protection, and Restoration Act
CY	Cubic yards
LDNR	Louisiana Department of Natural Resources
DOI	Department of Interior
DPS	Distinct Population Segment
EA	Environmental Assessment
EPA	Environmental Protection Agency
FDEP	Florida Department of Environmental Protection
IPPC	International Piping Plover Census
LDWF	Louisiana Department of Wildlife and Fisheries
MBTA	Migratory Bird Treaty Act
MHW	Mean High Water
MLW	Mean Low Water
MLLW	Mean Low Low Water
NAVD	North American Vertical Datum 1988
NBIR	North Breton Island Restoration
NMFS	National Marine Fisheries Service
NPS	National Park Service
NRA	Natural Resource Advisor
NRDAR	Natural Resource Damage Assessment and Restoration
NWR	National Wildlife Refuge
O&M	Operations and maintenance
ORV	Off-road vehicle
PCB	Polychlorinated Biphenol
PCE	Primary Constituent Element
SCAT	Shoreline Cleanup Assessment Team
Service	U.S. Fish and Wildlife Service
U.S.	United States
USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service



## United States Department of the Interior

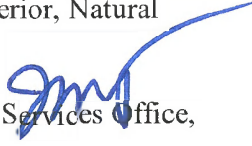
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May 9, 2014

### Memorandum

**To:** Deputy Case Manager, Deepwater Horizon, Department of the Interior, Natural Resources Damage Assessment and Restoration, Atlanta, GA

**From:** Field Supervisor, Fish and Wildlife Service, Louisiana Ecological Services Office, Lafayette, LA 

**Subject:** Biological and Conference Opinions for the Proposed North Breton Island Restoration Project, Plaquemines Parish, Louisiana

This document transmits the Fish and Wildlife Service's (Service) biological opinion based on our review of the U.S. Department of Interior's (DOI) proposed implementation of the North Breton Island Restoration (NBIR) project that would be located in Plaquemines Parish, Louisiana, and its effects on the endangered West Indian manatee (*Trichechus manatus*), the threatened piping plover (*Charadrius melodus*) and its designated critical habitat, and five species of sea turtles, in accordance with section 7 of the Endangered Species Act (Act) of 1973, as amended (16 United States Code [U.S.C.] 1531 *et seq.*). This document also transmits the Service's conference opinion of the NBIR project effects on the red knot (*Calidris canutus rufa*; proposed for listing). Your December 15, 2013, request for formal consultation and formal conference, as well as a biological assessment (BA), was received via mail on December 23, 2013.

These biological and conference opinions are based on information provided in the DOI's December 15, 2013, BA, telephone conversations, electronic mails, various shorebird surveys, and other sources of information. A complete administrative record of this consultation (Service Log No. 04EL1000-2014-F-0200) is on file at the Service's Louisiana Ecological Services Office.

The Service concurs with the DOI's determination that the proposed project is not likely to adversely affect the endangered West Indian manatee because: (1) manatees are not permanent inhabitants of the project area; and (2) the DOI would implement, as part of the project construction plan, standard conditions for in-water work in areas that may have manatees (Appendix A). The conservation measures described in Appendix A would also avoid take under the Marine Mammal Protection Act of 1972. Although sea turtles nested on the Breton National Wildlife Refuge (NWR) in the past and sea turtle crawls may still rarely occur, the Service has not documented successful nesting on the Breton NWR by federally listed sea turtles (i.e., Kemp's ridley (*Lepidochelys kempii*), loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), and green (*Chelonia mydas*) sea turtles) in recent years due to the refuge's low elevation and frequent inundation. Increased elevation as a result of project implementation may improve future nesting conditions; therefore, nesting sea turtles are not likely to be adversely affected. It is our understanding that the DOI is conducting a separate consultation with the National Marine Fisheries Service (NMFS) regarding project-related effects to sea turtles offshore as a result of dredging activities during project implementation. The NMFS is also responsible for section 7 consultation for the threatened Gulf sturgeon (*Acipenser oxyrinchus desotoi*) in marine waters. Accordingly, none of the federally listed species mentioned in this paragraph will be discussed further in our biological opinion (Table 1).

Table 1. Federally listed species and designated critical habitat evaluated for effects from the proposed action but not discussed further in this biological opinion.

Species or Critical Habitat	Present in Action Area*	Present in Action Area but "Not Likely to Adversely Affect"
West Indian manatee	Possible	Yes
Green sea turtle	Yes	Yes
Kemp's ridley sea turtle	Yes	Yes
Leatherback sea turtle	Yes	Yes
Loggerhead sea turtle	Yes	Yes

\*The Service's jurisdiction extends only to onshore sea turtles activities.

### Consultation History

According to the DOI's BA, the New Orleans District of the U.S. Army Corps of Engineers (USACE) completed an Environmental Assessment (EA) in 1999 for their proposal to beneficially use dredged material from the Mississippi River Gulf Outlet (MRGO) navigation channel for restoration of Breton Island in a configuration similar to the currently proposed action. The EA resulted in a Finding of No Significant Impact by the USACE which included consideration of federally threatened or endangered species, as well as critical habitat and essential fish habitat, and was concurred with by the Service and coordinated with the NMFS. That project, however, was never implemented.

As you know, the DOI is a designated natural resources trustee agency authorized by the Oil Pollution Act of 1990 (OPA) and other applicable federal laws to assess and assert a natural resources damage claim for the Deepwater Horizon Mississippi Canyon Well #252 (Deepwater Horizon) oil spill that occurred on April 20, 2010. That spill resulted in the discharge of millions of barrels of oil into the Gulf of Mexico (Gulf) over a period of 87 days. The process of investigating injuries to and losses of natural resources that occurred as a result of the Deepwater Horizon spill and restoration planning to restore those injured and lost natural resources is known as Natural Resources Damage Assessment and Restoration (NRDAR). According to your BA, on April 20, 2011, the DOI, the National Oceanic and Atmospheric Administration, and the Trustees for the five Gulf states affected by the Deepwater Horizon spill entered into an agreement with British Petroleum (a responsible party for the spill) under which British Petroleum agreed to provide funding for early restoration projects in the Gulf states to address injuries to and losses of natural resources caused by the Deepwater Horizon spill. The proposed NBIR project is being evaluated by the Trustees as a potential early restoration project, and if selected, would be implemented by the DOI.

On December 23, 2013, the Service received the DOI's December 15, 2013, BA regarding the potential effects of implementing the proposed NBIR project to federally listed, proposed, and candidate species and their critical habitats. Due to the nature of the project, the project-area environmental baseline, and the duration of construction, the DOI requested to initiate formal consultation for the piping plover and its critical habitat and formal conference for the red knot. On January 22, 2014, the Service provided confirmation to the DOI that all information had been received and that our biological and conference opinions would be issued no later than May 7, 2014. On April 25 and 28, 2014, and May 5, 2014, the DOI provided comments on the draft biological and conference opinions and clarification of proposed NRDAR monitoring requirements for the action. In order to provide the Service time to incorporate those comments, the DOI provided the Service an extension until May 13, 2014, to provide our final biological and conference opinions.

## BIOLOGICAL AND CONFERENCE OPINIONS

### DESCRIPTION OF THE PROPOSED ACTION

North Breton Island, located at the southern end of the Chandeleur and Breton Islands chain in Plaquemines Parish, Louisiana (Figure 1), is part of the Breton National Wildlife Refuge (NWR). The island chain starts approximately 16 miles northeast of Venice, Louisiana, and extends northward toward the Mississippi Gulf Coast. Breton NWR is recognized by the National Audubon Society as a globally important bird area because of the resources it provides to birds. North Breton Island hosts one of Louisiana's largest historical brown pelican nesting colonies. However, according to the DOI's BA, surveys by Breton NWR staff indicate that this colony has declined from over 15,000 pairs before 1998 to fewer than several thousand pairs in 2012, including a reduction of approximately 50 percent of breeding pelicans between 2008 and 2012. Erosion from tides and storms constitutes a major and ongoing threat to North Breton Island, its habitats, and the breeding bird colonies it supports (Lavoie 2009; Martinez et al. 2009; Kindinger et al. 2013). Without actions to restore sand into the North Breton Island system, the island is expected to be completely submerged sometime between 2014 and 2037, depending on the frequency and magnitude of future storms (Lavoie 2009).

The goal of the proposed NBIR project is to increase island longevity by: (1) restoring beach, dune, and back-barrier marsh habitats on the island, and (2) providing nesting and foraging habitat for brown pelicans, terns, skimmers and gulls injured by the Deepwater Horizon spill. According to the DOI's BA, restoration will be guided by the data analyses presented in Lavoie (2009), Visser et al. (2005), Hingtgen et al. (1985), and other related documents and would be designed to mimic the natural processes of barrier island evolution, including erosion and long-shore transport of sand. The proposed work would involve reestablishing a dune platform along the length of the Gulf shoreline and constructing a marsh platform on the bayside of that dune. The conceptual design for the placement of sand and back-barrier marsh sediment would mimic the pre-Hurricane Katrina island coverage and expected island evolution pattern (Figure 2).

The DOI's implementation of the NBIR project is intended to restore approximately 76.2 acres (16,000 linear feet) of beach, 138.7 acres of dune, and 137.3 acres of back barrier marsh for a total of 352 additional acres of barrier island habitats. Other design features include:

- a total island width of 1,100 feet, bounded by sloped foreshore and back barrier marsh platforms (optimum slope to be determined);
- an elevated dune platform of 8 to 10 feet above sea level (optimum elevation to be determined) by 400 feet-wide at the base and 100 feet-wide at the top;
- Gulf-side beach 3 feet above sea level by 200 feet-wide;
- a bayside back barrier marsh platform approximately 3 feet above sea level and 500 feet wide;
- sand fencing to trap and retain deposited sediments and build dune habitats; and
- vegetative plantings of dune and back barrier marsh.

To achieve the above conceptual design specifications, approximately 3.7 million cubic yards of sand,



silt and clay material would be dredged from one or more sites within an offshore shoals borrow area<sup>1</sup> (Figure 3) and placed on the existing submerged island platform to create the desired island configuration. Dredging would be accomplished using a 30-inch diameter cutter-head hydraulic dredge. Dredged material would be transported via temporary pipeline from the borrow area to North Breton Island and pumped directly to placement locations at the restoration site (i.e., single handling) through a submerged pipeline. Retention dikes would be constructed on the island and in shallow water to contain the dredged material for marsh restoration then leveled as needed to match the adjacent topography after construction. Dozers would shape the sand for the dune and beach portions of the project. The total area of construction footprint also includes all access routes and staging areas.

According to the DOI's BA, the NBIR project area would include the existing island, its intertidal zone and adjacent mud flats, the borrow area, the pipeline right-of-way, all access routes and staging areas, and the surrounding open water and underlying sediments in the north central Gulf of Mexico off the Louisiana coastline. A 2010 U.S. Geological Survey (USGS) description on the island described the island as 109 acres of intertidal zone, 88 acres of mud flat, 7 acres of salt scrub, 4 acres of salt marsh, 2 acres of *Spartina* salt marsh and 1 acre of bare sand, all of which encompasses approximately 10 square miles. Based on those acreages, most of the remnant island is over-wash and tidal mud flats that provide foraging habitat for birds but little shoreline or loafing areas (1 acre estimated). The project area also includes the offshore borrow area (Figure 3) along with the hydraulic dredge pipeline right-of-way from the borrow area to the island, all access routes and staging areas, any sedimentation controls necessary at North Breton Island, and noise disturbance around the borrow area and the island. The entirety of the borrow area from which material would be dredged, as well as the pipeline right-of-way, access routes, and staging areas, encompasses approximately 35 square miles. Thus, the total project area is 45 square miles, and consists predominantly of open water and the underlying sediments, the intertidal zone, mud flats, and the remaining island footprint.

According to the DOI's BA, project engineering and design has not yet proceeded to the point of producing a detailed construction schedule. However, construction duration could last from six months up to one year or more given potential logistics indicated by the conceptual design and weather conditions. Construction windows would take into consideration potential effects to fish and wildlife resources and would be adjusted to the maximum extent practicable in consultation with both the Service and NMFS. To this end, monitoring of fish and wildlife resources would be incorporated into the plan to include baseline (prior to construction), construction (to direct activities around resources), and post-construction (for a period after construction to evaluate physical and biological responses to the island restoration).

Project effects would occur across the current footprint of North Breton Island, its intertidal zone and adjacent mud flats, the pipeline right-of-way, all access routes and staging areas, the offshore shoals borrow area, and all adjacent open water and underlying sediments. North Breton Island is included in piping plover critical habitat Unit LA-7 (described in detail in the **Species/critical habitat description and Status of the species within the action area** sections of this document). The Service has described the action area to include the total project area of 45 square miles (i.e., the remaining island footprint, its intertidal zone, adjacent mud flats, the pipeline right-of-way, all access routes and staging areas, adjacent open water, the underlying sediments, and the offshore shoals borrow area), for reasons

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<sup>1</sup> Location and design of borrow sites within the borrow area would be developed during project development following acquisition of funding. However, conclusions following preliminary geotechnical and infrastructure review indicate that they would most likely be located within the existing borrow area that are used routinely for sediment sources for other projects.

that will be explained and discussed in detail in the **EFFECTS OF THE ACTION** section of this consultation/conference.

## **STATUS OF THE SPECIES/CRITICAL HABITAT**

### *PIPING PLOVER*

#### **Species/critical habitat description**

The piping plover is a small (7 inches long), pale, sand-colored shorebird with a wingspan of 15 inches (Palmer 1967). On January 10, 1986, the piping plover was listed as endangered in the Great Lakes watershed and threatened elsewhere within its range, including migratory routes outside of the Great Lakes watershed and wintering grounds (Service 1985). Piping plovers were listed principally because of habitat destruction and degradation, predation, and human disturbance. Protection of the species under the Act reflects the species' precarious status range-wide. Three separate breeding populations have been identified, each with its own recovery criteria: the northern Great Plains (threatened), the Great Lakes (endangered), and the Atlantic Coast (threatened). The piping plover winters in coastal areas of the United States (U.S.) from North Carolina to Texas, and along the coast of eastern Mexico and on Caribbean islands from Barbados to Cuba and the Bahamas (Haig and Elliott-Smith 2004). Piping plover subspecies are phenotypically indistinguishable, and most studies in the nonbreeding range report results without regard to breeding origin. Although a recent analysis shows strong patterns in the wintering distribution of piping plovers from different breeding populations, partitioning is not complete and major information gaps persist. Therefore, information summarized here pertains to the species as a whole (i.e., all three breeding populations), except where a particular breeding population is specified.

The Service has designated critical habitat for the piping plover on three occasions. Two of these designations protected different breeding populations. Critical habitat for the Great Lakes breeding population was designated May 7, 2001 (Service 2001a), and critical habitat for the northern Great Plains breeding population was designated September 11, 2002 (Service 2002). Critical habitat for the piping plover breeding populations does not occur in Louisiana; therefore, critical habitat for breeding plovers will not be discussed further in this document.

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

The primary constituent elements (PCEs) for piping plover wintering habitat are those biological and physical features that are essential to the conservation of the species. The PCEs are those habitat components that support foraging, roosting, and sheltering and the physical features necessary for maintaining the natural processes that support these habitat components. These areas typically include coastal areas that support intertidal beaches and flats and associated dune systems and flats above annual high tide (Service 2001a). PCEs of wintering piping plover critical habitat include sand or mud flats (or both) with no or sparse emergent vegetation. Adjacent unvegetated or sparsely vegetated sand, mud, or algal flats above high tide are also important, especially for roosting piping plovers (Service 2001a). Important components of the beach/dune ecosystem include surf-cast algae, sparsely vegetated back beach and salterns, spits, and over-wash areas. Over-wash areas are broad, unvegetated zones, with little or no topographic relief, that are formed and maintained by the action of hurricanes, storm surge, or other extreme wave action. The units designated as critical habitat are those areas that have consistent use by piping plovers and that best meet the biological needs of the species. The amount of wintering habitat included in the designation appears sufficient to support future recovered populations, and the existence of this habitat is essential to the conservation of the species. Additional information on each specific unit included in the designation can be found in the Service's final rule (Service 2001a).

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

## **Life History**

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

The most consistent finding in the various population viability analyses conducted for piping plovers indicates that even small declines in adult and juvenile survival rates will cause very substantial increases in extinction risk (Ryan et al. 1993; Melvin and Gibbs 1996; Plissner and Haig 2000; Wemmer et al. 2001; Larson et al. 2002; Amirault et al. 2005; Calvert et al. 2006; Brault 2007). This suggests that maximizing productivity does not ensure population increases. Efforts to partition survival within the annual cycle are beginning to receive more attention, but current information remains limited. Some evidence of correlation in year-to-year fluctuations in annual survival of Great Lakes and eastern Canada populations, both of which winter primarily along the southeastern U.S. Atlantic Coast, suggests that shared over-wintering and/or migration habitats may influence annual variation in survival. Further concurrent mark-resighting analysis of color-banded individuals across piping plover breeding populations has the potential to shed light on threats that affect survival in the migration and wintering range. However, very little to no information exists specifically for birds wintering along the northern Gulf of Mexico. An ongoing NRDAR study of piping plovers that are potentially affected by the 2010 Deepwater Horizon oil spill may provide such information once the data gathered are eligible for release to the public.

### *Migration*

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

### *Foraging (nonbreeding portion of annual cycle)*

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

### *Roosting*

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. Lott et al. (2009) found greater than 90 percent of roosting piping plovers in southwest Florida in old wrack with the remainder roosting on dry sand. In South Carolina, 45 percent of roosting piping plovers were in old wrack, and 18 percent were in fresh wrack. The remainder of roosting birds used intertidal habitat (22 percent), backshore (defined as zone of dry sand, shell, cobble and beach debris from mean high water line up to the toe of the dune)(8 percent), over-

wash and ephemeral pools 2 percent and 1 percent respectively (Maddock et al. 2009). Thirty percent of roosting piping plovers in northwest Florida were observed in wrack substrates with 49 percent on dry sand and 20 percent using intertidal habitat (Smith 2007). In Texas, sea grass debris (bay-shore wrack) was an important feature of piping plover roost sites (Drake 1999b).

### *Natural protection*

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

### *Wintering habitat*

Wintering piping plovers prefer coastal habitat that include sand spits, islets (small islands), tidal flats, shoals (usually flood tidal deltas), and sandbars that are often associated with inlets (Harrington 2008). Sandy mud flats, ephemeral pools, and over-wash areas are also considered primary foraging habitats. These substrate types have a richer infauna than the foreshore of high energy beaches and often attract large numbers of shorebirds (Cohen et al. 2006). Wintering plovers are dependent on a mosaic of habitat patches and move among these patches depending on local weather and tidal conditions (Nicholls and Baldassarre 1990a). However, piping plovers have been observed to exhibit wintering site fidelity. Mean home range size (95 percent of locations) for 49 radio-marked piping plovers in southern Texas in 1997-98 was 3,113 acres, mean core area (50 percent of locations) was 717 acres, and mean linear distance moved between successive locations ( $1.97 \pm 0.04$  days apart), averaged across seasons, was 2.1 miles (Drake 1999b; Drake et al. 2001). Seven radio-tagged piping plovers used a 4,967-acre area (100 percent minimum convex polygon) at Oregon Inlet in 2005-2006, and piping plover activity was concentrated in 12 areas totaling 544 acres (Cohen et al. 2008a). Noel and Chandler (2008) observed high fidelity of banded piping plovers to 0.62 to 2.8 miles sections of beach on Little St. Simons Island, Georgia.

Study results in North Carolina, South Carolina, and Florida complement information from earlier investigations in Texas and Alabama (summarized in the 1996 Atlantic Coast and 2003 Great Lakes Recovery Plans) regarding habitat use patterns of piping plovers in their coastal migration and wintering range. Lott et al. (2009) identified bay beaches (bay shorelines as opposed to ocean-facing beaches) as the most common landform used by foraging piping plovers in southwest Florida and found approximately 75 percent of foraging piping plovers on intertidal substrates. In northwest Florida, however, Smith (2007) reported landform use by foraging piping plovers about equally divided between Gulf of Mexico (ocean-facing) and bay beaches. Exposed intertidal areas were the dominant foraging substrate in South Carolina (accounting for 94 percent of observed foraging piping plovers; Maddock et al. 2009) and in northwest Florida (96 percent of foraging observations; Smith 2007). Atlantic Coast and Florida studies highlighted the importance of inlets for non-breeding piping plovers. Almost 90 percent of observations of roosting piping plovers at ten coastal sites in southwest Florida were on inlet shorelines (Lott et al. 2009). Piping plovers were among seven shorebird species found more often than expected ( $p = 0.0004$ ; Wilcoxon Scores test) at inlet locations versus non-inlet locations in an evaluation of 361 International Shorebird Survey sites from North Carolina to Florida (Harrington 2008).

Recent geographic analysis of piping plover distribution on the upper Texas coast noted major concentration areas at the mouths of rivers and over-wash passes (low, sparsely vegetated barrier island habitats created and maintained by temporary, storm-driven water channels) into major bay

systems (Arvin 2008). Earlier studies in Texas have drawn attention to over-wash passes, which are commonly used by piping plovers during periods of high bay-shore tides and during the spring migration period (Zonick 1997; Zonick 2000). Cobb (*in* Elliott-Smith et al. 2009) reported piping plover concentrations on exposed sea grass beds and oyster reefs during seasonal low water periods in 2006.

The effects of dredge-material deposition on piping plover habitat use merit further study. Drake et al. (2001) concluded that conversion of southern Texas mainland bay-shore tidal flats to dredged material impoundments results in a net loss of habitat for wintering piping plovers, because impoundments eventually convert to upland habitat not used by piping plovers. Zonick et al. (1998) reported that dredged material placement areas along the Intracoastal Waterway in Texas were rarely used by piping plovers, and noted concern that dredge islands block wind-driven water flows, which are critical to maintaining important shorebird habitats. By contrast, most of the sound islands used by foraging piping plovers at Oregon Inlet, North Carolina, were created by the USACE by deposition of dredged material in the subtidal bay bottom, with the most recent deposition ranging from 28 to less than 10 years prior to the study (Cohen et al. 2008a).

### Population dynamics

The 2006 International Piping Plover Census (IPPC) documented 3,497 breeding pairs with a total of 8,065 birds throughout all of the Canadian and U.S. breeding populations (Elliott-Smith et al. 2009). Results from the 2011 IPPC have not yet been released. A detailed status of each breeding population can be found in the Service’s 2009 species status review; however, some information is provided here for clarity of overall population stability.

#### *Northern Great Plains Population*

The IPPC, conducted every five years, estimates the number of piping plover adults and breeding pairs in the Northern Great Plains. As illustrated in Table 2, none of the IPPC estimates of the number of pairs in the U.S. suggests that the Northern Great Plains population has yet satisfied the recovery criterion as stated in the Service’s Recovery Plan (Service 1988) of 2,300 pairs (Plissner and Haig 1997; Ferland and Haig 2002; Elliot-Smith et al. 2009). The 2006 IPPC count in prairie Canada is also short of the recovery goal of 2,500 adult piping plovers.

Table 2. The number of adult piping plovers and breeding pairs reported in the U.S. Northern Great Plains by the IPPC efforts (Plissner and Haig 1997; Ferland and Haig 2002; Elliot-Smith et al. 2009).

YEAR	ADULTS	PAIRS REPORTED BY THE CENSUS
1991	2,023	891
1996	1,599	586
2001	1,981	899
2006	2,959	1,212

The IPPC indicates that the U.S. population decreased between 1991 and 1996, then increased in 2001 and 2006. The Canadian population showed the reverse trend for the first three censuses, increasing slightly as the U.S. population decreased, and then decreasing in 2001. Combined, the IPPC numbers suggest that the population declined from 1991 through 2001, then increased almost 58 percent between 2001 and 2006 (Elliott-Smith et al. 2009).

The increase in 2006 is likely due in large part to a multi-year drought across much of the region starting in 2001 that exposed thousands of acres of nesting habitat. The USACE ran low flows on the riverine stretches of the Missouri River for most of the years between censuses, allowing more habitat to be exposed and resulting in relatively high fledging ratios (USACE 2009b). The USACE also began to construct habitat using mechanical means (dredging sand from the riverbed) on the Missouri River in 2004, providing some new nesting and foraging habitat. The drought also caused reservoir levels to drop on many reservoirs throughout the Northern Great Plains (e.g., Missouri River Reservoirs in North and South Dakota, and Lake McConaughy in Nebraska), providing previously unavailable shoreline habitat. The population increase may also be partially due to more intensive management activities on the alkali lakes, with increased management actions to improve habitat and reduce predation pressures.

While the IPPC provides an index to the piping plover population, the design does not always provide sufficient information to understand the population's dynamics. The five-year time interval between IPPC efforts may be too long to allow managers to get a clear picture of what the short-term population trends are and to respond accordingly if needed. As noted above, the first three IPPCs (1991, 1996, and 2001) showed a declining population, while the fourth (2006) indicated a dramatic population rebound of almost 58 percent for the combined U.S. and Canada Northern Great Plains population between 2001 and 2006. With only four data points over 15 years, it is impossible to determine if and to what extent the apparent upswing reflects a real population trend versus error(s) in the 2006 census count and/or a previous IPPC. The 2006 IPPC included a detectability component, in which a number of pre-selected sites were visited twice by the same observer(s) during the two-week window to get an estimate of error rate. This study found an approximately 76 percent detectability rate through the entire breeding area, with a range of between 39 percent to 78 percent detectability among habitat types in the Northern Great Plains.

Such a reported large increase in population may indeed indicate a positive population trend, but with the limited data available, it is impossible to determine how much. Furthermore, with the 2011 IPPC results yet to be published and with the next IPPC not scheduled until 2016, there is limited feedback in many areas on whether this increase is being maintained or if the population is declining in the interim. Additionally, the results from the IPPC have been slow to be released, adding to the time lag between data collection and possible management response.

### *Great Lakes Population*

The Recovery Plan (Service 2003) sets a population goal of at least 150 pairs (300 individuals), for at least 5 consecutive years, with at least 100 breeding pairs (200 individuals) in Michigan and 50 breeding pairs (100 individuals) distributed among sites in other Great Lakes states.

The Great Lakes piping plover population, which has been traditionally represented as the number of breeding pairs, has increased since the completion of the recovery plan in 2003 (Cuthbert and Roche 2007; 2006; Westbrook et al. 2005; Stucker and Cuthbert 2004; Stucker et al. 2003). The census conducted in 2008 indicated an increase of approximately 23 percent from the 2002 census numbers. The nesting pairs in Michigan represent approximately 50 percent of the recovery criterion. The breeding pairs outside Michigan in the Great Lakes basin, represents 20 percent of the goal, albeit the number of breeding pairs outside Michigan has continued to increase over the past five years. Breeding pairs increased in 2009 but fell in 2010, and that decline is of particular concern because productivity of the Great Lakes population in 2008 and 2009 was very close to rates associated with

earlier population growth. In addition, the number of non-nesting individuals has increased annually since 2003. Although there was some fluctuation in the total population from 2002 to 2008 the overall increase in breeding pairs combined with the increased observance of non-breeding individuals indicates the population is increasing.

### *Atlantic Coast Population*

Available data suggest that the most recent population decline began in the late 1940s or early 1950s (Haig and Oring 1985). Reports of local or statewide declines between 1950 and 1985 are numerous, and many are summarized by Cairns and McLaren (1980) and Haig and Oring (1985). There was little focus on gathering quantitative data on piping plovers in Massachusetts through the late 1960s because the species was commonly observed and presumed to be secure. However, numbers of piping plover breeding pairs declined 50 to 100 percent at seven Massachusetts sites between the early 1970s and 1984 (Griffin and Melvin 1984). Piping plover surveys in the early years of the recovery effort found that counts of these cryptically colored birds sometimes went up with increased census effort, suggesting that some historic counts of piping plovers by one or a few observers may have underestimated the piping plover population. Thus, the magnitude of the species decline may have been more severe than available numbers imply.

Since its 1986 listing under the ESA, the Atlantic Coast population estimate (Service 2011a) has increased 234 percent by 2009, and the U.S. portion of the population has almost tripled. Even discounting apparent increases in New York, New Jersey, and North Carolina between 1986 and 1989, which likely were due in part to increased census effort (Service 1996), the population nearly doubled between 1989 and 2008. The largest population increase between 1989 and 2009 has occurred in New England (266 percent), followed by New York-New Jersey (70 percent). In the Southern (DE-MD-VA-NC) Recovery Unit, net growth between 1989 and 2009 was 52 percent, but almost all of this increase occurred in two years, 2003 to 2005. The eastern Canada population fluctuated from year to year, with increases often quickly eroded in subsequent years; net growth between 1989 and 2009 was 8 percent. The overall population growth pattern was tempered by periodic rapid declines in the Southern and Eastern Canada Recovery Units. The eastern Canada population decreased 21 percent in just three years (2002 to 2005), and the population in the southern half of the Southern Recovery Unit declined 68 percent in seven years (1995 to 2001). The recent 64 percent decline in the Maine population from 2002 to 2008, following only a few years of decreased productivity, provides an example of the continuing risk of rapid and precipitous reversals in population growth.

### **Status and distribution**

#### *Nonbreeding (migrating and wintering) Range*

Piping plovers spend up to 10 months of their life cycle on their migration and wintering grounds, generally July 15 through as late as May 15. Piping plover migration routes and habitats overlap breeding and wintering habitats, and, unless banded, migrants passing through a site usually are indistinguishable from breeding or wintering piping plovers. Migration stopovers by banded piping plovers from the Great Lakes have been documented in New Jersey, Maryland, Virginia, and North Carolina (Stucker and Cuthbert 2006). Migrating breeders from eastern Canada have been observed in Massachusetts, New Jersey, New York, and North Carolina (Amirault et al. 2005). Staging piping plovers have been tallied at various sites in the Atlantic breeding range (Perkins 2008 pers. comm.), but the composition (e.g., adults that nested nearby and their fledged young of the year versus migrants moving to or from sites farther north), stopover duration, and local movements are unknown. Review



of published records of piping plover sightings throughout North America by Pompei and Cuthbert (2004) found more than 3,400 fall and spring stopover records at 1,196 sites. Published reports indicated that piping plovers do not concentrate in large numbers at inland sites and that they seem to stop opportunistically. In most cases, reports of birds at inland sites were single individuals. In general, distance between stopover locations and duration of stopovers throughout the coastal migration range remains poorly understood.

Piping plovers migrate through and winter in coastal areas of the U.S. from North Carolina to Texas and in portions of Mexico and the Caribbean. Four range-wide, mid-winter (late January to early February) IPPC population surveys, conducted at five-year intervals starting in 1991, are summarized in Table 3. Total numbers have fluctuated over time, with some areas experiencing increases and others decreases. In 2001, only 40 percent of the known breeding birds recorded during a breeding census were accounted for during a winter census (Ferland and Haig 2002). About 89 percent of birds that are known to winter in the U.S. do so along the Gulf Coast (Texas to Florida), while 8 percent winter along the Atlantic Coast (North Carolina to Florida).

Table 3. Results of the 1991, 1996, 2001, and 2006 IPPCs of wintering birds (Haig et al. 2005, Elliott-Smith et al. 2009).

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

Regional and local fluctuations may reflect the quantity and quality of suitable foraging and roosting habitat, which vary over time in response to natural coastal formation processes as well as anthropogenic habitat changes (e.g., inlet relocation, dredging of shoals and spits). See, for example, discussions of survey number changes in Mississippi, Louisiana, and Texas by Winstead, Baka, and Cobb, respectively, in Elliott-Smith et al. (2009). Fluctuations may also represent localized weather conditions (especially wind) during surveys, or unequal survey coverage. For example, airboats facilitated first-time surveys of several central Texas sites in 2006 (Cobb in Elliott-Smith et al. 2009). Similarly, the increase in the 2006 numbers in the Bahamas is attributed to greatly increased census efforts; the extent of additional habitat not surveyed remains undetermined (Maddock and Wardle in Elliott-Smith et al. 2009). Changes in wintering numbers may also be influenced by growth or decline

in the particular breeding populations that concentrate their wintering distribution in a given area. Major opportunities to locate previously unidentified wintering sites are concentrated in the Caribbean and Mexico (see pertinent sections in Elliott-Smith et al. 2009). Further surveys and assessment of seasonally emergent habitats (e.g., sea grass beds, mudflats, oyster reefs) within bays lying between the mainland and barrier islands in Texas are also needed.

Mid-winter surveys may substantially underestimate the abundance of nonbreeding piping plovers using a site or region during other months. Local movements of nonbreeding piping plovers may also affect abundance estimates. At Deveaux Bank, South Carolina, five counts at approximately 10-day intervals between August 27 and October 7, 2006, oscillated from 28 to 14 to 29 to 18 to 26 birds (Maddock et al. 2009). Noel and Chandler (2008) detected banded Great Lakes piping plovers known to be wintering on their Georgia study site in  $73.8 \pm 8.1$  percent of surveys over three years. Abundance estimates for nonbreeding piping plovers may also be affected by the number of surveyor visits to the site. Preliminary analysis of detection rates by Maddock et al. (2009) found 87 percent detection during the mid-winter period on core sites surveyed three times a month during fall and spring and one time per month during winter, compared with 42 percent detection on sites surveyed three times per year (Cohen 2009 pers. comm.).

Gratto-Trevor et al. (2009; Figure 4) found strong patterns (but no exclusive partitioning) in winter distribution of uniquely banded piping plovers from four breeding populations. All eastern Canada and 94 percent of Great Lakes birds wintered from North Carolina to southwest Florida. However, eastern Canada birds were more heavily concentrated in North Carolina, and a larger proportion of Great Lakes piping plovers were found in South Carolina and Georgia. Northern Great Plains populations were primarily seen farther west and south, especially on the Texas Gulf Coast. Although the great majority of Prairie Canada individuals were observed in Texas, particularly southern Texas, individuals from the U.S. Great Plains were more widely distributed on the Gulf Coast from Florida to Texas.

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

This species exhibits a high degree of intra- and inter-annual wintering site fidelity (Nicholls and Baldassarre 1990a; Drake et al. 2001; Noel et al. 2005; Stucker and Cuthbert 2006). Gratto-Trevor et al. (2009) reported that six of 259 banded piping plovers observed more than once per winter moved across boundaries of the seven U.S. regions. Of 216 birds observed in different 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. 2009; Figure 4).

Local movements are more common. In South Carolina, Maddock et al. (2009) documented many cross-inlet movements by wintering banded piping plovers as well as occasional movements of up to 11 miles by approximately 10 percent of the banded population; larger movements within South Carolina were seen during fall and spring migration. Similarly, eight banded piping plovers that were

observed in two locations during 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 2004 and 2005 hurricane seasons affected a substantial amount of habitat along the Gulf Coast. Habitats such as those along Gulf Islands National Seashore have benefited from increased over-wash events, which created optimal habitat conditions for piping plovers. Conversely, hard shoreline structures put into place following storms throughout the species range to prevent such shoreline migration prevent habitat creation. Four hurricanes between 2002 and 2005 are often cited in reference to rapid erosion of the Chandeleur Islands, a chain of low-lying islands off the coast of Louisiana where the 1991 IPPC tallied more than 350 piping plovers. Those same storms, however, created habitats such as over-wash fans and sand spits on barrier islands and headlands in other portions of Louisiana. (See the Storm events section below for more details on their effects to habitat.)

The Service is aware of the following site-specific conditions that benefit several habitats piping plover use while wintering and migrating, including critical habitat units. In Texas, one critical habitat unit was afforded greater protection due to the acquisition of adjacent upland properties by the local Audubon chapter. On another unit in Texas, vehicles were removed from a portion of the beach decreasing the likelihood of automobile disturbance to plovers. Exotic plant removal that threatens to invade suitable piping plover habitat is occurring in a critical habitat unit in South Florida. The Service and other government agencies remain in a contractual agreement with the U.S. Department of Agriculture (USDA) for predator control within limited coastal areas in the Florida panhandle, including portions of some critical habitat units. Continued removal of potential terrestrial predators is likely to enhance survivorship of wintering and migrating piping plovers. In North Carolina, one critical habitat unit was afforded greater protection when the local Audubon chapter agreed to manage the area specifically for piping plovers and other shorebirds following the relocation of the nearby inlet channel.

#### *Recovery criteria*

##### Northern Great Plains Population (Service 1988, 1994)

1. Increase the number of birds in the U.S. northern Great Plains states to 2,300 pairs (Service 1994).
2. Increase the number of birds in the prairie region of Canada to 2,500 adult piping plovers (Service 1988).
3. Secure long term protection of essential breeding and wintering habitat (Service 1994).

##### Great Lakes Population (Service 2003)

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

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

#### Atlantic Coast Population (Service 1996)

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

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

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

#### *Threats to piping plovers/critical habitat*

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

#### Present or threatened destruction, modification, or curtailment of its habitat or range

The status of piping plovers on winter and migration grounds is difficult to assess, but threats to piping plover habitat used during winter and migration (identified by the Service during its designation of critical habitat) continue to affect the species. Unregulated motorized and pedestrian recreational use, inlet and shoreline stabilization projects, beach maintenance and nourishment, and pollution affect most winter and migration areas. Conservation efforts at some locations have likely resulted in the enhancement of wintering habitat.

The 1985 final listing rule stated that the number of piping plovers on the Gulf of Mexico coastal wintering grounds might be declining as indicated by preliminary analysis of Christmas Bird Count data. Independent counts of piping plovers on the Alabama coast indicated a decline in numbers between the 1950s and early 1980s. At the time of listing, the Texas Parks and Wildlife Department stated that 30 percent of wintering habitat in Texas had been lost over the previous 20 years. The final rule also stated that in addition to extensive breeding area problems, the loss and modification of wintering habitat was a significant threat to the piping plover.

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

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

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

#### Sand placement projects

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

Past and ongoing stabilization projects may fundamentally alter the naturally dynamic coastal processes that create and maintain beach strand and bayside habitats, including those habitat components that piping plovers rely upon. Although impacts may vary depending on a range of factors, stabilization projects may directly degrade or destroy piping plover roosting and foraging habitat in several ways. Front beach habitat may be used to construct an artificial berm that is densely planted in grass, which can directly reduce the availability of roosting habitat. Over time, if the beach narrows due to erosion, additional roosting habitat between the berm and the water can be lost. Berms can also prevent or reduce the natural over-wash that creates roosting habitats by converting vegetated areas to open sand areas. The vegetation growth caused by impeding natural over-wash can also reduce the maintenance and creation of bayside intertidal feeding habitats. In addition, stabilization projects may indirectly encourage further development of coastal areas and increase the threat of disturbance.

At least 668 of 2,340 coastal shoreline miles (29 percent of beaches throughout the piping plover winter and migration range in the U.S.) are bermed, nourished, or renourished, generally for recreational purposes and to protect commercial and private infrastructure (Table 4). However, only approximately 54 miles or 2.31 percent of these impacts have occurred within critical habitat.

Table 4. Summary of the extent of nourished beaches in piping plover wintering and migrating habitat within the conterminous United States. Data extracted from Service unpublished data (project files, gray literature, and field observations) as of 2009.

State	Sandy beach shoreline miles available	Sandy beach shoreline miles nourished to date (within CH <sup>g</sup> units)	Percent of sandy beach shoreline affected (within CH <sup>g</sup> units)
North Carolina	301 <sup>a</sup>	117 <sup>e</sup> (unknown)	39 (unknown)
South Carolina	187 <sup>a</sup>	56 (0.6)	30 (0.32)
Georgia	100 <sup>a</sup>	8 (0.4)	8 (0.40)
Florida	825 <sup>b</sup>	404 (6) <sup>f</sup>	49 (0.72)
Alabama	53 <sup>a</sup>	12 (2)	23 (3.77)
Mississippi	110 <sup>c</sup>	≥6 (0)	5 (0)
Louisiana	397 <sup>a</sup>	Unquantified (generally restoration-oriented)	Unknown
Texas	367 <sup>d</sup>	65 (45)	18 (12.26)
Overall Total	2,340 (does not include Louisiana)	≥668 does not include Louisiana (54 in CH)	29% (≥2.31% in CH)

(a) Data from [www.50states.com](http://www.50states.com); (b) Clark 1993; (c) N. Winstead, Mississippi Museum of Natural Science, in lit. 2008; (d) [www.Sufrider.org](http://www.Sufrider.org); (e) Hall 2009 pers. comm.; (f) Partial data from Lott et al. (2009); (g) CH = critical habitat.

In Louisiana, the sustainability of the coastal ecosystem is threatened by the inability of the barrier islands to maintain geomorphologic functionality (USACE 2011). Consequently, most of the planned sediment placement projects are conducted as environmental restoration projects by various Federal and State agencies because without the sediment many areas would erode below sea level since the Louisiana coastal systems are starved for sediment sources. Agencies conducting coastal restoration projects aim to design projects that mimic the natural existing elevations of coastal habitats (e.g., beach, dune, and marsh) in order to allow their projects to work within and be sustained by the natural ecosystem processes that maintain those coastal habitats. Due to the low elevation of barrier islands and coastal headlands, placement of additional sediment in those areas generally does not reach an elevation that would prevent the formation of over-wash areas or impede natural coastal processes, especially during storm events. Such careful design of these restoration projects allows daily tidal

processes or storm events to re-work the sediments to reform the Gulf/beach interface and create over-wash areas, sand flats, and mud flats on the bay-side of the islands, as well as sand spits on the ends of the islands; thus, the added sediment aids in sustaining the barrier island system.

Sediment placement also temporarily affects the benthic fauna found in intertidal systems by covering them with a layer of sediment. Some benthic species can burrow through a thin layer (varies from 15 to 35 inches for different species) of additional sediment since they are adapted to the turbulent environment of the intertidal zone; however, thicker layers (i.e., greater than 40 inches) of sediment are likely to smother the benthic fauna (Greene 2002). Various studies of such effects indicate that the recovery of benthic fauna after beach renourishment or sediment placement can take anywhere from six months to two years (Rakocinski et al. 1996; Peterson et al. 2000; Peterson et al. 2006). Such delayed recovery of benthic prey species temporarily affects the quality of piping plover foraging habitat.

#### Inlet stabilization/relocation

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

Using Google Earth© (accessed April 2009), Service biologists visually estimated the number of navigable mainland or barrier island tidal inlets throughout the wintering range of the piping plover in the conterminous U.S. that have some form of hardened structure. This includes seawalls or adjacent development, which lock the inlets in place (Table 5).

Table 5. Visually estimated numbers of navigable mainland and barrier island inlets and hardened inlets by state.

State	Number of navigable mainland and barrier island inlets	Number of hardened inlets	Percent of inlets affected
North Carolina	20	2.5*	12.5%
South Carolina	34	3.5*	10.3%
Georgia	26	2	7.7%
Florida	82	41	50%
Alabama	14	6	42.9%
Mississippi	16	7	43.8%
Louisiana	40	9	22.5%
Texas	17	10	58.8%
Overall Total	249	81	32.5%

\*An inlet at the state line is considered to be half an inlet counted in each state.

Tidal inlet relocation can cause loss and/or degradation of piping plover habitat; although less permanent than construction of hard structures, effects can persist for years. For example, a project on Kiawah Island, South Carolina, degraded one of the most important piping plover habitats in the State by reducing the size and physical characteristics of an active foraging site, changing the composition of the benthic community, decreasing the tidal lag in an adjacent tidal lagoon, and decreasing the exposure time of the associated sand flats (Service and Town of Kiawah Island 2006). In 2006, pre-project piping plover numbers in the project area recorded during four surveys conducted at low tide averaged 13.5 piping plovers. This contrasts with a post-project average of 7.1 plovers during eight surveys (four in 2007 and four in 2008) conducted during the same months (Service and Town of Kiawah Island 2006), indicating that reduced habitat quality was one possible cause of the lower usage by plovers. Service biologists are aware of at least seven inlet relocation projects (two in North Carolina, three in South Carolina, two in Florida), but this number likely under-represents the extent of this activity.

### Sand mining/dredging

Sand mining, the practice of extracting (dredging) sand from sand bars, shoals, and inlets in the near-shore zone, is a less expensive source of sand than obtaining sand from offshore shoals for beach nourishment. Sand bars and shoals are sand sources that move onshore over time and act as natural breakwaters. Inlet dredging reduces the formation of exposed ebb and flood tidal shoals considered to be primary or optimal piping plover roosting and foraging habitat. Removing these sand sources can alter depth contours and change wave refraction as well as cause localized erosion (Hayes and Michel 2008). Exposed shoals and sandbars are also valuable to piping plovers, as they tend to receive less human recreational use (because they are only accessible by boat) and therefore provide relatively less disturbed habitats for birds. We do not have a good estimate of the amount of sand mining that occurs across the piping plover wintering range, nor do we have a good estimate of the number of inlet dredging projects that occur. This number is likely greater than the number of total jettied inlets shown in Table 5, since most jettied inlets need maintenance dredging, but non-hardened inlets are often dredged as well.

### Groins

Groins (structures made of concrete, rip rap, wood, or metal built perpendicular to the beach in order to trap sand) are typically found on developed beaches with severe erosion. Although groins can be individual structures, they are often clustered along the shoreline. Groins can act as barriers to long-shore sand transport and cause down-drift erosion (Hayes and Michel 2008), which prevents piping plover habitat creation by limiting sediment deposition and accretion. These structures are found throughout the southeastern Atlantic Coast, and although most were in place prior to the piping plover's 1986 listing under the Act, installation of new groins continues to occur.

### Seawalls and revetments

Seawalls and revetments are vertical hard structures built parallel to the beach in front of buildings, roads, and other facilities to protect them from erosion. However, these structures often accelerate erosion by causing scouring in front of and down-drift from the structure (Hayes and Michel 2008), which can eliminate intertidal foraging habitat and adjacent roosting habitat. Physical characteristics that determine microhabitats and biological communities can be altered after installation of a seawall



or revetment, thereby depleting or changing composition of benthic communities that serve as the prey base for piping plovers. At four California study sites, each comprised of an unarmored segment and a segment seaward of a seawall, Dugan and Hubbard (2006) found that armored segments had narrower intertidal zones, smaller standing crops of macrophyte wrack, and lower shorebird abundance and species richness. Geotubes (long cylindrical bags made of high-strength permeable fabric and filled with sand) are softer alternatives, but act as barriers by preventing over-wash. We did not find any sources that summarize the linear extent of seawall, revetment, and geotube installation projects that have occurred across the piping plover's wintering and migration habitat.

### Exotic/invasive vegetation

A recently identified threat to piping plover habitat, not described in the listing rule or recovery plans, is the spread of coastal invasive plants into suitable piping plover habitat. Like most invasive species, coastal exotic plants reproduce and spread quickly and exhibit dense growth habits, often outcompeting native plant species. If left uncontrolled, invasive plants cause a habitat shift from open or sparsely vegetated sand to dense vegetation, resulting in the loss or degradation of piping plover roosting habitat, which is especially important during high tides and migration periods.

Beach vitex (*Vitex rotundifolia*) is a woody vine introduced into the southeastern U.S. as a dune stabilization and ornamental plant (Westbrooks and Madsen 2006). It currently occupies a very small percentage of its potential range in the U.S.; however, it is expected to grow well in coastal communities throughout the southeastern U.S. from Virginia to Florida, and west to Texas (Westbrooks and Madsen 2006). In 2003, the plant was documented in New Hanover, Pender, and Onslow counties in North Carolina, and at 125 sites in Horry, Georgetown, and Charleston counties in South Carolina. One Chesapeake Bay site in Virginia was eradicated, and another site on Jekyll Island, Georgia, is about 95 percent controlled (Suiter 2009 pers. comm.). Beach vitex has been documented from two locations in northwest Florida, but one site disappeared after erosional storm events. The landowner of the other site has indicated an intention to eradicate the plant, but follow through is unknown (Farley 2009 pers. comm.). The task forces formed in North and South Carolina in 2004 and 2005 have made great strides to remove this plant from their coasts. To date, about 200 sites in North Carolina have been treated, with 200 additional sites in need of treatment. Similar efforts are underway in South Carolina.

Unquantified amounts of crowfoot grass (*Dactyloctenium aegyptium*) grow invasively along portions of the Florida coastline. It forms thick bunches or mats that may change the vegetative structure of coastal plant communities and alter shorebird habitat. The Australian pine (*Casuarina equisetifolia*) also changes the vegetative structure of the coastal community in south Florida and islands within the Bahamas. Shorebirds prefer foraging in open areas where they are able to see potential predators, and tall trees provide good perches for avian predators. Australian pines potentially impact shorebirds, including the piping plover, by reducing attractiveness of foraging habitat and/or increasing avian predation.

The propensity of these exotic species to spread, and their tenacity once established, make them a persistent threat, partially countered by increasing landowner awareness and willingness to undertake eradication activities.

### 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. 2009) and many other shorebirds on their winter, breeding, and migration grounds. Because shorebird numbers are positively correlated with wrack cover and biomass of their invertebrate prey that feed on wrack (Tarr and Tarr 1987; Hubbard and Dugan 2003; Dugan et al. 2003), beach grooming will lower bird numbers (Defeo et al. 2009).

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

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

We estimate that 240 of 825 miles (29 percent) of sandy beach shoreline in Florida are cleaned or raked on various schedules (i.e., daily, weekly, monthly) (FDEP 2008). Service biologists estimate that South Carolina mechanically cleans approximately 34 of its 187 shoreline miles (18 percent), and Texas mechanically cleans approximately 20 of its 367 shoreline miles (5.4 percent). In Louisiana, beach raking occurs on Grand Isle (the state’s only inhabited island) along approximately 8 miles of shoreline, roughly 2 percent of the state’s 397 sandy shoreline miles. We are not aware of what percentage of mechanical cleaning occurs elsewhere in piping plover critical habitat.

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

### Disease

Neither the final listing rule nor the recovery plans state that disease is an issue for the species, and no plan assigns recovery actions to this threat factor. Based on information available to date, West Nile virus and avian influenza are a minor threat to piping plovers (Service 2009a).

### Predation

The impact of predation on migrating or wintering piping plovers remains largely undocumented. Except for one incident reported in 2007 by the New York Times involving a cat in Texas, no depredation of piping plovers during winter or migration has been noted, although it would be difficult to document. Avian and mammalian predators are common throughout the species’ wintering range. Predatory birds are relatively common during fall and spring migration, and it is possible that raptors

occasionally take piping plovers (Drake et al. 2001). The 1996 Atlantic Coast Recovery Plan summarized evidence that human activities affect types, numbers, and activity patterns of some predators, thereby exacerbating natural predation on breeding piping plovers. It has been noted, however, that the behavioral response of crouching when in the presence of avian predators may minimize avian predation on piping plovers (Morrier and McNeil 1991; Drake 1999a; Drake et al. 2001).

Piping plovers may reap some collateral benefits from predator management on their migration and wintering grounds conducted for the primary benefit of other species. In 1997, the USDA implemented a public lands predator control partnership in northwest Florida that included the Department of Defense, National Park Service (NPS), the State of Florida (state park lands), and the Service (National Wildlife Refuges and Ecological Services). The program continues with all partners except Florida – in 2008, lack of funding precluded inclusion of Florida state lands (although Florida Department of Environmental Protection staff conduct occasional predator trapping on state lands, trapping is not implemented consistently). The NPS and individual state park staff in North Carolina participate in predator control programs (Rabon 2009 pers. comm.). The Service issued permit conditions for raccoon eradication to Indian River County staff in Florida as part of a coastal Habitat Conservation Plan (Adams 2009 pers. comm.). Destruction of turtle nests by dogs or coyotes in the Indian River area justified the need to amend the permit to include an education program targeting dog owners regarding the appropriate means to reduce impacts to coastal species caused by their pets. The Service partnered with Texas Audubon and the Coastal Bend Bays and Estuaries Program in Texas to implement predator control efforts on colonial water bird nesting islands (Cobb 2009 pers. comm.). Some of these predator control programs may provide limited protection to piping plovers, should they use these areas for roosting or foraging. Table 6 summarizes predator control actions on a state-by-state basis. The Service is not aware of any current predator control programs targeting protection of coastal species in Georgia, Alabama, Mississippi, or Louisiana.

Table 6. Summary of predator control programs that may benefit piping plovers on winter and migration grounds (as of 2009).

<b>State</b>	<b>Entities with Predator Control Programs</b>
North Carolina	State Parks, Cape Lookout and Cape Hatteras National Seashores.
South Carolina	As needed throughout the state, targets raccoons and coyotes.
Georgia	No programs known.
Florida	Merritt Island NWR, Cape Canaveral AFS, Indian River County, Eglin AFB, Gulf Islands NS, northwest Florida state parks (up until 2008), St. Vincent NWR, Tyndall AFB.
Alabama	Late 1990's Gulf State Park and Orange Beach for beach mice, no current programs known.
Mississippi	No programs known.
Louisiana	No programs known.
Texas	Aransas NWR (hog control for habitat protection), Audubon (mammalian predator control on colonial water bird islands that have occasional piping plover use).

Regarding predation, the magnitude of this threat to nonbreeding piping plovers remains unknown, but given the pervasive, persistent, and serious impacts of predation on other coastal reliant species, it remains a potential threat. Focused research to confirm impacts as well as to ascertain effectiveness of predator control programs may be warranted, especially in areas frequented by Great Lakes birds

during migration and wintering months. We consider predator control on their wintering and migration grounds to be a low priority at this time.<sup>2</sup>

### Human disturbance

Disturbance (i.e., human and pet presence that alters bird behavior) disrupts piping plovers as well as other shorebird species. Intense human disturbance in shorebird winter habitat can be functionally equivalent to habitat loss if the disturbance prevents birds from using an area for a significant amount of time (Goss-Custard et al. 1996), which can lead to roost abandonment and local population declines (Burton et al. 1996). Pfister et al. (1992) implicate anthropogenic disturbance as a factor in the long-term decline of migrating shorebirds at staging areas. Disturbance can also cause shorebirds to spend less time roosting or foraging and more time in alert postures or fleeing from the disturbances (Johnson and Baldassarre 1988; Burger 1991; Burger 1994; Elliott and Teas 1996; Lafferty 2001a, 2001b; Thomas et al. 2002), which limits the local abundance of piping plovers (Zonick and Ryan 1995; Zonick 2000). Shorebirds that are repeatedly flushed in response to disturbance expend energy on costly short flights (Nudds and Bryant 2000) and may not feed enough to support migration and/or subsequent breeding efforts (Puttick 1979; Lafferty 2001b).

Elliott and Teas (1996) found a significant difference in actions between piping plovers encountering pedestrians and those not encountering pedestrians. Piping plovers encountering pedestrians spend proportionately more time in non-foraging behavior. This study suggests that interactions with pedestrians on beaches cause birds to shift their activities from calorie acquisition to calorie expenditure. In wintering and migration sites, human disturbance continues to decrease the amount of undisturbed habitat and appears to limit local piping plover abundance (Zonick and Ryan 1995).

Shorebirds are more likely to flush from the presence of dogs than people, and birds react to dogs from farther distances than people (Lafferty 2001a, 2001b; Thomas et al. 2002). Dogs off leash are more likely to flush piping plovers from farther distances than are dogs on leash; nonetheless, dogs both on and off leashes disturb piping plovers (Hoopes 1993). Pedestrians walking with dogs often go through flocks of foraging and roosting shorebirds, which may increase the likelihood that dogs would chase birds. Although the timing, frequency, and duration of human and dog presence throughout the wintering range are unknown, studies in Alabama and South Carolina suggest that most disturbances to piping plovers occur during periods of warmer weather, which coincides with piping plover migration (Johnson and Baldassarre 1988; Lott et al. 2009; Maddock et al. 2009). Smith (2007) documents varying disturbance levels throughout the nonbreeding season at northwest Florida sites.

Off-road vehicles can significantly degrade piping plover habitat (Wheeler 1979) or disrupt the birds' normal behavior patterns (Zonick 2000). The 1996 Atlantic Coast Recovery Plan cites tire ruts crushing wrack into the sand, making it unavailable as cover or as foraging substrate (Hoopes 1993; Goldin 1993). The plan also notes that the magnitude of the threat from off-road vehicles is particularly significant, because vehicles extend impacts to remote stretches of beach where human disturbance will otherwise be very slight. Godfrey et al. (1978, 1980 as cited in Lamont et al. 1997) postulated that vehicular traffic along the beach may compact the substrate and kill marine invertebrates that are food for the piping plover. Zonick (2000) found that the density of off-road vehicles negatively correlated with abundance of roosting piping plovers on the ocean beach. Cohen et al. (2008a) found that radio-tagged piping plovers using ocean beach habitat at Oregon Inlet in North

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<sup>2</sup> The threat of direct predation should be distinguished from the threat of disturbance to roosting and feeding piping plovers posed by dogs off leash.

Carolina were far less likely to use the north side of the inlet where off-road vehicle use is allowed, and recommended controlled management experiments to determine if recreational disturbance drives roost site selection. Ninety-six percent of piping plover detections occurred on the south side of the inlet even though it was farther away from foraging sites (1.1 miles from the sound side foraging site to the north side of the inlet versus 0.25-mile from the sound side foraging site to the north side of the inlet) (Cohen et al. 2008a).

Based on surveys with land managers and biologists, knowledge of local site conditions, and other information, the Service has estimated the levels of eight types of disturbance at sites in the U.S. with wintering piping plovers. Table 7 summarizes the disturbance analysis results (Service 2009b). Data are not available on human disturbance at wintering sites in the Bahamas, other Caribbean countries, or Mexico. There are few areas used by wintering piping plovers that are devoid of human presence, and just under half have leashed and unleashed dog presence (Smith 2007; Lott et al. 2009, Service unpublished data 2009; Maddock and Bimbi unpublished data).

Table 7. Percent of known piping plover winter and migration habitat locations, by state, where various types of anthropogenic disturbance have been reported.

Disturbance Type	Percent by State							
	AL	FL	GA	LA	MS	NC	SC	TX
Pedestrians	67	92	94	25	100	100	88	54
Dogs on leash	67	69	31	25	73	94	25	25
Dogs off leash	67	81	19	25	73	94	66	46
Bikes	0	19	63	25	0	0	28	19
ATVs <sup>a</sup>	0	35	0	25	0	17	25	30
ORVs <sup>b</sup>	0	21	0	25	0	50	31	38
Boats	33	65	100	100	0	78	63	44
Kite surfing	0	10	0	0	0	33	0	0

(a) ATV = all-terrain vehicle; (b) ORV = off-road vehicle

LeDee et al. (2010) collected survey responses in 2007 from 35 managers (located in seven states) at sites that were designated as critical habitat for wintering piping plovers. Ownership included federal, state, and local governmental agencies and non-governmental organizations managing national wildlife refuges; national, state, county, and municipal parks; state and estuarine research reserves; state preserves; state wildlife management areas; and other types of managed lands. Of 43 reporting sites, 88 percent allowed public beach access year-round and four sites were closed to the public. Sixty-two percent of site managers reported greater than 10,000 visitors from September through March, and 31 percent reported greater than 100,000 visitors. Restrictions on visitor activities on the beach included automobiles (at 81 percent of sites), all-terrain vehicles (89 percent), and dogs during the winter season (50 percent). Half of the survey respondents reported funding as a primary limitation in managing piping plovers and other threatened and endangered species at their sites. Other limitations included “human resource capacity” (24 percent), conflicting management priorities (12 percent), and lack of research (3 percent).

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

In summary, although there is some variability among states, disturbance from human activities and pets poses a moderate to high and escalating threat to migrating and wintering piping plovers. Systematic review of recreation policy and beach management across the nonbreeding range will assist in better understanding cumulative impacts. Site-specific analysis and implementation of conservation measures should be a high priority at piping plover sites that have moderate or high levels of disturbance. The Service and state wildlife agencies should increase technical assistance to land managers to implement management strategies and monitor their effectiveness.

Military Actions

Twelve coastal military bases are located in the Southeast. To date, five bases have consulted with the Service under section 7 of the Act, on military activities on beaches and baysides that may affect piping plovers or their habitat (Table 8). Camp Lejeune in North Carolina consulted formally with the Service in 2002 on troop activities, dune stabilization efforts, and recreational use of Onslow Beach. The permit conditions require twice-monthly piping plover surveys and use of buffer zones and work restrictions within buffer zones. Naval Air Station-Mayport in Duval County, Florida, consulted with the Service on Marine USACE training activities that included beach exercises and use of amphibious assault vehicles. The area of impact was not considered optimal for piping plovers, and the consultation was concluded informally. Similar informal consultations have occurred with Tyndall Air Force Base (Bay County) and Eglin Air Force Base (Okaloosa and Santa Rosa counties) in northwest Florida. Both consultations dealt with occasional use of motorized equipment on the beaches and associated baysides. Tyndall Air Force Base has minimal on-the-ground use, and activities, when conducted, occur on the Gulf of Mexico beach, which is not considered the optimal area for piping plovers within this region. Eglin Air Force Base conducts bi-monthly surveys for piping plovers, and habitats consistently documented with piping plover use are posted with avoidance requirements to minimize direct disturbance from troop activities. A 2001 consultation with the Navy for one-time training and retraction operations on Peveto Beach, in Cameron Parish, Louisiana, concluded informally.

Table 8. Military bases that occur within the wintering/migration range of piping plovers and contain piping plover habitat.

State	Coastal Military Bases
North Carolina	Camp Lejeune*
South Carolina	No coastal beach bases
Georgia	Kings Bay Naval Base
Florida	Key West Base, Naval Air Station-Mayport*, Cape Canaveral Air Force Station, Patrick AFB, MacDill AFB, Eglin AFB*, Tyndall AFB*
Alabama	No coastal beach bases
Mississippi	Keesler AFB
Louisiana	No coastal beach bases
Texas	Corpus Christi Naval Air Station

\*Bases which conduct activities that may affect piping plovers or their habitat.

Overall, project avoidance and minimization actions currently reduce threats from military activities to wintering and migrating piping plovers to a minimal threat level. However, prior to removal of the piping plover from protection under the Act, Integrated Resource Management Plans or other agreements should clarify if and how a change in legal status would affect plover protections.

## Environmental contaminants

Contaminants have the potential to cause direct toxicity to individual birds or negatively affect their invertebrate prey base (Rattner and Ackerson 2008). Depending on the type and degree of contact, contaminants can have lethal and sub-lethal effects on birds, including behavioral impairment, deformities, and impaired reproduction (Rand and Petrocelli 1985; Gilbertson et al. 1991; Hoffman et al. 1996). The Great Lakes Recovery Plan (Service 2003) states that concentration levels of polychlorinated biphenol (PCB) detected in Michigan piping plover eggs have the potential to cause reproductive harm. The recovery plan also states that analysis of prey available to piping plovers at representative Michigan breeding sites indicated that breeding areas along the upper Great Lakes region are not likely the major source of contaminants to this population.

Petroleum products are the contaminants of primary concern, as opportunities exist for petroleum to pollute intertidal habitats that provide foraging substrate. Impacts to piping plovers from oil spills have been documented throughout their life cycle (Chapman 1984; Service 1996; Burger 1997; Massachusetts Audubon 2003; Amirault-Langlais et al. 2007; Amos 2009 pers. comm.). This threat persists due to the high volume of shipping vessels (from which most documented spills have originated) traveling offshore and within connected bays along the Atlantic Coast and the Gulf of Mexico. Additional risks exist for leaks or spills from offshore oil rigs, associated undersea pipelines, and onshore facilities such as petroleum refineries and petrochemical plants. Beach-stranded 55-gallon barrels and smaller containers, which may fall from moving cargo ships or offshore rigs and are not uncommon on the Texas coast, contain primarily oil products (gasoline or diesel), as well as other chemicals such as methanol, paint, organochlorine pesticides, and detergents (Lee 2009 pers. comm.). Federal and state land managers have protective provisions in place to secure and remove the barrels, thus reducing the likelihood of contamination.

Lightly oiled piping plovers have survived and successfully reproduced (Chapman 1984; Amirault-Langlais et al. 2007; Amos 2009 pers. comm.). Chapman (1984) noted shifts in habitat use as piping plovers moved out of spill areas. This behavioral change was believed to be related to the demonstrated decline in benthic infauna (prey items) in the intertidal zone and may have decreased the direct impact to the species. To date, no plover mortality has been attributed to oil contamination outside the breeding grounds, but latent effects would be difficult to prove.

## Oil spills

On April 20, 2010, an explosion and fire occurred on the mobile offshore drilling unit Deepwater Horizon, which was being used to drill a well in the Macondo prospect (Mississippi Canyon 252) (Natural Resource Trustees 2012). The rig sank and left the well releasing tens of thousands of barrels of oil per day into the Gulf of Mexico. It is estimated that 5 million barrels (210 million gallons) of oil were released from the Macondo wellhead. Of that, approximately 4.1 million barrels (172 million gallons) of oil were released directly into the Gulf of Mexico over nearly three months. In what was the largest and most prolonged offshore oil spill in U.S. history, oil and dispersants impacted all aspects of the coastal and oceanic ecosystems (Natural Resource Trustees 2012). At the end of July 2010, approximately 625 miles of Gulf of Mexico shoreline were oiled. By the end of October, 93 miles were still affected by moderate to heavy oil, and 483 miles of shoreline were affected by light to trace amounts of oil (Service 2012a; Unified Area Command 2010). These numbers reflect weekly snapshots of shorelines experiencing impacts from oil and do not include cumulative impacts or shorelines that had already been cleaned (Bimbi 2012 pers. comm.; Service 2012a). Limited cleanup operations were still ongoing throughout the spill area in November 2012 (Service 2012a). A NRDAR

case to assess injury to wildlife resources is in progress (Natural Resource Trustees 2012), but due to the legal requirements of the NRDAR process, avian injury information, including any impacts to red knots, has not been released (Tuttle 2012 pers. comm.).

The USCG, the states, and responsible parties that form the Unified Area Command (with advice from federal and state natural resource agencies) initiated protective measures and clean-up efforts per prepared contingency plans to deal with petroleum and other hazardous chemical spills for each state's coastline. The contingency plans identify sensitive habitats, including all federally listed species' habitats, which receive a higher priority for response actions. Those plans allow for immediate habitat protective measures for clean-up activities in response to large contaminant spills. While such plans usually ameliorate the threat to piping plovers, their effectiveness has yet to be determined in this particular incident.

The Operational Science Advisory Team (OSAT-2) of the Gulf Coast Incident Management Team published the *Summary Report for Fate and Effects of Remnant Oil Remaining in the Beach Environment* on February 10, 2011. The OSAT-2 report indicates that:

“Much of the oil residue on and near the shoreline has been cleaned during the Response phase of the oil spill. As the Gulf shoreline is a dynamic environment, oil residue that is uncovered or moved onto beaches (for example, tar residue balls) will continue to be removed as part of the Monitoring and Maintenance phase of the recovery. Three types of located oil residue were identified as particularly challenging, or potentially damaging to the environment if removed. These three types are the following: supratidal buried oil (SBO), small surface residual balls (SSRBs), and surf zone submerged oil mats (SOM). Previous oil spills have demonstrated that removing oil residue from shoreline environments can cause more harm to the ecosystem than leaving the residue in place.”

Thus, specific guidelines for the Monitoring and Maintenance phase of recovery have been developed to determine whether certain oiled habitats warrant further cleaning depending upon the anticipated damage to the environment by oil removal activities. In addition, NRDAR studies regarding potential effects to fish and wildlife resources are still underway along the northern Gulf of Mexico coast.

Throughout the 2010-2011 wintering season piping plovers were observed along the northern Gulf of Mexico coast. Casual observations from local birders and surveys conducted by oil spill responders reported visibly oiled piping plovers at various locations in Louisiana. However, exact numbers of oiled piping plovers documented from this spill and the potential expanse of effects to those birds are currently being assessed through specific NRDAR studies; those results have yet to be released to the public. Impacts to the species and its habitat are expected but the extent of those impacts remains hard to predict. Based on all available data prior to the Deepwater Horizon oil spill, the risk of impacts from contamination to piping plovers and their habitat was recognized, but the safety contingency plans were considered adequate to alleviate most of these concerns. The Deepwater Horizon incident has brought heightened awareness of the intensity and extent to fish and wildlife habitat from large-scale releases. In addition to potential direct habitat degradation from oiling of intertidal habitats and retraction of stranded boom, impacts to piping plovers may occur from ingestion of oiled benthic prey, loss of benthic prey from shoreline/beach cleaning, and the prolonged human disturbance associated with boom deployment and retraction, clean-up activities, wildlife response, and damage assessment crews working along affected shorelines.

## Pesticides



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

### Climate change

Over the past 100 years, the globally averaged sea level has risen approximately 3.9 to 9.8 inches (Rahmstorf et al. 2007), a rate that is an order of magnitude greater than that seen in the past several thousand years (Douglas et al. 2001 as cited in Hopkinson et al. 2008). The Intergovernmental Panel on Climate Change (IPCC) suggests that by 2080 sea-level rise could convert as much as 33 percent of the world's coastal wetlands to open water (IPCC 2007). Although rapid changes in sea level are predicted, estimated time frames and resulting water levels vary due to the uncertainty about global temperature projections and the rate of ice sheets melting and slipping into the ocean (IPCC 2007; CCSP 2008).

Potential effects of sea-level rise on coastal beaches may vary regionally due to subsidence or uplift as well as the geological character of the coast and near-shore (CCSP 2009; Galbraith et al. 2002). In the last century, for example, sea-level rise along the U.S. Gulf Coast exceeded the global average by 5.1 to 5.9 inches, because coastal lands west of Florida are subsiding (EPA 2009). Sediment compaction and oil and gas extraction compound tectonic subsidence (Penland and Ramsey 1990; Morton et al. 2003; Hopkinson et al. 2008). Low elevations and proximity to the coast make all nonbreeding coastal piping plover foraging and roosting habitats vulnerable to the effects of rising sea level. Furthermore, areas with small astronomical tidal ranges (e.g., portions of the Gulf Coast where intertidal range is less than 1 meter) are the most vulnerable to loss of intertidal wetlands and flats induced by sea-level rise (EPA 2009). Sea-level rise was cited as a contributing factor in the 68 percent decline in tidal flats and algal mats in the Corpus Christi area (i.e., Lamar Peninsula to Encinal Peninsula) in Texas between the 1950s and 2004 (Tremblay et al. 2008). Mapping by Titus and Richman (2001) showed that more than 80 percent of the lowest land along the Atlantic and Gulf coasts was in Louisiana, Florida, Texas, and North Carolina, where 73.5 percent of all wintering piping plovers were tallied during the 2006 IPCC (Elliott-Smith et al. 2009).

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

Modeling for three sea-level rise scenarios (reflecting variable projections of global temperature rise) at five important U.S. shorebird staging and wintering sites predicted loss of 20 to 70 percent of current intertidal foraging habitat (Galbraith et al. 2002). These authors estimated probabilistic sea-level changes for specific sites partially based on historical rates of sea-level change (from tide gauges at or near each site); they then superimposed this on projected 50 percent and 5 percent probability of global sea-level changes by 2100 of 13.4 inches and 30.3 inches, respectively. The 50 percent and 5 percent probability sea level change projections were based on assumed global temperature increases of 35.6° Fahrenheit (F) (50 percent probability) and 40.46° F (5 percent probability). The most severe losses were projected at sites where the coastline is unable to move inland due to steep topography or seawalls. The Galbraith et al. (2002) Gulf Coast study site at Bolivar Flats, Texas, is a designated critical habitat unit known to host high numbers of piping plovers during migration and throughout the winter (e.g., 275 individuals were tallied during the 2006 IPPC) (Elliott-Smith et al. 2009). Under the 50 percent likelihood scenario for sea-level rise, Galbraith et al. (2002) projected approximately 38 percent loss of intertidal flats at Bolivar Flats by 2050; however, after initially losing habitat, the area of tidal flat habitat was predicted to slightly increase by the year 2100, because Bolivar Flats lacks armoring, and the coastline at this site can thus migrate inland. Although habitat losses in some areas are likely to be offset by gains in other locations, Galbraith et al. (2002) noted that time lags may exert 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 reproductive fitness.

Table 9 displays the potential for adjacent development and/or hardened shorelines to impede response of habitat to sea-level rise in the eight states supporting wintering piping plovers. Although complete linear shoreline estimates are not readily obtainable, almost all known piping plover wintering sites in the U.S. were surveyed during the 2006 IPPC. To estimate effects at the census sites, as well as additional areas where piping plovers have been found outside of the census period, Service biologists reviewed satellite imagery and spoke with other biologists familiar with the sites. Of 406 sites, 204 (50 percent) have adjacent structures that may prevent the creation of new habitat if existing habitat were to become inundated. These threats will be perpetuated in places where damaged structures are repaired and replaced, and exacerbated where the height and strength of structures are increased. Data do not exist on the amount or types of hardened structures at wintering sites in the Bahamas, other Caribbean countries, or Mexico.

Table 9. Number of sites surveyed during the 2006 winter IPPC with hardened or developed structures adjacent to the shoreline. Those marked with an asterisk (\*) are additional sites that were not surveyed in the 2006 IPPC.

State	Number of sites surveyed during the 2006 winter Census	Number of sites with some armoring or development	Percent of sites affected
North Carolina	37 (+2)*	20	51
South Carolina	39	18	46
Georgia	13	2	15
Florida	188	114	61
Alabama	4 (+2)*	3	50
Mississippi	16	7	44
Louisiana	25 (+2)*	9	33
Texas	78	31	40
Overall Total	406	204	50

Sea-level rise poses a significant threat to all piping plover populations during the migration and wintering portion of their life cycle. Ongoing coastal stabilization activities may strongly influence the effects of sea-level rise on piping plover habitat. Improved understanding of how sea-level rise will affect the quality and quantity of habitat for migrating and wintering piping plovers is an urgent need.

### Storm events

Although coastal piping plover habitats are storm-created and maintained, the 1996 Atlantic Coast Recovery Plan also notes that storms and severe cold weather may take a toll on piping plovers, and the 2003 Great Lakes Recovery Plan postulates that loss of habitats, such as over-wash passes or wrack, where birds shelter during harsh weather, poses a threat. Storms are a component of the natural processes that form coastal habitats used by migrating and wintering piping plovers, and positive effects of storm-induced over-wash and vegetation removal have been noted in portions of the wintering range. For example, Gulf Islands National Seashore habitats in the NPS' Florida district benefited from increased over-wash events that created optimal habitat conditions during the 2004 and 2005 hurricane seasons, with biologists reporting piping plover use of these habitats within six months of the storms (Nicholas 2005 pers. comm.). Hurricane Katrina (2005) over-washed the mainland beaches of Mississippi, creating many tidal flats where piping plovers were subsequently observed (Winstead 2008). Hurricane Katrina also created a new inlet and improved habitat conditions on some areas of Dauphin Island, Alabama (LeBlanc 2009 pers. comm.). Conversely, localized storms, since Katrina, have induced habitat losses on Dauphin Island (LeBlanc 2009 pers. comm.).

Noel et al. (2005) suspect that changes in habitat caused by multiple hurricanes along the Georgia coastline altered the spatial distribution of piping plovers and may have contributed to mortality of three Great Lakes piping plovers wintering along the Georgia coastline. Following Hurricane Ike in 2008, Arvin (2009) reported decreased numbers of piping plovers at some heavily eroded Texas beaches in the center of the storm impact area and increases in plover numbers at sites about 100 miles to the southwest. However, piping plovers were observed later in the season using tidal lagoons and pools that Ike created behind the eroded beaches (Arvin 2009).

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

(2011) believe that higher numbers of piping plovers are likely using the islands during spring and fall migration.

Other storm-induced adverse effects include post-storm acceleration of human activities such as beach nourishment, sand scraping, and berm and seawall construction. Such stabilization activities can result in the loss and degradation of feeding and resting habitats. Storms also can cause widespread deposition of debris along beaches. Removal of debris often requires large machinery, which can cause extensive disturbance and adversely affect habitat elements such as wrack. Another example of indirect adverse effects linked to a storm event is the increased access to Pelican Island (LeBlanc 2009 pers. comm.) due to merging with Dauphin Island following a 2007 storm (Gibson et al. 2009).

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

#### Threats summary

Habitat loss and degradation on winter and migration grounds from shoreline and inlet stabilization efforts, both within and outside of designated critical habitat, remain a serious threat to all piping plover populations. Modeling strongly suggests that the population is very sensitive to adult and juvenile survival. Therefore, while there is a great deal of effort extended to improve breeding success, and thus improve and maintain a higher population over time, it is also necessary to ensure that the wintering habitat, where birds spend most of their time, is secure. On some of the wintering grounds, the shoreline areas used by wintering piping plovers are being developed, stabilized, or otherwise altered, generally making the habitat unsuitable. Even in areas where habitat conditions are appropriate, human disturbance on beaches may negatively impact piping plovers' energy budget, as they may spend more time being vigilant and less time in foraging and roosting behavior. In many cases, the disturbance is severe enough that piping plovers appear to avoid some areas altogether. In addition, natural events (e.g., climate change, hurricanes, etc.) can pose a potential threat to piping plover habitat on an irregular basis. Threats on the wintering grounds may impact piping plovers' breeding success if they start migration or arrive at the breeding grounds with a poor body condition.

#### **Analysis of the species/critical habitat likely to be affected**

The proposed action has the potential to adversely affect migrating and wintering piping plovers, including piping plover designated critical habitat in Unit LA-7, within the action area. The construction activities may lead to temporarily diminished quantity and quality of intertidal foraging and roosting habitats within the project area and action area, resulting in decreased survivorship of migrating and wintering plovers and temporary adverse effects to critical habitat. The length of construction activities (which varies from six months to years) may delay the recovery of prey species due to the prolonged disturbance of the benthic fauna. Ultimately, the project goal is to increase the longevity and restore the diversity of coastal barrier island habitats, but the temporary effects of construction will require time for natural recovery and would extend beyond more than one migration

and wintering season. The detailed effects of the proposed action on piping plovers and critical habitat will be considered further in the **Environmental Baseline, Effects of the Action, and Cumulative Effects** sections of this opinion.

## *RED KNOT*

### **Species/critical habitat description**

The red knot (*Calidris canutus rufa*) is a medium-sized shorebird about 9 to 11 inches (in) (23 to 28 centimeters (cm)) in length. The red knot is easily recognized during the breeding season by its distinctive rufous (red) plumage (feathers). The face, prominent stripe above the eye, breast, and upper belly are a rich rufous-red to a brick or salmon red, sometimes with a few scattered light feathers mixed in. The feathers of the lower belly and under the tail are whitish with dark flecks. Upperparts are dark brown with white and rufous feather edges; outer primary feathers are dark brown to black (Harrington 2001; Davis 1983). Females are similar in color to males, though the rufous colors are typically less intense, with more buff or light gray on the dorsal (back) parts (Niles et al. 2008). Red knots have a proportionately small head, small eyes, and short neck, and a black bill that tapers from a stout base to a relatively fine tip. The bill length is not much longer than head length. Legs are short and typically dark gray to black, but sometimes greenish in juveniles or older birds in nonbreeding plumage (Harrington 2001). Nonbreeding plumage is dusky gray above and whitish below. Juveniles resemble nonbreeding adults, but the feathers of the scapulars (shoulders) and wing coverts (small feathers covering base of larger feathers) are edged with white and have narrow, dark bands, giving the upperparts a scalloped appearance (Davis 1983).

There are six recognized subspecies of red knots (*Calidris canutus*), and on September 30, 2013, the Service published a proposed rule in the Federal Register recommending that the rufa subspecies of red knot (*Calidris canutus rufa*) be listed as a threatened species and afforded protection under the Act (Service 2013). The Service accepts the characterization of *C.c. rufa* as a subspecies because each recognized subspecies is believed to occupy separate breeding areas, in addition to having distinctive morphological traits (i.e., body size and plumage characteristics), migration routes, and annual cycles. The Service has determined that the rufa red knot is threatened due to loss of both breeding and nonbreeding habitat; potential for disruption of natural predator cycles on the breeding grounds; reduced prey availability throughout the nonbreeding range; and increasing frequency and severity of asynchronies (“mismatches”) in the timing of the birds’ annual migratory cycle relative to favorable food and weather conditions. Main threats to the rufa red knot in the United States include: reduced forage base at the Delaware Bay migration stopover; decreased habitat availability from beach erosion, sea level rise, and shoreline stabilization in Delaware Bay; reduction in or elimination of forage due to shoreline stabilization, hardening, dredging, beach replenishment, and beach nourishment in Massachusetts, North Carolina, and Florida; and beach raking which diminishes red knot habitat suitability. These and other threats in Canada and South America are detailed in the Species Assessment and Listing Priority Assignment Form (Service 2011b) and the proposed listing rule (Service 2013). Unknown threats may occur on the breeding grounds. (Throughout this document, the “rufa red knot” will be referred to as the “red knot” unless there is specific reference to a distinct subspecies.)

Critical habitat has not been proposed or designated for the red knot at the time of this document’s writing. However, important habitat characteristics for the red knot are discussed further in the **Life history** section below.

## Life history

### *Breeding*

Based on estimated survival rates for a stable population, few red knots live for more than about seven years (Niles et al. 2008). Age of first breeding is uncertain but for most birds is probably at least two years (Harrington 2001). Red knots generally nest in the Canadian Arctic in dry, slightly elevated tundra locations, often on windswept slopes with little vegetation. Breeding territories are located inland, but near arctic coasts, and foraging areas are located near nest sites in freshwater wetlands (Niles et al. 2008; Harrington 2001). Breeding occurs in June (Niles et al. 2008), and flocks of red knot sometimes arrive at breeding latitudes before snow-free habitat is available. Upon arrival or as soon as favorable conditions exist, male and female red knots occupy breeding habitat, and territorial displays begin (Harrington 2001). In red knots, pair bonds form soon after arrival on the breeding grounds and remain intact until shortly after the eggs hatch (Niles et al. 2008). Female red knots lay only one clutch (group of eggs) per season, and, as far as is known, do not lay a replacement clutch if the first is lost. The usual clutch size is four eggs, though three-egg clutches have been recorded. The incubation period lasts approximately 22 days from the last egg laid to the last egg hatched, and both sexes participate equally in egg incubation. Young are precocial, leaving the nest within 24 hours of hatching and foraging for themselves (Niles et al. 2008). No information is available regarding chick survival rates (Niles et al. 2008). Females are thought to leave the breeding grounds and start moving south soon after the chicks hatch in mid-July. Thereafter, parental care is provided solely by the males, but about 25 days later (around August 10) they also abandon the newly fledged juveniles and move south. Not long after, they are followed by the juveniles (Niles et al. 2008).

Breeding success of High Arctic shorebirds such as red knot varies dramatically among years in a somewhat cyclical manner. Two main factors seem to be responsible for this annual variation: weather that affects nesting conditions and food availability and the abundance of arctic lemmings (*Dicrostonyx torquatus* and *Lemmus sibiricus*). Production of shorebird young is sensitive to adverse weather during the breeding season. Red knot chicks grow poorly during cold weather due to higher rates of energy expenditure, shorter foraging periods, and reduced prey availability (Piersma and Lindström 2004; Schekkerman et al. 2003). Growth rate of red knot chicks is very high compared to similarly sized shorebirds nesting in more temperate climates and is strongly correlated with weather-induced and seasonal variation in availability of invertebrate prey (Schekkerman et al. 2003). Second, successful shorebird reproduction occurs almost exclusively during peak lemming years when snowmelt is early (Piersma and Lindström 2004; Blomqvist et al. 2002; Summers and Underhill 1987). Arctic fox (*Alopex lagopus*) and snowy owl (*Nyctea scandiaca*) feed largely on lemmings, which are easily caught when their abundance is high. However, in years when lemming numbers are low, the predators turn to alternative prey, such as shorebird eggs, chicks, and adults. Lemming abundance is often cyclical, and the variation in shorebird production closely follows variations in lemming abundance due to their affected predation rates.

### *Nonbreeding Birds*

Little information is available about nonbreeding red knots. Unknown numbers of nonbreeding red knots remain south of the breeding grounds during the breeding season, and many, but not all, of these knots are 1-year-old (i.e., immature) birds (Niles et al. 2008). Nonbreeding knots, usually individuals or small groups, have been reported during June along the U.S. Atlantic and Gulf coasts, with smaller numbers around the Great Lakes and Northern Plains in both the United States and Canada (eBird.org 2012). There is also little information on where juvenile red knots spend their winter months (Service

and Conserve Wildlife Foundation 2012), and there may be at least partial segregation of juvenile and adult red knots on the wintering grounds. All juveniles of the Tierra del Fuego wintering region are thought to remain in the Southern Hemisphere during their first year of life, possibly moving to northern South America, but their distribution is largely unknown (Niles et al. 2008). Because there is a lack of specific information on juvenile red knots, the Service uses the best available data from adult red knots to draw conclusions about juvenile foraging and habitat use.

### *Migration*

The red knot migrates annually between its breeding grounds in the Canadian Arctic and several wintering regions, including the Southeast United States (Southeast), the Northeast Gulf of Mexico, northern Brazil, and Tierra del Fuego at the southern tip of South America (Figure 5). Departure from the breeding grounds begins in mid-July and continues through August. Red knots tend to migrate in single-species flocks with departures typically occurring in the few hours before twilight on sunny days. Based on the duration and distance of migratory flight segments estimated from geolocator results, red knots are inferred to migrate during both day and night (Normandeau Associates. Inc. 2011). The size of departing flocks tends to be large (greater than 50 birds) (Niles et al. 2008), and females are thought to leave first followed by males and then juveniles (Niles et al. 2008; Harrington 2001).

Red knots make one of the longest distance migrations known in the animal kingdom, traveling up to 19,000 miles annually, and may undertake long flights that span thousands of miles without stopping. As red knots prepare to depart on long migratory flights, they undergo several physiological changes. Before takeoff, the birds accumulate and store large amounts of fat to fuel migration and undergo substantial changes in metabolic rates. In addition, leg muscles, gizzard (a muscular organ used for grinding food), stomach, intestines, and liver all decrease in size, while pectoral (chest) muscles and heart increase in size. Due to these physiological changes, red knots arriving from lengthy migrations are not able to feed maximally until their digestive systems regenerate, a process that may take several days. Because stopovers are time-constrained, red knots require stopovers rich in easily digested food to achieve adequate weight gain (Niles et al. 2008; van Gils et al. 2005a; van Gils et al. 2005b; Piersma et al. 1999) that fuels the next leg of migratory flight and, upon arrival in the Arctic, fuels a body transformation to breeding condition (Morrison 2006). At each stopover, the adults gradually replace their red breeding plumage with white and gray, but generally they do not molt their flight or tail feathers until they reach their wintering areas (Niles et al. 2008; Morrison and Harrington 1992).

During both the northbound (spring) and southbound (fall) migrations, red knots use key staging and stopover areas to rest and feed (Figure 6). Major spring stopover areas along the Atlantic coast include Río Gallegos, Península Valdés, and San Antonio Oeste (Patagonia, Argentina); Lagoa do Peixe (eastern Brazil, State of Rio Grande do Sul); Maranhão (northern Brazil); the Virginia barrier islands (United States); and Delaware Bay (Delaware and New Jersey, United States) (Cohen et al. 2009; Niles et al. 2008; González 2005). Important fall stopover sites include southwest Hudson Bay (including the Nelson River delta), James Bay, the north shore of the St. Lawrence River, the Mingan Archipelago, and the Bay of Fundy in Canada; the coasts of Massachusetts and New Jersey and the mouth of the Altamaha River in Georgia, United States; the Caribbean (especially Puerto Rico and the Lesser Antilles); and the northern coast of South America from Brazil to Guyana (Newstead et al. in press; Niles 2012a; Mizrahi 2011 pers. comm.; Niles et al. 2010; Schneider and Winn 2010; Niles et al. 2008; Harrington 2006 pers. comm.; Antas and Nascimento 1996; Morrison and Harrington 1992; Spaans 1978). However, large and small groups of red knots, sometimes numbering in the thousands,

may occur in suitable habitats all along the Atlantic and Gulf coasts from Argentina to Canada during migration (Niles et al. 2008).

Red knots are restricted to the ocean coasts during winter, and occur primarily along the coasts during migration. However, small numbers of red knots are reported annually across the interior United States (i.e., greater than 25 miles from the Gulf or Atlantic Coasts) during spring and fall migration. Such reported sightings are concentrated along the Great Lakes, but multiple reports have been made from nearly every interior State (eBird.org 2012). For example, Texas knots follow an inland flyway to and from the breeding grounds, using spring and fall stopovers along western Hudson Bay in Canada and in the northern Great Plains (Newstead et al. in press; Skagen et al. 1999). Some red knots wintering in the Southeastern United States and the Caribbean migrate north along the U.S. Atlantic coast before flying over land to central Canada from the mid-Atlantic, while others migrate over land directly to the Arctic from the Southeastern U.S. coast (Niles et al. in press). These eastern red knots typically make a short stop at James Bay in Canada, but may also stop briefly along the Great Lakes, perhaps in response to weather conditions (Niles et al. 2008; Morrison and Harrington 1992). Thus, red knots from different wintering areas appear to employ different migration strategies, including differences in timing, routes, and stopover areas. However, full segregation of migration strategies, routes, or stopover areas does not occur among red knots from different wintering areas.

### *Wintering*

Red knots occupy all known wintering areas from December to February, but may be present in some wintering areas as early as September or as late as May. In the Southern Hemisphere, these months correspond to the austral summer (i.e., summer in the Southern Hemisphere). Wintering areas for the red knot include the Atlantic coasts of Argentina and Chile (particularly the island of Tierra del Fuego that spans both countries), the north coast of Brazil (particularly in the State of Maranhão), the Northwest Gulf of Mexico from the Mexican State of Tamaulipas through Texas (particularly at Laguna Madre) to Louisiana, and the Southeast United States from Florida (particularly the central Gulf coast) to North Carolina (Newstead et al. in press; Patrick 2012 pers. comm.; Niles et al. 2008). Smaller numbers of knots winter in the Caribbean, and along the central Gulf coast (Alabama, Mississippi), the mid-Atlantic, and the Northeast United States. Red knots are also known to winter in Central America and northwest South America, but it is not yet clear if those birds are the *rufa* subspecies. Little information exists on where juvenile red knots spend the winter months (Service and Conserve Wildlife Foundation 2012), and there may be at least partial segregation of juvenile and adult red knots on the wintering grounds.

Examples of red knots changing wintering regions do exist but are few. Generally red knots are thought to return to the same wintering region each year. Re-sightings of marked birds indicate few or no inter-annual movements of red knots between the Brazil and Tierra del Fuego wintering areas, or between the Southeast and Tierra del Fuego wintering areas (Baker et al. 2005; Harrington 2005a).

### *Migration and Wintering Habitat*

Long-distance migrant shorebirds are highly dependent on the continued existence of quality habitat at a few key staging areas. These areas serve as stepping stones between wintering and breeding areas. Habitats used by red knots in migration and wintering areas are generally coastal marine and estuarine habitats with large areas of exposed intertidal sediments. In many wintering and stopover areas, quality high-tide roosting habitat (i.e., close to feeding areas, protected from predators, with sufficient space during the highest tides, free from excessive human disturbance) is limited (Kalasz 2012 pers.



comm.; Niles 2012 pers. comm.). The supra-tidal (above the high tide) sandy habitats of inlets provide important areas for roosting, especially at higher tides when intertidal habitats are inundated (Harrington 2008). In some localized areas, red knots will use artificial habitats that mimic natural conditions, such as nourished beaches, dredged spoil sites, elevated road causeways, or impoundments; however, there is limited information regarding the frequency, regularity, timing, or significance of red knots' use of such artificial habitats.

In South American wintering areas, red knots are found in intertidal marine habitats, especially near coastal inlets, estuaries, and bays. Habitats include sandy beaches, mudflats, mangroves, saltwater and brackish lagoons, and "restinga" formations (an intertidal shelf of densely packed dirt blown by strong, offshore winds) (Niles et al. 2008; Harrington 2001). Red knots were recently observed using rice fields in French Guiana (Niles 2012b) and in Trinidad (eBird.org 2012). In Suriname in the early 1970s, small numbers of red knots were observed on firm and tough clay banks emerging from the eroding coastline and in shallow lagoons, but knots were never found on soft tidal flats (Spaans 1978); those observations suggest a deviation from the red knot's typical nonbreeding habitats.

In North America, red knots are commonly found along sandy, gravel, or cobble beaches, tidal mudflats, salt marshes, shallow coastal impoundments and lagoons, and peat banks (Cohen et al. 2010; Cohen et al. 2009; Niles et al. 2008; Harrington 2001; Truitt et al. 2001). In Massachusetts, red knots use sandy beaches and tidal mudflats during fall migration. In New York and the coast of New Jersey, knots use sandy beaches during spring and fall migration (Niles et al. 2008). In Delaware Bay, red knots are found primarily on beaches of sand or peat at the mouths of tidal creeks, along the edge of tidal marshes dominated by salt marsh cordgrass (*Spartina alterniflora*) and saltmeadow cordgrass (*S. patens*), and in salt pannes (shallow, high salinity, mud-bottomed depressions on the marsh surface) and shallow coastal ponds or embayments (Clark 2012 pers. comm.; Cohen et al. 2009; Niles et al. 2008; Karpanty et al. 2006; Meyer et al. 1999; Burger et al. 1997). In the southeastern U.S., red knots forage along sandy beaches during spring and fall migration from Maryland through Florida. During migration, knots also use tidal mudflats in Maryland and along North Carolina's barrier islands. In addition to the sandy beaches, red knots forage along peat banks for mussel spat in Virginia and along small pockets of peat banks where the beach is eroding in Georgia (Niles et al. 2008). In Florida, the birds also use mangrove and brackish lagoons. Along the Texas coast, red knots forage on beaches, oyster reefs, and exposed bay bottoms and roost on high sand flats, reefs, and other sites protected from high tides. Red knots also show some fidelity to particular migration staging areas between years (Duerr et al. 2011; Harrington 2001).

### *Foraging*

The red knot is a specialized molluscivore, eating hard-shelled mollusks, sometimes supplemented with easily accessed softer invertebrate prey, such as shrimp- and crab-like organisms, marine worms, and horseshoe crab (*Limulus polyphemus*) eggs (Piersma and van Gils 2011; Harrington 2001). Mollusk prey are swallowed whole and crushed in the gizzard (Piersma and van Gils 2011). From studies of other subspecies, Zwarts and Blomert (1992) concluded that the red knot cannot ingest prey with a circumference greater than 1.2 inches (in) (30 millimeters (mm)). Foraging activity is largely dictated by tidal conditions, as the red knot rarely wades in water more than 0.8 to 1.2 in (2 to 3 centimeters (cm)) deep (Harrington 2001). Due to bill morphology, the red knot is limited to foraging on only shallow-buried prey, within the top 0.8 to 1.2 in (2 to 3 cm) of sediment (Gerasimov 2009; Zwarts and Blomert 1992).

On the breeding grounds, the red knot's diet consists mostly of terrestrial invertebrates such as insects (Harrington 2001). In non-breeding habitats, the primary prey of the red knot include blue mussel (*Mytilus edulis*) spat (juveniles); Donax and Darina clams; snails (*Littorina spp.*), and other mollusks, with polychaete worms, insect larvae, and crustaceans also eaten in some locations. A prominent departure from typical prey items occurs each spring when red knots feed on the eggs of horseshoe crabs, particularly during the key migration stopover within the Delaware Bay of New Jersey and Delaware. Delaware Bay serves as the principal spring migration staging area for the red knot because of the availability of horseshoe crab eggs (Clark et al. 2009; Harrington 2001; Harrington 1996; Morrison and Harrington 1992), which provide a superabundant source of easily digestible food.

Red knots and other shorebirds that are long-distance migrants must take advantage of seasonally abundant food resources at intermediate stopovers to build up fat reserves for the next nonstop, long-distance flight (Clark et al. 1993). Although foraging red knots can be found widely distributed in small numbers within suitable habitats during the migration period, birds tend to concentrate in those areas where abundant food resources are consistently available from year to year.

### **Population dynamics**

Localized and regional red knot surveys have been conducted across the subspecies' range with widely differing levels of geographic, temporal, and methodological consistency. Available survey data are presented in detail in the Service's September 30, 2013, Proposed Rule (Service 2013). However, some general characterizations of the available data are noted as follows:

- No population information exists for the breeding range because, in breeding habitats, red knots are thinly distributed across a huge and remote area of the Arctic. Despite some localized survey efforts, (e.g., Bart and Johnston 2012; Niles et al. 2008), there are no regional or comprehensive estimates of breeding abundance, density, or productivity (Niles et al. 2008).
- Few regular surveys are conducted in fall because southbound red knots tend to be less concentrated than during winter or spring.
- Some survey data are available for most wintering and spring stopover areas. For some areas, long-term data sets have been compiled using consistent survey methodology.
- Because there can be considerable annual fluctuations in red knot counts, longer-term trends are more meaningful. At several key sites, the best available data show that numbers of red knots declined and remain low relative to counts from the 1980s, although the rate of decline appears to have leveled off since the late 2000s.
- Inferring long-term population trends from various national or regional datasets derived from volunteer shorebird surveys and other sources, Andres (2009) and Morrison et al. (2006) also concluded that red knot numbers declined, probably sharply, in recent decades.

### *Wintering Areas*

Counts in wintering areas are particularly useful in estimating red knot populations and trends because the birds generally remain within a given wintering area for a longer period of time compared to the areas used during migration. This eliminates errors associated with turnover or double-counting that can occur during migration counts.

### Argentina and Chile

Aerial surveys of Tierra del Fuego (Chile and Argentina) and the adjacent Patagonian coast to the north (Argentina) have been conducted since 2000, and previously in the early 1980s, by the same observers using consistent methodology (Morrison et al. 2004). This is the best available long-term data set for a wintering area. However, as those are not the only red knot wintering areas, the survey results are best interpreted as one indicator of population trends rather than estimates of the total population.

Counts have been markedly lower in recent years. Comparing the average counts for Tierra del Fuego from 1985 and 2000 with counts from 2010 to 2012, the recent counts are about 75 percent lower than the earlier counts. An independent population estimate, using re-sighting data from Río Grande fitted to binomial models, supports the observation that declines did not begin until after 2000. This same model produced population estimates that were within 5 to 15 percent of the aerial counts from 2001 to 2003, giving confidence in the model results. Declines were even sharper (about 96 percent) along the roughly 1,000 miles of Patagonian coast than in the core area on Tierra del Fuego. Thus, the population appears to have contracted to the core sites, leaving few birds at the “peripheral” Patagonian sites (COSEWIC 2007). Reflecting the larger downward trend in Patagonia, local winter counts at Península Valdés also show an overall decline in bird numbers from 1994 to 2010 (Western Hemisphere Shorebird Reserve Network (WHSRN) (2012).

#### Northern South America and Central America

Counts of wintering red knots along the north coast of South America have been sporadic and have varied in geographic coverage. Morrison and Ross (1989, Vol. 2) conducted aerial surveys of the entire South American coast in the 1980s. In northern Brazil, red knots were found in three out of four survey segments: North, North-Central, and Northeast. No red knots were observed in the Amazon survey segment of Brazil, which is between North and North-Central (Morrison and Ross 1989, Vol. 2). Using the same surveyor team and methods as the 1986 survey, the North-Central segment of Brazil was again surveyed by air in 2011 (Mizrahi 2012 pers. comm.; Morrison et al. 2012) and results may suggest a decline. These 2011 results require further confirmation; however, redistribution of birds to the west is an unlikely explanation for the lower numbers in 2011, based on recent surveys of Guyana, Suriname, and French Guiana (discussed below) (Morrison et al. 2012).

Covering about 30 percent (by linear miles of coastline) of the North-Central Brazil survey segment, Baker et al. (2005) counted knots in western Maranhão during an aerial survey in February 2005. In a repeat of this survey in December 2006 (winter of 2007), fewer knots were counted (Niles et al. 2008). The shores of Maranhão are complex and highly fragmented making accurate counting more difficult. To allow for this, aerial coverage was more extensive and included not only the ocean shore but also a variety of back bays and channels (Niles et al. 2008). In December 2007 (winter of 2008), ground surveys were conducted at two sites in the Brazilian State of Ceará, within the Northeast Brazil survey segment (where only 15 red knots had been counted in 1983). Only small numbers of knots (average peak of  $8 \pm 8.5$ ) were observed at Ilha Grande, but an average peak count of  $481 \pm 31$  red knots was recorded at Cajuais Bank (Carlos et al. 2010). Lower numbers (up to 80) of red knots have been observed in winter at four other sites in Ceará (Serrano 2007).

Morrison and Ross (1989, Vol. 2) documented 520 red knots in western Venezuela in 1982. Ruiz-Guerra (2011, p. 194) documented 20 red knots at Musichi (Department of La Guajira) on the Caribbean coast of Colombia near Venezuela in January 2008. It is not known if the birds observed around the Colombia-Venezuela border were all of the *rufa* subspecies, but recent geolocator results suggest at least some of the winter birds in this area are *C. c. rufa* (Niles et al. in press). During the

1980s surveys, no red knots were observed between western Venezuela and the west end of Brazil (the North segment), with no knots recorded in eastern Venezuela, Trinidad, Guyana, Suriname, or French Guiana (Morrison and Ross 1989, Vol. 1). With the same survey team and methods from the 1980s, aerial shorebird surveys were recently repeated in Guyana (January 2010), Suriname (December 2008, January 2010, and January 2011), and French Guiana (December 2008 and January 2010) (Morrison et al. 2012). No red knots were detected in 2011, and a negligible number in December 2008 (i.e., winter 2009) and in 2010 (Mizrahi 2011, 2012 pers. comm.). However, small, isolated groups of wintering red knots may extend along most of the northern coast of South America (Niles 2013 pers. comm.).

On the southern (Pacific) coast of Panama, Buehler (2002) counted 100 red knots near Panama City and another 100 near Chitré in February 2002. Another researcher has also surveyed this area and agrees with an estimate of about 200 wintering red knots (Watts 2012 pers. comm.). It is not known if all the birds observed in Panama were of the *rufa* subspecies, but three marked birds resighted in Panama were all banded in known *rufa* red knot areas (Watts 2012 pers. comm.; Niles et al. 2008; Buehler 2002). Thus, at least some of these birds are considered *rufa* red knots. Also on the Pacific, Laguna Superior (State of Oaxaca, Mexico) is a recently documented wintering area for red knots (Newstead 2012 pers. comm.), with over 300 birds reported in the winters of 2011 and 2012 (eBird.org 2012). Three birds marked in Texas in April 2010 were resighted at Laguna Superior in February 2012; it is unknown if those three birds or others in this wintering area are *C.c. rufa*, *C.c. roselaari*, or both (Carmona et al. in press).

#### The North American Atlantic Coast

Small numbers of wintering red knots have also been reported from Maryland, United States, to Nova Scotia, Canada (Burger et al. 2012; BandedBirds.org 2012; eBird.org 2012; Hanlon 2012 pers. comm.; Dey 2012 pers. comm.), but no systematic winter surveys have been conducted in these northern areas. In surveys of five sites within North Carolina's Outer Banks in 1992 and 1993, Dinsmore et al. (1998) found over 500 red knots per year.

#### Southeastern United States and Caribbean

Extensive data for Florida are available from the International Shorebird Survey and other sources. However, geographic coverage has been inconsistent, ranging from 1 to 29 sites per year from 1974 to 2004. Statewide annual totals ranged from 5 knots (1 site in 1976) to 7,764 knots (7 sites in 1979). The greatest geographic coverage occurred in 1993 (4,265 knots at 25 sites) and 1994 (5,018 knots at 29 sites) (Niles et al. 2008). Harrington et al. (1988) reported that the mean count of birds wintering in Florida was 6,300 birds ( $\pm 3,400$ , one standard deviation) based on four aerial surveys conducted from October to January in 1980 to 1982. These surveys covered the Florida Gulf coast from Dunedin to Sanibel-Captiva, sometimes going as far south as Cape Sable (Harrington 2012 pers. comm.). Based on those surveys and other work, the Southeast wintering group was estimated at roughly 10,000 birds in the 1970s and 1980s (Harrington 2005a).

Sprandel et al. (1997) identified the top 60 sites for wintering shorebirds in Florida and surveyed those areas in 1994. Red knots were found at 27 sites, mainly on the central Gulf coast. Adding the average number of birds counted at each site, these authors estimated a statewide total of 1,452 red knots across three sites in the Florida Panhandle, 18 sites in southwest Florida, four sites in the Everglades, and two sites in northeast Florida (Sprandel et al. 1997). During frequent surveys of nine sites along about 55 miles of the central Florida Panhandle, Smith (2010) found a mean of about 84 wintering red knots in

the winter of 2007. Smith (2010) covered roughly 25 percent of the Panhandle region as delineated by Sprandel et al. (1997), with the survey sites clustered on the eastern end of that region.

Niles (2009) conducted winter aerial and ground counts along Florida's Gulf coast from 2006 to 2010, covering essentially the same area in which Harrington et al. (1988) had reported an average of 6,300 red knots ( $\pm 3,400$ ) in the winters of 1980 to 1982. As the more recent aerial counts were lower, red knot numbers may have decreased in western Florida, perhaps due to birds shifting elsewhere within the larger Southeast wintering region (Harrington 2005a). However, a comparison of the geographic coverage of Sprandel et al. (1997) with Niles (2009) suggests that red knot numbers did not change much from 1994 to 2010.

Based on resightings of birds banded in South Carolina and Georgia from 1999 to 2002, the Southeast wintering population was estimated at  $11,700 \pm 1,000$  (standard error) red knots. Although there appears to have been a gradual shift by some of the southeastern knots from the Florida Gulf coast to the Atlantic coasts of Georgia and South Carolina, population estimates for the Southeast region in the 2000s were at about the same level as during the 1980s (Harrington 2005a). Based on recent modeling using resightings of marked birds staging in Georgia in fall, as well as other evidence, the Southeast wintering group may number as high as 20,000 (Harrington 2012 pers. comm.), but field survey data are not available to corroborate this estimate.

Two recent winter estimates are available for the central Gulf of Mexico. During the IPCCs in 2006 and 2011 (Patrick 2012 pers. comm.), 250 to 500 knots were counted from Alabama to Louisiana. From work related to the Deepwater Horizon oil spill, an estimated 900 red knots were reported from the Florida Panhandle to Mississippi (Hunter 2012 pers. comm.). Older surveys recorded similar numbers from the central Gulf coast, with peak counts of 752 red knots in Alabama (1971) and 40 knots in Mississippi (1979) (Morrison and Harrington 1992). Numbers of red knots wintering in the Caribbean are essentially unknown, but in the course of piping plover surveys in February 2011 in the Bahamas, 70 red knots were observed on the Joulters Cays just north of Andros Island, and 7 knots were observed on the Berry Islands. In December 2012 (i.e., winter 2013), 52 red knots were observed in the Green Turtle Cay flats in Abaco, Bahamas (Jeffery 2013 pers. comm.). Roughly 50 red knots occur annually on Green Turtle Cay (eBird.org 2012; Pover 2012 pers. comm.).

### Northwest Gulf of Mexico

Except for localized areas, there have been no long-term systematic surveys of red knots in Texas or Louisiana, and no information is available about the number of knots that winter in northeastern Mexico. From survey work in the 1970s, Morrison and Harrington (1992) reported peak winter counts of 120 red knots in Louisiana and 1,440 in Texas, although numbers in Texas between December and February were typically in the range of 100 to 300 birds. Records compiled by Skagen et al. (1999) give peak counts of 2,838 and 2,500 red knots along the coasts of Texas and Louisiana, respectively, between January and June over the period 1980 to 1996, but these figures could include spring migrants. Morrison et al. (2006) estimated only about 300 red knots wintering along the Texas coast, based on surveys in January 2003 (Niles et al. 2008). Higher counts of roughly 700 to 2,500 knots have recently been made on Padre Island, Texas, during October, which could include wintering birds (Newstead et al. in press; Niles et al. 2009).

Foster et al. (2009) found a mean daily abundance of 61.8 red knots on Mustang Island, Texas, based on surveys every other day from 1979 to 2007. Similar winter counts were reported by Dey et al. (2011b) for Mustang Island from 2005 to 2011. From 1979 to 2007, mean abundance of red knots on

Mustang Island decreased 54 percent, but this may have been a localized response to increasing human disturbance, coastal development, and changing beach management practices (Newstead et al. in press; Foster et al. 2009) (i.e., it is possible these birds shifted elsewhere in the region).

There are no current estimates for the size of the Northwest Gulf of Mexico wintering group as a whole (Mexico to Louisiana). The best available current estimates for portions of this wintering region are about 2,000 in Texas (Niles 2012a), or about 3,000 in Texas and Louisiana, with about half in each State and movement between them (Hunter 2012 pers. comm.).

### *Spring Stopover Areas*

Records of migrating red knots have been collected at many sites along the Atlantic coast. Not all migration areas are well surveyed, and considerable turnover of individuals occurs as birds migrate through an area. Consequently, using counts of migrating red knots as a basis for population estimates may lead to inaccuracies due to errors associated with turnover or double-counting. However, long-term counts made at a specific location are good indicators of usage trends for that area and, considered together, may reflect trends in the overall population of the red knot.

### South America

Peak counts of red knots declined at three South American stopover sites (i.e., Fracasso Beach, Argentina; Bahía San Antonio, Argentina; and Lagoa do Peixe, Brazil) from the 1990s through the mid-2000s. Although trends at stopover areas can reflect changing usage of the site, the timing of these declines over roughly the same period as those in Tierra del Fuego and Delaware Bay (late 1990s to early 2000s) is more suggestive of a decrease in the overall subspecies. At Fracasso Beach on Península Valdés in Argentina, ground surveys were conducted weekly from February through April (González 2005). At Bahía San Antonio in Argentina, the surveys were ground-based counts conducted January to April, weekly through 1999, but varying from daily to every 10 days from 2000 to 2005 (González 2005). Counts at Lagoa do Peixe in Brazil were obtained during expeditions that covered the peak spring passage in April (Niles et al. 2008). Other observers noted 5,000 red knots at Lagoa do Peixe in April 2005 (Fedrizzi and Carlos in Lanctot 2009) suggesting that usage of this site had partially rebounded from lower numbers seen in the early 2000s.

### Virginia

Aerial surveys of the entire chain of barrier island beaches in Virginia have been conducted since 1995 using consistent methods and observers. Although the number of surveys has varied from one to six per year, the aerial survey effort has consistently covered the peak period during the last week of May (Watts 2012 pers. comm.). Since 2007, Karpenty et al. (2012) have estimated total red knots based on ground counts at 100 to 150 randomly selected points throughout Virginia's barrier island beaches including peat banks, with each location visited from one to three times per stopover season. Although the recent ground surveys show an upward trend, the aerial counts have been relatively steady since the mid-1990s. Because of differences in methodology and timing, the two data sets are not comparable.

Because birds pass in and out of a stopover area, the peak count (the highest number of birds seen on a single day) for a particular year is lower than the total passage population (i.e., the total number of birds that stopped at that site over the course of that migration season). Using resightings of marked birds, several attempts have been made to estimate the total passage population of Virginia through mathematical modeling.

## Delaware Bay

Aerial surveys have been conducted in Delaware Bay since 1981. Methods and observers were consistent from 1986 to 2008. The methodology during this period involved weekly counts; thus, it was possible the absolute peak number of birds was missed in some years. However, since most shorebirds remain in Delaware Bay at least a week, it is likely that the true peak was captured in most years (Clark et al. 1993). The surveys covered consistent areas of New Jersey and Delaware from the first week of May to the second week of June. All flights were conducted 3 to 4 hours after high tide, a period when birds are usually feeding on the beaches (Clark et al. 2009).

Methodologies and observers changed several times from 2009 to 2012. Flights are now flown only during the end of May. In addition, aerial counts for 2010 and 2011 were adjusted with ground counts from Mispillion Harbor, Delaware, to more accurately reflect large concentrations of birds at this key site (Dey et al. 2011b). Further, problems in 2009 and 2012 prevented accurate aerial counts, and ground counts have been substituted. Caution should be used in comparing ground and aerial counts (Laursen et al. 2008). Differences between the two methods may account for markedly higher counts in 2009 and 2012. Although aerial counts had typically been higher than ground counts prior to 2009, this was likely because many areas that could be surveyed by air were inaccessible on the ground. Since 2009, ground survey crews have attempted to minimize the access problem by using boats in remote areas (Dey 2013 pers. comm.; Clark 2013 pers. comm.).

As with other stopover areas, it is impossible to separate population-wide trends from trends in usage of a particular spring site. Because birds pass in and out of a stopover area, the peak count for a particular year is lower than the total passage population. Thus, differences in the number of birds in Delaware Bay may reflect stopover patterns rather than (or in addition to) trends in the overall red knot population (Clark et al. 1993). Using resightings of marked birds, several attempts have been made to estimate the total passage population of Delaware Bay through mathematical modeling. However, the pattern and timing of these declines in Delaware Bay relative to Tierra del Fuego and other stopovers is suggestive of a decrease in the overall population. Comparing four different time periods, average red knot counts in Delaware Bay declined by approximately 70 percent from 1981 to 2012.

## Other areas along the U.S. Atlantic Coast

Beginning in 2006, coordinated red knot surveys have been conducted from Florida to Delaware Bay during two consecutive days from May 20 to 24. This period is thought to represent the peak of the red knot migration. There has been variability in methods, observers, and areas covered. From 2006 to 2010, there was no change in counts that could not be attributed to varying geographic survey coverage (Dey et al. 2011b); thus, we do not consider any apparent trends in these data before 2010. Because red knot numbers peak earlier in the Southeast than in the mid-Atlantic (Bimbi 2013 pers. comm.), the late-May coast-wide survey data likely reflect the movement of some birds north along the coast, and may miss other birds that depart for Canada from the Southeast along an interior (overland) route prior to the survey window. Thus, greater numbers of red knots may utilize Southeastern stopovers than suggested by the data.

## *Fall Stopover Areas*

Few regular surveys are conducted in fall because southbound red knots tend to be less concentrated than during winter or spring. No regular surveys are conducted in Hudson Bay or James Bay, Canada.

However, aerial surveys of the Ontario coastlines of James Bay and Hudson Bay in the late 1970s produced totals of 7,000 to 10,000 red knots, with more recent surveys reporting 5,000 to 10,000 (Morrison and Harrington 1992). There were numerous reports of 100 to 1,300 red knots at James Bay (Ontario) in August 2011, and one report of nearly 4,000 birds in this area (eBird.org 2012). Based on intensive field work and analysis of resightings of marked birds, at least 7,200 red knots are estimated to have used the Mingan Islands Archipelago (Canada) in fall 2008 (Service 2011b; Wilson et al. 2010).

Using daily checklist data submitted by birdwatchers during fall migrations from 1976 to 1998 in southern Quebec, Canada, Aubry and Cotter (2001) found a statistically significant decline in sightings of red knots. In surveys of Eastern Canada (New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland), fall counts of red knots dropped 5.3 to 15.3 percent per year (depending on the statistical method used) from 1974 to 1991, with considerably greater decreases later in the study period; however, the findings were not statistically significant (Morrison et al. 1994). Analyzing more years from this same data set from 1974 to 1998, Morrison et al. (2001) found a statistically significant annual decrease of 17.6 percent.

Fall peak counts from International Shorebird Survey sites along the U.S. Atlantic coast ranged from 6,000 to 9,000 red knots during the mid- to late-1970s (Morrison and Harrington 1992). In a review of numbers and distribution of red knots on the Massachusetts coast during southward migration, Harrington et al. (2010a) found that overall red knot numbers increased from the late 1940s to the early 1970s, especially on the mainland (western Cape Cod Bay), with a smaller increase on outer Cape Cod. After 1975, counts declined significantly on the mainland, but increased significantly on outer Cape Cod (Harrington et al. 2010b). Evidence suggests that both the mainland and the Cape Cod areas were historically used by knots having Argentina-Chile destinations, but that recently the Cape Cod locations have increasingly been used by knots with wintering destinations in the Southeast United States, thus balancing out the declining numbers of knots with Argentina-Chile wintering destinations (Harrington et al. 2010b). By 2008, peak counts of Argentina-Chile knots in Massachusetts had fallen to about 1,000 birds, while birds from the Southeast group increased to about 800 (Harrington et al. 2010a).

No regular counts are currently conducted in Massachusetts (Koch 2012 pers. comm.), but flocks of over 100 knots are routinely reported from Monomoy National Wildlife Refuge (eBird.org 2012). About 1,500 red knots were present in Avalon on the coast of New Jersey in the fall of 2011 (Service 2011c). Also on the coast of New Jersey, hundreds of red knots are regularly reported from North Brigantine and Stone Harbor, sometimes in flocks of over 500 (eBird.org 2012). Islands at the mouth of the Altamaha River, Georgia, support the only known late summer and fall staging site on the east coast of the United States, attracting as many as 12,000 knots at one time (Schneider and Winn 2010).

The Caribbean islands may be an important refuge for migrating shorebirds during storms (Nebel 2011). Puerto Rico and the some of the Lesser Antilles (e.g., St. Croix in the U.S. Virgin Islands, Guadeloupe, Barbados, and Trinidad) are also used as fall stopover areas (Niles et al. 2010; eBird.org 2012), with birds occurring regularly but in small numbers. In Guadeloupe, the red knot is an uncommon but regular visitor during fall migration, typically in small groups of up to 3 birds, but as many as 16 have been observed in a flock (Levesque 2011 pers. comm.). In Barbados, the red knot is a fairly regular fall transient in small numbers, usually occurring as single individuals and in small groups, but occasionally knots may occur in flocks of up to a dozen birds, and a group of 63 birds was recorded in 1951. Detailed records from 1950 to 1965 show an average of about 20 red knots per year



in Barbados (Hutt and Hutt 1992). Flocks of up to a dozen red knots were reported from Trinidad each year from 2008 to 2011, with multiple sightings each fall (eBird.org 2012).

In late August 2012, 1,700 knots were observed in rice fields near Mana, French Guiana, and a large number of these birds had been marked in the Chile portion of Tierra del Fuego (Niles 2012b). Based on this survey and recent geolocator results, French Guiana is emerging as an important fall stopover area (Niles 2012b). Adjacent Suriname and Brazil are also used in fall (Niles et al. 2010; Spaans 1978), but little information is available regarding the numbers of birds in these areas. In Suriname, a total of nearly 160 red knots were counted during two surveys conducted in late August of 1970 to 1973. Larger red knot numbers apparently do not occur in Suriname as the habitat is not ideal (Harrington 2006 pers. comm.). In September 2007, the average peak count of red knots at Cajuais Bank in the Brazilian State of Ceará was  $434 \pm 95$  (Carlos et al. 2010). During aerial surveys of Panama Bay in the fall of 1997, Watts (1998) documented a peak count of 2,460 red knots in September; the subspecies composition is unknown. Watts (1998) also reported that red knot counts in Panama were likely underestimated.

### *Summary*

After a careful review of available survey data from areas regularly used by substantial numbers of red knots in spring, fall, and winter, the Service has determined that: (1) for some areas, available data are insufficient to substantiate any conclusions regarding population trends over time; (2) for other areas, there are apparent trends, but they are associated with relatively low confidence; and, (3) for a few key areas, the consistency of geographic coverage, methodologies, and surveyors lead us to greater confidence in apparent trends. Those population data are summarized as follows:

- Patagonia and Tierra del Fuego wintering region: There are declines through the 2000s, possibly stabilizing at a relatively low level since 2008, which are associated with higher confidence.
- North-Central Brazil wintering region: There is apparent decline when comparing surveys with similar methods, coverage, and observers in 1982 and 2011, which are associated with lower confidence due to the availability of only two data points, and the complexity of the shoreline that makes surveying difficult. Partial surveys in the winters of 2005 and 2007 suggest that any declines occurred after 2005.
- Northwest Gulf of Mexico wintering region: There are insufficient data for trend analysis.
- Southeast wintering region: There is apparent decline on Florida's Gulf coast when comparing aerial surveys from 1980 to 1982 with similar surveys (using different surveyors) of approximately the same area from 2006 to 2010, which are associated with lower confidence because birds may have simply shifted elsewhere within this large wintering region. The two region-wide survey efforts to date (from the 2006 and 2011 piping plover surveys) are associated with lower confidence inherent in the methodology (red knots are not the focus of this survey), but do tend to support the perception that knots shift from state to state within this region among years. A long-term data set from Georgia, showing wide inter-annual fluctuations, also supports this perception. Data from the Caribbean are insufficient to infer any trends. Comparing ground surveys of Florida's Gulf coast in 1994 to aerial surveys of about this same area from 2006 to 2010, red knot counts were roughly the same over this time period.
- South American spring stopover sites: There are apparent declines at three key stopover sites from the late 1990s through the mid-2000s, which are associated with moderate confidence

because we have little information regarding the consistency of methodologies or surveyors and because no data are available after 2005.

- Virginia barrier islands spring stopover area: There is no apparent trend based on aerial surveys since 1995, which is associated with high confidence. A newer data set based on ground surveys suggests an increase since 2007.
- Delaware Bay spring stopover area: There is a highly variable data set showing possible declines in the 1990s, and more consistent and substantial declines through the mid-2000s, which are associated with high confidence during the core years of 1986 to 2008. Numbers may have stabilized from 2009 to 2012, but we have lower confidence in trends over this later period due to multiple shifts in methodology and surveyors.
- Atlantic coast spring window survey: There is an apparent increase from 2010 to 2012, but it is associated with lower confidence because, despite improvements, methodology and geographic coverage are still stabilizing and because only three years of (relatively consistent) data are available.
- Fall stopover areas: There are insufficient data for trend analysis in most areas. Since the 1970s, there were probable declines in some parts of eastern Canada and changes in red knot usage of Massachusetts (mainland versus Cape Cod, proportion of birds bound for Southeast versus Argentina-Chile wintering destinations).

In conclusion, we have high confidence in two data sets from key red knot areas, Tierra del Fuego and Delaware Bay, showing declines over roughly the same period. Data sets associated with lower confidence from the Brazil wintering region and three South American spring stopovers also suggest declines roughly over this same timeframe. We conclude that the Virginia spring stopover was stable during this period (the 2000s). We do not conclude that the Southeast wintering region declined, due to the likelihood that knot usage shifted geographically within this region from year to year. Our analysis of the best available data concludes that an overall, sustained decline of red knot numbers occurred in the 2000s, and that red knot populations may have stabilized at a relatively low level in the last few years. Inferring long-term population trends from various national or regional datasets derived from volunteer shorebird surveys and other sources, Andres (2009) and Morrison et al. (2006) also concluded that red knot numbers declined, probably sharply, in recent decades.

### **Status and distribution**

The red knot's range spans 40 states, 24 countries, and their administrative territories or regions extending from their breeding grounds in the Canadian Arctic to migration stopover areas along the Atlantic and Gulf coasts of North America to wintering grounds throughout the Southeastern U.S., the Gulf coast, and South America (reaching as far south as Tierra del Fuego at the southern tip of South America). In Delaware Bay and Tierra del Fuego, the era of modern surveys for the red knot and other shorebird species began in the early 1980s. Systematic red knot surveys of other areas began later, and for many portions of the knot's range, available survey data are patchy. Prior to the 1980s, numerous natural history accounts are available, but provide mainly qualitative or localized population estimates. Nonetheless, a consistent narrative emerges across many historical accounts that red knots were extremely abundant in the early 1800s, decreased sharply starting in the mid-1800s, and may have begun to recover by the mid-1900s. Most writers agree the cause of that historical decline was intensive sport and market hunting. It is unclear whether the red knot population fully recovered its historical numbers (Harrington 2001) following the period of unregulated hunting.

The current geographic distribution of the red knot has not changed relative to that recorded in historical writings with the notable exception of Delaware Bay (discussed in detail below). Several early writers reported that red knots breed in the Arctic and winter along the U.S. Gulf coast and in South America including Brazil and Tierra del Fuego (Lowery 1974; Hellmayr and Conover 1948; Bent 1927; Ridgway 1919; Forbush 1912; Eaton 1910; Shriner 1897; Mackay 1893; Audubon 1844). Bent (1927) included Jamaica and Barbados as part of the possible wintering range of red knots, and described knots as “rarely” wintering in parts of Louisiana and Florida. Hellmayr and Conover (1948) noted the use of the West Indies (Jamaica, Barbados, and Trinidad) during migration. Several writers described the red knot as occurring primarily along the coasts with relatively few sightings inland, but interior migration routes through the central United States were also known (Lowery 1974; Hellmayr and Conover 1948; Bent 1927; Ridgway 1919; Forbush 1912; Eaton 1910; Audubon 1844). As with the geographic distribution, a number of historical accounts suggest that the timing of the red knot’s spring and fall migrations along the Atlantic coast was generally the same in the past as it is today (Myers and Myers 1979; Urner and Storer 1949; Stone 1937; Bent 1927; Forbush 1912; Shriner 1897; Dixon 1895 in Barnes and Truitt 1997; Mackay 1893; Stearns and Coues 1883; Roosevelt 1866; Giraud 1944; Wilson 1829).

Although the large-scale geographic distribution of migration stopover habitats does not seem to have changed, some authors have noted regional changes in the patterns of red knot stopover habitat usage along the U.S. Atlantic coast. For example, based on a review of early literature, Cohen et al. (2008c) suggest that red knots had a more extensive spring stopover range a century ago than now, with thousands of birds noted in spring in Massachusetts, New York, New Jersey, and Virginia. Harrington et al. (2010a) found changes in the regional patterns of stopover habitat usage in Massachusetts, as well as a shift in the wintering destination of birds stopping in Massachusetts during fall migration.

### Delaware Bay

Delaware Bay was not recognized as a major shorebird stopover area until the early 1980s, despite detailed shorebird studies (e.g., Urner and Storer 1949; Stone 1937) in the South Jersey region (Clark et al. 2009; Botton et al. in Shuster et al. 2003; Clark in Farrell and Martin 1997; Clark et al. 1993). There were some early anecdotal reports involving horseshoe crabs, as summarized by Botton et al. (in Shuster et al. 2003). Wilson (1829) noted that ruddy turnstones in the bay fed “almost wholly on the eggs, or spawn, of the great King Crab,” but no similar accounts were made of red knots. Forbush (1912) noted that red knots “are fond of the spawn of the horsefoot crab, which, often in company with the Turnstone, they dig out of the sand...” Stone (1937) observed ruddy turnstones and black-bellied plovers regularly feeding on dead horseshoe crabs in Delaware Bay. Stone (1937) also mentions flights of ruddy turnstones across the Cape May Peninsula in the spring, as happens today when they go to roost at night along the Atlantic coastal marshes (Botton et al. in Shuster et al. 2003). Interestingly, no mention of horseshoe crab eggs as food is found in Stone’s (1937) accounts of any shorebird in the Cape May area, or in the decade-long study by Urner and Storer (1949) (Botton et al. in Shuster et al. 2003). During his early studies of horseshoe crabs in 1951, Shuster observed many shorebirds feeding along Delaware Bay beaches, including red knots. However, another 30 years elapsed before scientists began to study the shorebird/horseshoe crab relationship in detail, and documented the very large numbers of shorebirds using the bay as a stopover (Botton et al. in Shuster et al. 2003). Lack of earlier scientific documentation cannot be attributed to remoteness. Delaware Bay is located within a few hours’ drive of millions of people, and university marine laboratories were established many years ago on both shores of the bay (Botton et al. in Shuster et al. 2003).

It is unclear if the large magnitude of the shorebird-horseshoe crab phenomenon was simply missed by science until 1981, or if the distribution of the red knot and other shorebird species changed over the period of the historical record. For much of the 20th century, this phenomenon in Delaware Bay may have been much reduced (relative to 1980s levels), and therefore easier to miss, due to the occurrence of low points in the abundance of both shorebirds (caused by hunting) and horseshoe crabs (caused by intensive harvest) (Botton et al. in Shuster et al. 2003; Clark in Farrell and Martin 1997).

Alternatively, it may be that the red knot did not make extensive use of Delaware Bay prior to its population decline a century ago. Under this scenario, red knots came to rely on Delaware Bay because their populations were recovering at the same time that Atlantic-side stopover habitats in the region were becoming developed and the shorelines stabilized (Cohen et al. 2008c). We have no means to determine how long shorebirds have been reliant on horseshoe crab eggs in Delaware Bay (Botton et al. in Shuster et al. 2003) prior to the early 1980s.

The middle part of the 20th century coincided with the recovery of shorebird populations following the regulation of hunting (Urner and Storer 1949; Bent 1927), a low point in horseshoe crab abundance following a period of intensive harvest (Atlantic States Marine Fisheries Commission (ASMFC) 2009), and the large-scale development and stabilization of Atlantic coast beaches in the mid-Atlantic region (Nordstrom and Mauriello 2001; Nordstrom 2000). Any or all of these factors may have influenced the red knot's use of, and reliance on, Delaware Bay as its primary Atlantic stopover site in spring.

#### *Threats to Red Knots and Their Habitat*

In this section, we provide an analysis of threats to red knots and their habitat in their migration and wintering range, with some specific references to their breeding range. Although the red knot's range extends farther than the piping plover's, some similarities exist in habitat use between the species within the U.S. portion of their migration and wintering ranges. Subsequently, there are similarities in the threats to those shared habitat features. The information presented in this section, however, is specific to the red knot and may cover a broader area and/or spectrum of similar threats than the information presented in the *Threats to piping plover/critical habitat* section. Because we lack information on threats to red knots for many countries outside the U.S. (with a few exceptions), this analysis is mainly focused on threats to red knots within the continental U.S. portion of their migration and wintering range, unless otherwise noted.

#### The inadequacy of existing regulatory mechanisms

There are some conservation efforts and regulatory mechanisms in place throughout the red knot's range that may help reduce threats to the subspecies. In the United States, the Migratory Bird Treaty Act of 1918 (MBTA) (40 Stat. 755, as amended; 16 U.S.C. 703 et seq.) is the only federal law currently providing specific protection for the red knot due to its status as a migratory bird by prohibiting the following actions, unless permitted by Federal regulation: to "pursue, hunt, take, capture, kill, attempt to take, capture or kill, possess, offer for sale, sell, offer to purchase, purchase, deliver for shipment, ship, cause to be shipped, deliver for transportation, transport, cause to be transported, carry, or cause to be carried by any means whatever, receive for shipment, transportation or carriage, or export, at any time, or in any manner, any migratory bird...or any part, nest, or egg of any such bird." Through issuance of Migratory Bird Scientific Collecting permits, the Service ensures that best practices are implemented for the careful capture and handling of red knots during banding operations and other research activities. However, there are no provisions in the MBTA that prevent habitat destruction unless the activity causes direct mortality or the destruction of active nests, which would not apply since red knots do not breed in the United States. The MBTA does not address threats

to the red knot from further population declines associated with habitat loss, insufficient food resources, climate change, or the other threats discussed in the remainder of the threats section.

Reduced food availability at the Delaware Bay stopover site due to commercial harvest of the horseshoe crab is considered a primary causal factor in the decline of the red knot in the 2000s. The Atlantic Coastal Fisheries Cooperative Management Act of 1993 set forth the current role of the Atlantic States Marine Fisheries Commission (ASMFC), which had been established under an interstate compact among all States from Maine to Florida and previously approved by Congress (P.L. 77-539 and 81-721). Under the 1993 law, the ASMFC develops coastal fishery management plans and monitors each State's compliance with the plans. If a State fails to implement and enforce a fishery plan, NOAA declares a moratorium on the fishery in question within the waters of the non-complying State. The ASMFC adopted a horseshoe crab management plan in 1998, with different provisions for the bait industry versus the biomedical industry. In 2012, the ASMFC adopted Addendum VII to the plan, which utilizes an Adaptive Resource Management (ARM) framework to manage the bait fishery in the Delaware Bay Region (New Jersey, Delaware, and parts of Maryland and Virginia) (ASMFC 2012). Under the ARM, bait harvest levels are tied to red knot populations via scientific modeling. There have been no instances of State noncompliance with the horseshoe crab management plan. In 2008, New Jersey enacted a law (N.J.S.A. 23.2b.21) extending an earlier (2006) statewide moratorium on the bait harvest until specific red knot recovery targets are achieved. Thus, New Jersey does not use its bait harvest quota as allocated by the ASMFC. Regulation of the horseshoe crab harvest is discussed in further detail below.

There are some state wildlife laws that also protect the red knot from direct take resulting from scientific study and hunting. Other Federal laws (e.g., the Sikes Act, the National Park Service Organic Act, and the National Wildlife Refuge System Improvement Act) provide protection for the red knot from habitat loss and inappropriate management on many Federal lands. Although shorebirds are not their focus, some laws do regulate shoreline stabilization and coastal development, including section 404 of the Clean Water Act, the Rivers and Harbors Act, the Coastal Barrier Resources Act, and the Coastal Zone Management Act as implemented by Federal and State regulations. We have limited information regarding State and local regulations regarding beach cleaning or recreational disturbance. Several Federal and State policies are in effect to stem the introductions and effects of invasive species, but collectively these do not provide complete protection for the red knot from impacts to its habitats or food supplies resulting from beach or marine invaders or the spread of harmful algal species. Although threats to the horseshoe crab egg resource remain, the current regulatory management of the horseshoe crab fishery is adequately addressing threats to the knot's Delaware Bay food supply from direct harvest. Although we lack information regarding the overall effect of recreation management policies on the red knot, we are aware of only a few locations in which beaches are closed, regulated, or monitored to protect nonbreeding shorebirds. Relatively strong Federal laws likely reduce risks to red knots from oil spills and pesticides, but both have caused documented shorebird mortalities and other impacts in recent decades. Similarly, existing Federal laws and policies are likely to reduce the red knot's collision risks from new wind turbine development, but some level of mortality is expected upon build-out of the Nation's wind energy infrastructure.

Canada also has laws (e.g., Canadian Species at Risk Act and Migratory Birds Convention Act) that provide protections to the red knot and its habitat both on and off Federal lands. We also know that red knots are legally protected from direct take and hunting in several Caribbean and Latin American countries, but we lack information regarding the implementation or effectiveness of those measures. We also lack information for countries outside the United States regarding protection or management

of red knot habitat, and regarding the regulation of other activities that threaten the red knot such as development, disturbance, oil spills, environmental contaminants, and wind energy development.

### Climate change

The natural history of Arctic-breeding shorebirds makes this group of species particularly vulnerable to global climate change (e.g., Meltofte et al. 2007; Piersma and Lindström 2004; Rehfisch and Crick 2003; Piersma and Baker 2000; Zöckler and Lysenko 2000; Lindström and Agrell 1999). Relatively low genetic diversity, which is thought to be a consequence of survival through past climate-driven population bottlenecks, may put shorebirds at more risk from human-induced climate variation than other avian taxa (Meltofte et al. 2007); low genetic diversity may result in reduced adaptive capacity as well as increased risks when population sizes drop to low levels.

In the short term, red knots may benefit if warmer temperatures result in fewer years of delayed horseshoe crab spawning in Delaware Bay (Smith and Michaels 2006) or fewer occurrences of late snow melt in the breeding grounds (Meltofte et al. 2007). However, there are indications that changes in the abundance and quality of red knot prey are already under way (Escudero et al. 2012; Jones et al. 2010), and prey species face ongoing climate-related threats from warmer temperatures (Jones et al. 2010; Philippart et al. 2003; Rehfisch and Crick 2003), ocean acidification (National Research Council (NRC) 2010; Fabry et al. 2008), and possibly increased prevalence of disease and parasites (Ward and Lafferty 2004). In addition, red knots face imminent threats from loss of habitat caused by sea level rise (NRC 2010; Galbraith et al. 2002; Titus 1990), and increasing asynchronies (“mismatches”) between the timing of their annual breeding, migration, and wintering cycles and the windows of peak food availability on which the birds depend (Smith et al. 2011; McGowan et al. 2011; Meltofte et al. 2007; van Gils et al. 2005a; Baker et al. 2004).

Several threats are related to the possibility of changing storm patterns. While variation in weather is a natural occurrence and is normally not considered a threat to the survival of a species, persistent changes in the frequency, intensity, or timing of storms at key locations where red knots congregate (e.g., key stopover areas) can pose a threat. Storms impact migratory shorebirds like the red knot both directly and indirectly. Direct impacts include energetic costs from a longer migration route as birds avoid storms, blowing birds off course, and outright mortality (Niles et al. 2010). Indirect impacts include changes to habitat suitability, storm-induced asynchronies between migration stopover periods and the times of peak prey availability, and possible prompting of birds to take refuge in areas where shorebird hunting is still practiced (Niles et al. 2012; Dey et al. 2011a; Nebel 2011).

With arctic warming, vegetation conditions in the red knot’s breeding grounds are expected to change, causing the zone of nesting habitat to shift and perhaps contract, but this process may take decades to unfold (Feng et al. 2012; Meltofte et al. 2007; Kaplan et al. 2003). Ecological shifts in the Arctic may appear sooner. High uncertainty exists about when and how changing interactions among vegetation, predators, competitors, prey, parasites, and pathogens may affect the red knot, but the impacts are potentially profound (Fraser et al. 2013; Schmidt et al. 2012; Meltofte et al. 2007; Ims and Fuglei 2005).

Due to background rates of sea level rise and the naturally dynamic nature of coastal habitats, we conclude that red knots are adapted to moderate (although sometimes abrupt) rates of habitat change in their wintering and migration areas. However, rates of sea level rise are accelerating beyond those that have occurred over recent millennia. In most of the red knot’s nonbreeding range, shorelines are expected to undergo dramatic reconfigurations over the next century as a result of accelerating sea

level rise. Extensive areas of marsh are likely to become inundated, which may reduce foraging and roosting habitats. Marshes may be able to establish farther inland, but the rate of new marsh formation (e.g., intertidal sediment accumulation, development of hydric soils, colonization of marsh vegetation) may be slower than the rate of deterioration of existing marsh, particularly under higher sea level rise scenarios. The primary red knot foraging habitats (i.e., intertidal flats and sandy beaches) will likely be locally or regionally inundated, but replacement habitats are likely to reform along the shoreline in its new position. However, if shorelines experience a decades-long period of high instability and landward migration, the formation rate of new beach habitats may be slower than the inundation rate of existing habitats. In addition, low-lying and narrow islands (e.g., in the Caribbean and along the Gulf and Atlantic coasts) may disintegrate rather than migrate, representing a net loss of red knot habitat. Superimposed on these changes are widespread human attempts to stabilize the shoreline, which are known to exacerbate losses of intertidal habitats by blocking their landward migration. The cumulative loss of habitat across the nonbreeding range could affect the ability of red knots to complete their annual cycles, possibly affecting fitness and survival, and is thereby likely to negatively influence the long-term survival of the red knot.

In summary, climate change is expected to affect red knot fitness and, therefore, survival through direct and indirect effects on breeding and nonbreeding habitat, food availability, and timing of the birds' annual cycle. Ecosystem changes in the arctic (e.g., changes in predation patterns and pressures) may also reduce reproductive output. Together, these anticipated changes will likely negatively influence the long-term survival of the red knot.

#### Reduced food availability

Commercial harvest of horseshoe crabs has been implicated as a causal factor in the decline of the red knot populations in the 2000s, by decreasing the availability of horseshoe crab eggs in the Delaware Bay stopover (Niles et al. 2008). Due to harvest restrictions and other conservation actions, horseshoe crab populations showed some signs of recovery in the early 2000s, with apparent signs of red knot stabilization (survey counts, rates of weight gain) occurring a few years later (as might be expected due to biological lag times). Since about 2005, however, horseshoe crab population growth has stagnated for unknown reasons. Under the current management framework, the present horseshoe crab harvest is not considered a threat to the red knot. However, it is not yet known if the horseshoe crab egg resource will continue to adequately support red knot populations over the next 5 to 10 years. In addition, implementation of the current management framework could be impeded by insufficient funding.

The causal role of reduced Delaware Bay food supplies in driving red knot population declines shows the vulnerability of red knots to declines in the quality or quantity of their prey. This vulnerability has also been demonstrated in other *C. canutus* subspecies, although not to the severe extent experienced by the *rufa* subspecies. In addition to the fact that horseshoe crab population growth has stagnated, red knots now face several emerging threats to their food supplies throughout their nonbreeding range. These threats include: small prey sizes (from unknown causes) at two key wintering sites on Tierra del Fuego; warming water temperatures that may cause mollusk population declines and range contractions (including the likely loss of a key prey species from the Virginia spring stopover within the next decade); ocean acidification to which mollusks are particularly vulnerable; physical habitat changes from climate change affecting invertebrate communities; possibly increasing rates of mollusk diseases due to climate change; invasive marine species from ballast water and aquaculture; and the burial and crushing of invertebrate prey from sand placement and recreational activities. Although threats to food quality and quantity are widespread, red knots in localized areas have shown some adaptive capacity to switch prey when the preferred prey species became reduced (Escudero et al.

2012; Musmeci et al. 2011), suggesting some adaptive capacity to cope with this threat. Nonetheless, based on the combination of documented past impacts and a spectrum of ongoing and emerging threats, we conclude that reduced quality and quantity of food supplies is a threat to the rufa red knot at the subspecies level, and the threat is likely to continue into the future.

#### Asynchronies (“mismatches”) in the red knot’s annual cycle

The red knot’s life history strategy makes this species inherently vulnerable to mismatches in timing between its annual cycle and those periods of optimal food and weather conditions upon which it depends. For unknown reasons, more red knots arrived late in Delaware Bay in the early 2000s, which is generally accepted as a key causative factor (along with reduced supplies of horseshoe crab eggs) behind red knot population declines that were observed over this same timeframe. Thus, the red knot’s sensitivity to timing asynchronies has been demonstrated through a population-level response. Both adequate supplies of horseshoe crab eggs and high-quality foraging habitat in Delaware Bay can serve to partially mitigate minor asynchronies at this key stopover site. However, the factors that caused delays in the spring migrations of red knots from Argentina and Chile are still unknown, and we have no information to indicate if this delay will reverse, persist, or intensify.

Superimposed on this existing threat of late arrivals in Delaware Bay are new threats of asynchronies emerging due to climate change. Climate change is likely to affect the reproductive timing of horseshoe crabs in Delaware Bay, mollusk prey species at other stopover sites, or both, possibly pushing the peak seasonal availability of food outside of the windows when red knots rely on them. In addition, both field studies and modeling have shown strong links between the red knot’s reproductive output and conditions in the Arctic including insect abundance and snow cover. Climate change may also cause shifts in the period of optimal arctic conditions relative to the time period when red knots currently breed.

The red knot’s adaptive capacity to deal with numerous changes in the timing of resource availability across its geographic range is largely unknown. A few examples suggest some flexibility in migration strategies. However, available information suggests that the timing of the red knot’s annual cycle is controlled at least partly by celestial and endogenous cues, while the reproductive seasons of prey species, including horseshoe crabs and mollusks, are largely driven by environmental cues such as water temperature. These differences between the timing cues of red knots and their prey suggest limitations on the adaptive capacity of red knots to deal with numerous changes in the timing of resource availability across their geographic range. Based on the combination of documented past impacts and a spectrum of ongoing and emerging threats, we conclude that asynchronies (mismatches between the timing of the red knot’s annual cycles and the periods of favorable food and weather upon which it depends) are likely to cause deleterious subspecies-level effects.

#### Shoreline stabilization and coastal development

Much of the U.S. coast within the range of the red knot is already extensively developed. Direct loss of shorebird habitats occurred over the past century as substantial commercial and residential developments were constructed in and adjacent to ocean and estuarine beaches along the Atlantic and Gulf coasts. In addition, red knot habitat was also lost indirectly, as sediment supplies were reduced and stabilization structures were constructed to protect developed areas. Sea level rise and human activities within coastal watersheds can lead to long-term reductions in sediment supply to the coast. The damming of rivers, bulk-heading of highlands, and armoring of coastal bluffs have reduced erosion in natural source areas and consequently the sediment loads reaching coastal areas. Although



it is difficult to quantify, the cumulative reduction in sediment supply from human activities may contribute substantially to the long-term shoreline erosion rate. Along coastlines subject to sediment deficits, the amount of sediment supplied to the coast is less than that lost to storms and coastal sinks (inlet channels, bays, and upland deposits), leading to long-term shoreline recession (Coastal Protection and Restoration Authority of Louisiana 2012; Florida Oceans and Coastal Council 2010; CCSP 2009b; Defeo et al. 2009; Morton et al. 2004; Morton 2003; Herrington 2003; Greene 2002).

In addition to reduced sediment supplies, other factors such as stabilized inlets, shoreline stabilization structures, and coastal development can exacerbate long-term erosion (Herrington 2003). Coastal development and shoreline stabilization can be mutually reinforcing. Coastal development often encourages shoreline stabilization because stabilization projects cost less than the value of the buildings and infrastructure. Conversely, shoreline stabilization sometimes encourages coastal development by making a previously high-risk area seem safer for development (CCSP 2009b). Protection of developed areas is the driving force behind ongoing shoreline stabilization efforts. Large-scale shoreline stabilization projects became common in the past 100 years with the increasing availability of heavy machinery. Shoreline stabilization methods change in response to changing new technologies, coastal conditions, and preferences of residents, planners, and engineers. Along the Atlantic and Gulf coasts, an early preference for shore-perpendicular structures (e.g., groins) was followed by a period of construction of shore-parallel structures (e.g., seawalls), and then a period of beach nourishment, which is now favored (Morton et al. 2004; Nordstrom 2000).

The mid-Atlantic coast from New York to Virginia is the most urbanized shoreline in the country, except for parts of Florida and southern California. In New York and New Jersey, hard structures and beach nourishment programs cover much of the coastline. Farther south, there are more undeveloped and preserved sections of coast (Leatherman 1989). Along the entire Atlantic, most of the ocean coast is fully or partly (intermediate) developed, less than 10 percent is in conservation, and about one-third is undeveloped and still available for new development (Table 10).

Table 10. Percent\* of dry land within 3.3 feet (1 m) of high water by intensity of development along the U.S. Atlantic Coast (Titus et al. 2009).

State	Developed	Intermediate	Undeveloped	Conservation
Massachusetts	26	29	22	23
Rhode Island	36	11	48	5
Connecticut	80	8	7	5
New York	73	18	4	6
New Jersey	66	15	12	7
Pennsylvania	49	21	26	4
Delaware	27	26	23	24
Maryland	19	16	56	9
District of Columbia	82	5	14	0
Virginia	39	22	32	7
North Carolina	28	14	55	3
South Carolina	28	21	41	10
Georgia	27	16	23	34
Florida	65	10	12	13
Coastwide	42	15	33	9

\* Percentages may not add up to 100 due to rounding.

The U.S. southeastern coast from North Carolina to Florida is the least urbanized along the Atlantic coast, although both coasts of Florida are urbanizing rapidly. Texas has the most extensive sandy

coastline in the Gulf, and much of the area is sparsely developed (Leatherman 1989). Table 11 gives the miles of developed and undeveloped beach from North Carolina to Texas. Region-wide, about 40 percent of the southeast and Gulf coast is already developed, as shown in Table 11. Not all of the remaining 60 percent in the “undeveloped” category, however, is still available for development because about 43 percent (about 910 miles) of beaches across this region are considered preserved. Preserved beaches include those in public or nongovernmental conservation ownership and those under conservation easements.

Table 11. The lengths and percentages of developed and undeveloped sandy, oceanfront beaches along the Southeast Atlantic and Gulf coasts (Rice 2013 pers. comm.; Rice 2012a; Service 2012a).

State	Miles of Shoreline	Miles and percent of developed beach	Miles and percent of undeveloped beach*
North Carolina	326	159 (49%)	167 (51%)
South Carolina	182	93 (51%)	89 (49%)
Georgia	90	15 (17%)	75 (83%)
Florida	809	459 (57%)	351 (43%)
Alabama	46	25 (55%)	21(45%)
Mississippi barrier islands	27	0 (0%)	27 (100%)
Mississippi mainland**	51	41 (80%)	10 (20%)
Louisiana	218	13 (6%)	205 (94%)
Texas	370	51 (14%)	319 (86%)
Coast-wide	2,119	856 (40%)	1,264 (60%)

\* Beaches classified as “undeveloped” occasionally include a few scattered structures.

\*\* The mainland Mississippi coast along Mississippi Sound includes 51.3 mi 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).

Past and ongoing stabilization projects fundamentally alter the naturally dynamic coastal processes that create and maintain beach strand and bayside habitats, including those habitat components that red knots rely upon. Past loss of stopover and wintering habitat likely reduce the resilience of the red knot by making it more dependent on those habitats that remain, and more vulnerable to threats (e.g., disturbance, predation, reduced quality or abundance of prey, increased intraspecific and interspecific competition) within those restricted habitats.

### Hard structures

Hard structures constructed of stone, concrete, wood, steel, or geotextiles have been used for centuries as a coastal defense strategy (Defeo et al. 2009). The most common hard stabilization structures fall into two groups: structures that run parallel to the shoreline (e.g., seawalls, revetments, bulkheads) and structures that run perpendicular to the shoreline (e.g., groins, jetties). Groins are often clustered in groin fields, and are intended to protect a finite section of beach, while jetties are normally constructed at inlets to keep sand out of navigation channels and provide calm-water access to harbor facilities (USACE 2002). Descriptions of the different types of stabilization structures can be found in Rice (2009), Herrington (2003), and USACE (2002, Parts V and VI).

Prior to the 1950s, the general practice in the United States was to use hard structures to protect developments from beach erosion or storm damages (USACE 2002). The pace of constructing new hard stabilization structures has since slowed considerably (USACE 2002). Many states within the range of the red knot now discourage or restrict the construction of new, hard oceanfront protection structures, although the hardening of bayside shorelines is generally still allowed (Kana 2011; Greene

2002; Titus 2000). Most existing hard oceanfront structures continue to be maintained, and some new structures continue to be built. While some states have restricted new construction, hard structures are still among the alternatives in the Federal shore protection program (USACE 2002).

Hard shoreline stabilization projects are typically designed to protect property (and its human inhabitants) not beaches (Kana 2011; Pilkey and Howard 1981). Through effects on waves and currents, sediment transport rates, Aeolian (wind) processes, and sand exchanges with dunes and offshore bars, hard structures change the erosion/accretion dynamics of beaches and constrain the natural migration of shorelines (CCSP 2009b; Defeo et al. 2009; Morton 2003; Scavia et al. 2002; Nordstrom 2000). There is ample evidence of accelerated erosion rates, pronounced breaks in shoreline orientation, and truncation of the beach profile down-drift of perpendicular structures, and of reduced beach widths (relative to unprotected segments) where parallel structures have been in place over long periods of time (Hafner 2012; CCSP 2009b; Morton 2003; Scavia et al. 2002; USACE 2002; Nordstrom 2000; Pilkey and Wright 1988). In addition, marinas and port facilities built out from the shore can have effects similar to hard stabilization structures (Nordstrom 2000).

Structural development along the shoreline and manipulation of natural inlets upset the naturally dynamic coastal processes and result in loss or degradation of beach habitat (Melvin et al. 1991). As beaches narrow, the reduced habitat can directly lower the diversity and abundance of biota (life forms), especially in the upper intertidal zone. Shorebirds may be impacted both by reduced habitat area for roosting and foraging, and by declining intertidal prey resources, as has been documented in California (Defeo et al. 2009; Dugan and Hubbard 2006). In an estuary in England, Stillman et al. (2005) found that a two to eight percent reduction in intertidal area (the magnitude expected through sea level rise and industrial developments including extensive stabilization structures) decreased the predicted survival rates of five out of nine shorebird species evaluated (although not of red knots). In Delaware Bay, hard structures also cause or accelerate loss of horseshoe crab spawning habitat (CCSP 2009b; Botton et al. in Shuster et al. 2003; Botton et al. 1988), and shorebird habitat has been, and may continue to be, lost where bulkheads have been built (Clark in Farrell and Martin 1997). In addition to directly eliminating red knot habitat, hard structures interfere with the creation of new shorebird habitats by interrupting the natural processes of over-wash and inlet formation. Where hard stabilization is installed, the eventual loss of the beach and its associated habitats is virtually assured (Rice 2009), absent beach nourishment, which may also impact red knots as discussed below. Where they are maintained, hard structures are likely to significantly increase the amount of red knot habitat lost as sea levels continue to rise.

In a few isolated locations, however, hard structures may enhance red knot habitat, or may provide artificial habitat. In Delaware Bay, for example, Botton et al. (1994) found that, in the same manner as natural shoreline discontinuities like creek mouths, jetties and other artificial obstructions can act to concentrate drifting horseshoe crab eggs and thereby attract shorebirds. Another example comes from the Delaware side of the bay, where a seawall and jetty at Mispillion Harbor protect the confluence of the Mispillion River and Cedar Creek. These structures create a low energy environment in the harbor, which seems to provide highly suitable conditions for horseshoe crab spawning over a wider variation of weather and sea conditions than anywhere else in the bay (Breese 2013 pers. comm.). Horseshoe crab egg densities at Mispillion Harbor are consistently an order of magnitude higher than at other bay beaches (Dey et al. 2011b), and this site consistently supports upwards of 15 to 20 percent of all the knots recorded in Delaware Bay (Lathrop 2005). In Florida, Schwarzer (2013 pers. comm.) has observed multiple instances of red knots using artificial structures such as docks, piers, jetties, causeways, and construction barriers; we have no information regarding the frequency, regularity, timing, or significance of this use of artificial habitats. Notwithstanding localized red knot use of

artificial structures, and the isolated case of hard structures improving foraging habitat at Mispillion Harbor, the nearly universal effect of such structures is the degradation or loss of red knot habitat.

### Mechanical sediment transport

Several types of sediment transport are employed to stabilize shorelines, protect development, maintain navigation channels, and provide for recreation (Gebert 2012; Kana 2011; USACE 2002). The effects of these projects are typically expected to be relatively short in duration, usually less than 10 years, but often these actions are carried out every few years in the same area, resulting in a more lasting impact on habitat suitability for shorebirds. Mechanical sediment transport practices include beach nourishment, sediment back-passing, sand scraping, and dredging.

Since the 1970s, 90 percent of the Federal appropriation for shore protection has been for beach nourishment (USACE 2002), which has become the preferred course of action to address shoreline erosion in the United States (Kana 2011; Morton and Miller 2005; Greene 2002). Beach nourishment requires an abundant source of sand that is compatible with the native beach material. The sand is trucked to the target beach or hydraulically pumped using dredges (Hafner 2012). Sand for beach nourishment operations can be obtained from dry land-based sources; estuaries, lagoons, or inlets on the backside of the beach; sandy shoals in inlets and navigation channels; near-shore ocean waters; or offshore ocean waters; with the last two being the most common sources (Greene 2002).

Where shorebird habitat has been severely reduced or eliminated by hard stabilization structures, beach nourishment may be the only means available to replace any habitat for as long as the hard structures are maintained (Nordstrom and Mauriello 2001), although such habitat will persist only with regular nourishment episodes (typically on the order of every two to six years). In Delaware Bay, beach nourishment has been recommended to prevent loss of spawning habitat for horseshoe crabs (Kalasz 2008; Carter et al. in Guilfoyle et al. 2007; Atlantic States Marine Fisheries Commission (ASMFC) 1998), and is being pursued as a means of restoring shorebird habitat in Delaware Bay following Hurricane Sandy (Niles et al. 2013; USACE 2012). Beach nourishment was part of a 2009 project to maintain important shorebird foraging habitat at Mispillion Harbor, Delaware (Kalasz 2013 pers. comm.; Siok and Wilson 2011). However, red knots may be directly disturbed if beach nourishment takes place while the birds are present. On New Jersey's Atlantic coast, beach nourishment has typically been scheduled for the fall, when red knots are present, because of various constraints at other times of year. In addition to causing disturbance during construction, beach nourishment often increases recreational use of the widened beaches that, without careful management, can increase disturbance of red knots. Beach nourishment can also temporarily depress, and sometimes permanently alter, the invertebrate prey base on which shorebirds depend.

In addition to disturbing the birds and impacting the prey base, beach nourishment can affect the quality and quantity of red knot habitat (Bimbi 2012 pers. comm.; Greene 2002). The artificial beach created by nourishment may provide only suboptimal habitat for red knots, as a steeper beach profile is created when sand is stacked on the beach during the nourishment process. In some cases, nourishment is accompanied by the planting of dense beach grasses, which can directly degrade habitat, as red knots require sparse vegetation to avoid predation. By precluding over-wash and Aeolian transport, especially where large artificial dunes are constructed, beach nourishment can also lead to further erosion on the bayside and promote bayside vegetation growth, both of which can degrade the red knot's preferred foraging and roosting habitats (sparsely vegetated flats in or adjacent to intertidal areas). Preclusion of over-wash also impedes the formation of new red knot habitats. Beach nourishment can also encourage further development, bringing further habitat impacts, reducing

future alternative management options such as a retreat from the coast, and perpetuating the developed and stabilized conditions that may ultimately lead to inundation where beaches are prevented from migrating (Bimbi 2012 pers. comm.; Greene 2002).

Following placement of sediments much coarser than those native to the beach, Peterson et al. (2006) found that the area of intertidal-shallow sub-tidal shorebird foraging habitat was reduced by 14 to 29 percent at a site in North Carolina. Presence of coarse shell material armored the substrate surface against shorebird probing, further reducing foraging habitat by 33 percent, and probably also inhibiting manipulation of prey when encountered by a bird's bill (Peterson et al. 2006). In addition to this physical change from adding coarse sediment, nourishment that places sediment dissimilar to the native beach also substantially increases impacts to the red knot's invertebrate prey base.

Sediment back-passing is a technique that reverses the natural migration of sediment by mechanically (via trucks) or hydraulically (via pipes) transporting sand from accreting, downdrift areas of the beach to eroding, up-drift areas of the beach (Kana 2011; Chasten and Rosati 2010). Currently less prevalent than beach nourishment, sediment back-passing is an emerging practice because traditional nourishment methods are beginning to face constraints on budgets and sediment availability (Hafner 2012; Chase 2006). Beach bulldozing or scraping is the process of mechanically redistributing beach sand from the littoral zone (along the edge of the sea) to the upper beach to increase the size of the primary dune or to provide a source of sediment for beaches that have no existing dune; no new sediment is added to the system (Kana 2011; Greene 2002; Lindquist and Manning 2001). Beach scraping tends to be a localized practice. In Florida beach scraping is usually used only in emergencies such as after hurricanes and other storms, but in New Jersey this practice is more routine in some areas. Many of the effects of sediment back-passing and beach scraping are similar to those for beach nourishment (Service 2011c; Lindquist and Manning 2001), including disturbance during and after construction, alteration of prey resources, reduced habitat area and quality, and precluded formation of new habitats. Relative to beach nourishment, sediment back-passing and beach scraping can involve considerably more driving of heavy trucks and other equipment on the beach including areas outside the sand placement footprint, potentially impacting shorebird prey resources over a larger area (Service 2011c). In addition, these practices can directly remove sand from red knot habitats, as is the case in one red knot concentration area in New Jersey (Service 2011c). Back-passing and sand scraping can involve routine episodes of sand removal or transport that maintain the beach in a narrower condition, indefinitely reducing the quantity of back-beach roosting habitat.

Sediments are also manipulated to maintain navigation channels. Many inlets in the U.S. range of the red knot are routinely dredged and sometimes relocated. In addition, near-shore areas are routinely dredged ("mined") to obtain sand for beach nourishment. Regardless of the purpose, inlet and near-shore dredging can affect red knot habitats. Dredging often involves removal of sediment from sand bars, shoals, and inlets in the near-shore zone, directly impacting optimal red knot roosting and foraging habitats (Harrington 2008; Harrington in Guilfoyle et al. 2007; Winn and Harrington in Guilfoyle et al. 2006). These ephemeral habitats are even more valuable to red knots because they tend to receive less recreational use than the main beach strand. In addition to causing this direct habitat loss, the dredging of sand bars and shoals can preclude the creation and maintenance of red knot habitats by removing sand sources that would otherwise act as natural breakwaters and weld onto the shore over time (Hayes and Michel 2008; Morton 2003). Further, removing these sand features can cause or worsen localized erosion by altering depth contours and changing wave refraction (Hayes and Michel 2008), potentially degrading other nearby red knot habitats indirectly because inlet dynamics exert a strong influence on the adjacent shorelines. Studying barrier islands in Virginia and North Carolina, Fenster and Dolan (1996) found that inlet influences extend 3.4 to 8.1 mi (5.4 to 13.0 km),

and that inlets dominate shoreline changes for up to 2.7 mi (4.3 km). Changing the location of dominant channels at inlets can create profound alterations to the adjacent shoreline (Nordstrom 2000).

#### Wrack removal and beach cleaning

The effects of wrack removal and beach cleaning to red knot migration and wintering habitat are similar to those described in the *Threats to piping plovers/critical habitat* section on page 22 of this document. Therefore, that information will not be reiterated here and we provide the following summary.

The occurrence of beach raking in the Southeast and Gulf coasts were discussed in the *Threats to piping plovers/critical habitat* section on page 22. Only minimal disturbance is likely to occur on mid-Atlantic and northern Atlantic beaches because raking in these areas is most prevalent from Memorial Day to Labor Day, when only small numbers of red knots typically occur in this region. However, the practice of intensive beach raking may cause physical changes to beaches that degrade their suitability as red knot habitat. Removal of wrack may also have an effect on the availability of red knot food resources, particularly in those times and places that birds are more reliant on wrack-associated prey items. Beach cleaning machines are likely to cause disturbance to roosting and foraging red knots, particularly in the U.S. wintering range. Mechanized beach cleaning is widespread within the red knot's U.S. range, particularly in developed areas. We anticipate beach grooming may expand in some areas that become more developed but may decrease in other areas due to increasing environmental regulations, such as restrictions on beach raking in piping plover nesting areas (e.g., Nordstrom and Mauriello 2001).

#### Invasive vegetation

The effects of invasive vegetation to red knot migration and wintering habitat are similar to those described in the *Threats to piping plovers/critical habitat* section on page 21 of this document. Therefore, that information will not be reiterated here and we provide the following summary.

Although the extent of the threat is uncertain, that uncertainty may be due to poor survey coverage more than an absence of species invasions. The propensity of invasive species to spread, and their tenacity once established, make them a persistent problem that is only partially countered by increasing awareness and willingness of beach managers to undertake control efforts (Service 2012a). Red knots require open habitats that allow them to see potential predators and that are away from tall perches used by avian predators. Invasive species, particularly woody species, degrade or eliminate the suitability of red knot roosting and foraging habitats by forming dense stands of vegetation. Although not a primary cause of habitat loss, invasive species can be a regionally important contributor to the overall loss and degradation of the red knot's nonbreeding habitat.

#### Aquaculture and agriculture

In some localized areas within the red knot's range, aquaculture or agricultural activities are impacting habitat quality and quantity. Those impacts, however, occur mainly in Canada, Brazil, Río Gallegos (southern Argentina), and Bahía Lomas (Chilean Tierra del Fuego). In the United States, Luckenbach (2007) found that aquaculture of clams (*Mercenaria mercenaria*) in the lower Chesapeake Bay occurs in close proximity to shorebird foraging areas. The current distribution of clam aquaculture in the very low intertidal zone minimizes the amount of direct overlap with shorebird foraging habitats, but if clam aquaculture expands farther into the intertidal zone, more shorebird impacts (e.g., habitat alteration)

may occur. However, these Chesapeake Bay intertidal zones are not considered the primary habitat for red knots (Cohen et al. 2009), and red knots were not among the shorebirds observed in this study (Luckenbach 2007). Likewise, oyster aquaculture is practiced in Delaware Bay (NJDEP 2011), but we have no information to indicate that this activity is affecting red knots.

### Hunting

Since the late 19th century, hunters concerned about the future of wildlife and the outdoor tradition have made countless contributions to conservation. In many cases, managed hunting is an important tool for wildlife management. However, unregulated or illegal hunting can cause population declines, as was documented in the 1800s for red knots in the United States. While no longer a concern in the United States, under-regulated or illegal hunting of red knots and other shorebirds is ongoing in parts of the Caribbean and South America.

### Scientific study

Considerable care is taken to minimize disturbance caused to shorebirds from these research activities. Numbers of birds per catch and total numbers caught over the season are limited, and careful handling protocols are followed, including a 3-hour limit on holding times (Niles et al. 2010; Niles 2008 pers. comm.; Sitters 2008 pers. comm.; Niles et al. 2008). Despite these measures, hundreds of red knots are temporarily stressed during the course of annual research, and mortality, though rare, does occasionally occur (Clark 2013 pers. comm.; Taylor 1981). However, we conclude that these research activities are not a threat to the red knot because evaluations have shown no effects of these short-term stresses on red knot survival. Further, the rare, carefully documented, and properly permitted mortality of an individual bird in the course of well-founded research does not affect red knot populations or the overall subspecies.

### Disease

Red knots are exposed to parasites and disease throughout their annual cycle. Susceptibility to disease may be higher when the energy demands of migration have weakened the immune system. Studying red knots in Delaware Bay in 2007, Buehler et al. (2010) found that several indices of immune function were lower in birds recovering protein after migration than in birds storing fat to fuel the next leg of the migration. These authors hypothesized that fueling birds may have an increased rate of infection or may be bolstering immune defense, or recovering birds may be immuno-compromised because of the physical strain of migratory flight or as a result of adaptive energy tradeoffs between immune function and migration, or both (Buehler et al. 2010). A number of known parasites (e.g., sporozoans, hookworms, flatworms, and ectoparasites) and viruses (e.g., avian influenza and avian paramyxovirus) have been documented in red knots, but we have no evidence that disease is a current threat to the red knot.

### Predation

In wintering and migration areas, the most common predators of red knots are peregrine falcons, harriers, accipiters, merlins, short-eared owls, and greater black-backed gulls (Niles et al. 2008). In addition to greater black-backed gulls, other large gulls (e.g., herring gulls) are anecdotally known to prey on shorebirds (Breese 2010). Predation by a great horned owl has been documented in Florida (Schwarzer 2013 pers. comm.). Nearly all documented predation of wintering red knots in Florida has been by avian, not terrestrial, predators (Schwarzer 2013 pers. comm.). However in migration areas

like Delaware Bay, terrestrial predators such as red foxes and feral cats may be a threat to red knots by causing disturbance, but direct mortality from these predators may be low (Niles et al. 2008).

Raptor predation has been shown to be an important mortality factor for shorebirds at several sites (Piersma et al. 1993). However, Niles et al. (2008) concluded that increased raptor populations have not been shown to affect the size of shorebird populations. Based on studies of other *C. canutus* subspecies in the Dutch Wadden Sea, Piersma et al. (1993) concluded that the chance for an individual to be attacked and captured is small, as long as the birds remain in the open and in large flocks so that approaching raptors are likely to be detected. Although direct mortality from predation is generally considered relatively low in nonbreeding areas, predators also impact red knots by affecting habitat use and migration strategies (Niles et al. 2008; Stillman et al. 2005) and by causing disturbance, thereby potentially affecting red knots' rates of feeding and weight gain.

In wintering and migration areas, predation is not directly impacting red knot populations despite some direct mortality. At key stopover sites, however, localized predation pressures are likely to exacerbate other threats to red knot populations, such as habitat loss, food shortages, and asynchronies between the birds' stopover period and the occurrence of favorable food and weather conditions. Predation pressures worsen these threats by pushing red knots out of otherwise suitable foraging and roosting habitats, causing disturbance, and possibly causing changes to stopover duration or other aspects of the migration strategy.

Although little information is available from the breeding grounds, the long-tailed jaeger is prominently mentioned as a predator of red knot chicks in most accounts. Other avian predators include parasitic jaeger, pomarine jaeger, herring gull, glaucous gull, gyrfalcon, peregrine falcon, and snowy owl. Mammalian predators include arctic fox and sometimes arctic wolves (Niles et al. 2008; COSEWIC 2007). Predation pressure on Arctic-nesting shorebird clutches varies widely regionally, inter-annually, and even within each nesting season, with nest losses to predators ranging from close to 0 percent to near 100 percent (Moltofte et al. 2007), depending on ecological factors. In the Arctic, 3- to 4-year lemming cycles give rise to similar cycles in the predation of shorebird nests. When lemmings are abundant, predators concentrate on the lemmings, and shorebirds breed successfully. When lemmings are in short supply, predators switch to shorebird eggs and chicks (Niles et al. 2008; COSEWIC 2007; Moltofte et al. 2007; Service 2003; Blomqvist et al. 2002; Summers and Underhill 1987).

In addition to affecting reproductive output, these cyclic predation pressures have been shown to influence shorebird nesting chronology and distribution. Studying 12 shorebird species, including red knot, over 11 years at four sites in the eastern Canadian Arctic, Smith et al. (2010) found that both snow conditions and predator abundance have significant effects on the chronology of breeding. Higher predator abundance resulted in earlier nesting than would be predicted by snow cover alone (Smith et al. 2010). Based on the adaptations of various species to deal with predators, Larson (1960) concluded that the distribution and abundance of red knots and other Arctic-breeding shorebirds were strongly influenced by arctic fox and rodent cycles, such that birds were in low numbers or absent in areas without lemmings because foxes preyed predominately on birds in those areas (as cited in Fraser et al. 2013). Unsuccessful breeding seasons contributed to at least some of the observed reductions in the red knot population in the 2000s. However, rodent-predator cycles have always affected the productivity of Arctic-breeding shorebirds and have generally caused only minor year-to-year changes in otherwise stable populations (Niles et al. 2008).



We conclude that cyclic predation in the Arctic results in years with extremely low reproductive output but does not threaten the red knot. The cyclical nature of this predation on shorebirds is a situation that has probably occurred over many centuries, and under historic conditions likely had no lasting impact on red knot populations. Where and when rodent-predator cycles are operating, we expect red knot reproductive success will also be cyclic. However, these cycles are being interrupted for reasons that are not yet fully clear. The geographic extent and duration of future interruptions to the cycles cannot be forecasted but may intensify as the arctic climate changes. Disruptions in the rodent-predator cycle pose a substantial threat to red knot populations, as they may result in prolonged periods of very low reproductive output. Superimposed on these potential cycle disruptions are warming temperatures and changing vegetative conditions in the Arctic, which are likely to bring about additional changes in the predation pressures faced by red knots on the breeding grounds; we cannot forecast how such ecosystem changes are likely to unfold.

### Human disturbance

In some wintering and stopover areas, red knots and recreational users (e.g., pedestrians, ORVs, dog walkers, boaters) are concentrated on the same beaches (Niles et al. 2008; Tarr 2008). Recreational activities affect red knots both directly and indirectly. These activities can cause habitat damage (Schlacher and Thompson 2008; Anders and Leatherman 1987), cause shorebirds to abandon otherwise preferred habitats, negatively affect the birds' energy balances, and reduce the amount of available prey. Effects to red knots from vehicle and pedestrian disturbance can also occur during construction of shoreline stabilization projects including beach nourishment. Red knots can also be disturbed by motorized and non-motorized boats, fishing, kite surfing, aircraft, and research activities (Kalasz 2011 pers. comm.; Niles et al. 2008; Peters and Otis 2007; Harrington 2005b; Meyer et al. 1999; Burger 1986) and by beach raking. In Delaware Bay, red knots could also potentially be disturbed by hand-harvest of horseshoe crabs during the spring migration stopover period, but under the current management of this fishery, State waters from New Jersey to coastal Virginia are closed to horseshoe crab harvest and landing from January 1 to June 7 each year (ASMFC 2012); thus, disturbance from horseshoe crab harvest is no longer occurring. Active management can be effective at reducing and minimizing the adverse effects of recreational disturbance (Burger and Niles in press; Forsy 2011; Burger et al. 2004), but such management is not occurring throughout the red knot's range.

Red knots are exposed to disturbance from recreational and other human activities throughout their nonbreeding range. Excessive disturbance has been shown to preclude shorebird use of otherwise preferred habitats and can impact energy budgets. Both of these effects are likely to exacerbate other threats to the red knot, such as habitat loss, reduced food availability, asynchronies in the annual cycle, and competition with gulls (such competition is greater in Delaware Bay when foraging on horseshoe crab eggs; in other areas, the two species' diets do not tend to overlap).

### Harmful algal blooms

A harmful algal bloom (HAB) is the proliferation of a toxic or nuisance algal species (which can be microscopic or macroscopic, such as seaweed) that negatively affects natural resources or humans (Florida Fish and Wildlife Conservation Commission (FFWCC) 2011). The primary groups of microscopic species that form HABs are flagellates (including dinoflagellates), diatoms, and blue-green algae (which are actually cyanobacteria, rather than true algae). Of the approximately 85 HAB-forming species currently documented, almost all of them are plant-like microalgae that require light and carbon dioxide to produce their own food using chlorophyll (FFWCC 2011). Blooms can appear

green, brown, or red-orange, or may be colorless, depending upon the species blooming and environmental conditions. Although HABs are popularly called “red tides,” this name can be misleading, as it includes many blooms that discolor the water but cause no harm, while also excluding blooms of highly toxic cells that cause problems at low (and essentially invisible) concentrations (Woods Hole 2012). In this document, the term “red tide” refers only to blooms of the dinoflagellate *Karenia brevis*.

For shorebirds, shellfish are a key route of exposure to algal toxins. When toxic algae are filtered from the water as food by shellfish, their toxins accumulate in those shellfish to levels that can be lethal to animals that eat the shellfish (Anderson 2007). Several shellfish poisoning syndromes have been identified according to their symptoms. Those shellfish poisoning syndromes that occur prominently within the range of the red knot include: Amnesic Shellfish Poisoning (ASP), occurring in Atlantic Canada, caused by *Pseudo-nitzschia* spp.; Neurotoxic Shellfish Poisoning (NSP, also called “red tide”), occurring on the U.S. coast from Texas to North Carolina, caused by *Karenia brevis* and other species; and Paralytic Shellfish Poisoning (PSP), occurring in Atlantic Canada, the U.S. coast in New England, Argentina, and Tierra del Fuego, caused by *Alexandrium* spp. and others (Woods Hole 2012; FAO 2004). The highest levels of PSP toxins have been recorded in shellfish from Tierra del Fuego (International Atomic Energy Agency 2004), and high levels can persist in mollusks for months following a PSP bloom (FAO 2004). In Florida, the St. Johns, St. Lucie, and Caloosahatchee Rivers and estuaries have also been affected by persistent HABs of cyanobacteria (FFWCC 2011).

Algal toxins may be a direct cause of death in seabirds and shorebirds via an acute or lethal exposure, or birds can be exposed to chronic, sub-lethal levels of a toxin over the course of an extended bloom. Sub-acute doses may contribute to mortality due to an impaired ability to forage productively, disrupted migration behavior, reduced nesting success, or increased vulnerability to predation, dehydration, disease, or injury (VanDeventer 2007). It is commonly believed that the primary risk to shorebirds during an HAB is via contamination of shellfish and other invertebrates that constitute their normal diet. Coquina clams and other items that shorebirds feed upon can accumulate marine toxins during HABs and may pose a risk to foraging shorebirds. In addition to consuming toxins via their normal prey items, shorebirds have been observed consuming dead fish killed by HABs (VanDeventer 2007). Brevetoxins were found both in the dead fish and in the livers of dead shorebirds that were collected from beaches and rehabilitation centers (VanDeventer et al. 2011). Although scavenging has not been documented in red knots, clams and other red knot prey species are among the organisms that accumulate algal toxins.

Sick or dying birds often seek shelter in dense vegetation; thus, those that succumb to HAB exposure are not often observed or documented. Birds that are debilitated or die in exposed areas are subject to predation or may be swept away in tidal areas. When extensive fish kills occur from HABs, the carcasses of smaller birds such as shorebirds may go undetected. Some areas affected by HABs are remote and rarely visited. Thus, mortality of shorebirds associated with HABs is likely underreported.

To date, direct impacts to red knots from HABs have been documented only in Texas, although a large die-off in Uruguay may have also been linked to an HAB. We conclude that some level of undocumented red knot mortality from HABs likely occurs most years, based on probable underreporting of shorebird mortalities from HABs and the direct exposure of red knots to algal toxins (particularly via contaminated prey) throughout the knot’s nonbreeding range. We have no documented evidence that HABs were a driving factor in red knot population declines in the 2000s. However, HAB frequency and duration have increased and do not show signs of abating over the next

few decades. Combined with other threats, ongoing and possibly increasing mortality from HABs may affect the red knot at the population level.

### Environmental contaminants

Although red knots are exposed to a variety of contaminants across their nonbreeding range, we have no evidence that such exposure is impacting health, survival, or reproduction at the subspecies level. Exposure risks exist in localized red knot habitats in Canada, but best available data suggest shorebirds in Canada are not impacted by background levels of contamination. Levels of most metals in red knot feathers from the Delaware Bay have been somewhat high but generally similar to levels reported from other studies of shorebirds. One preliminary study suggests organochlorines and trace metals are not elevated in Delaware Bay shorebirds, although this finding cannot be confirmed without updated testing. Levels of metals in horseshoe crabs are generally low in the Delaware Bay region and not likely impacting red knots or recovery of the crab population.

Horseshoe crab reproduction does not appear impacted by the mosquito control chemical methoprene (at least through the first juvenile molt) or by ambient water quality in mid-Atlantic estuaries. Shorebirds have been impacted by pesticide exposure, but use of the specific chemical that caused a piping plover death in Florida has subsequently been banned in the United States. Exposure of shorebirds to agricultural pollutants in rice fields may occur regionally in parts of South America, but red knot usage of rice field habitats was low in the several countries surveyed. Finally, localized urban pollution has been shown to impact South American red knot habitats, but we are unaware of any documented health effects or population-level impacts. Thus, we conclude that environmental contaminants are not a threat to the red knot.

### Oil spills

The red knot has the potential to be exposed to oil spills and leaks throughout its migration and wintering range. Oil, as well as spill response activities, can directly and indirectly affect both the bird and its habitat through several pathways. Red knots can be exposed to petroleum products via spills from shipping vessels, leaks or spills from offshore oil rigs or undersea pipelines, leaks or spills from onshore facilities such as petroleum refineries and petrochemical plants, and beach-stranded barrels and containers that can fall from moving cargo ships or offshore rigs. Several key red knot wintering or stopover areas also contain large-scale petroleum extraction, transportation, or both activities. With regard to potential effects on red knot habitats, the geographic location of a spill, weather conditions (e.g., prevailing winds), and type of oil spilled are as important, if not more so, than the volume of the discharge.

Red knots are exposed to large-scale petroleum extraction and transportation operations in many key wintering and stopover habitats including Tierra del Fuego, Patagonia, the Gulf of Mexico, Delaware Bay, and the Gulf of St. Lawrence. To date, the documented effects to red knots from oil spills and leaks have been minimal; however, information regarding any oiling of red knots during the Deepwater Horizon spill has not yet been released. (See the *Threats to piping plovers/critical habitat* section on pages 28 and 29 of this document for further details regarding potential impacts related to the Deepwater Horizon oil spill). We conclude that high potential exists for small or medium spills to impact moderate numbers of red knots or their habitats, such that one or more such events is likely over the next few decades, based on the proximity of key red knot habitats to high-volume oil operations. Risk of a spill may decrease with improved spill contingency planning, infrastructure safety upgrades, and improved spill response and recovery methods. However, these decreases in risk

(e.g., per barrel extracted or transported) could be offset if the total volume of petroleum extraction and transport continues to grow. A major spill affecting habitats in a key red knot concentration area (e.g., Tierra del Fuego, Gulf coasts of Florida or Texas, Delaware Bay, Mingan Archipelago) while knots are present is less likely but would be expected to cause population-level impacts.

### Wind energy development

Within the red knot's U.S. wintering and migration range, substantial development of offshore wind facilities is planned, and the number of wind turbines installed on land has increased considerably over the past decade. The rate of wind energy development will likely continue to increase into the future as the United States looks to decrease reliance on the traditional sources of energy (e.g., fossil fuels). Wind turbines can have a direct (e.g., collision mortality) and indirect (e.g., migration disruption, displacement from habitat) impact on shorebirds. We have no information on wind energy development trends in other countries, but risks of red knot collisions would likely be similar wherever large numbers of turbines are constructed along migratory pathways, either on land or offshore.

We analyzed shorebird mortality at land-based wind turbines in the United States, and we considered the red knot's vulnerability factors for collisions with offshore wind turbines that we expect will be built in the next few decades. Based on our analysis of wind energy development in the United States, we expect ongoing improvements in turbine siting, design, and operation will help minimize bird collision hazards. However, we also expect cumulative avian collision mortality to increase through 2030 as the number of turbines continues to grow, and as wind energy development expands into coastal and offshore environments. Shorebirds as a group have constituted only a small percentage of collisions with U.S. turbines in studies conducted to date, but wind development along the coasts (where shorebirds might be at greater risk) did not begin until 2005.

We are not aware of any documented red knot mortalities at any wind turbines to date, but low levels of red knot mortality from turbine collisions may be occurring now based on the number of turbines along the red knot's migratory routes and the frequency with which red knots traverse these corridors. Based on the current number and geographic distribution of turbines, if any such mortality is occurring, it is likely not causing subspecies-level effects. However, as build-out of offshore, coastal, and inland wind energy infrastructure progresses, increasing mortality from turbine collisions may contribute to a subspecies-level effect due to the red knot's vulnerability to direct human-caused mortality. We anticipate that the threat to red knots from wind turbines will be primarily related to collision or behavioral changes during migratory or daily flights. Unless facilities are constructed at key stopover or wintering habitats we do not expect wind energy development to cause significant direct habitat loss or degradation or displacement of red knots from otherwise suitable habitats.

### Threats summary

The Service has assessed the best scientific and commercial data available regarding past, present, and future threats to the red knot. The primary threats to the red knot are from habitat loss and degradation due to sea level rise, shoreline stabilization, and Arctic warming, and reduced food availability and asynchronies in the annual cycle. Other threats are moderate in comparison to the primary threats; however, cumulatively, they could become significant when working in concert with the primary threats if they further reduce the species' resiliency. Such secondary threats include hunting, predation, human disturbance, harmful algal blooms, oil spills, and wind energy development, all of which affect red knots across their range. Although conservation efforts (e.g., management of the horseshoe crab population and regulatory mechanisms for the species and its habitat) are being

implemented in many areas of the red knot's range and reduce some threats, significant risks to the subspecies remain.

### **Analysis of the species/critical habitat likely to be affected**

The proposed action has the potential to adversely affect migrating and wintering red knots and their habitat within the action area. The construction activities may lead to temporarily diminished quantity and quality of intertidal foraging and roosting habitats within the project area and action area, resulting in decreased survivorship of migrating and wintering knots and temporary adverse effects to suitable foraging and roosting habitat. The length of construction activities (which varies from six months to one year or more) may delay the recovery of prey species due to the prolonged disturbance of the benthic fauna. Ultimately, the project goal is to increase the longevity and restore the diversity of coastal barrier island habitats, but the temporary effects of construction will require time for natural recovery and would extend beyond more than one migration and wintering season. The detailed effects of the proposed action on red knots and their habitat will be considered further in the **Environmental Baseline, Effects of the Action, and Cumulative Effects** sections of this opinion.

### **ENVIRONMENTAL BASELINE**

Because the piping plover and red knot share similar coastal habitats within Louisiana, the environmental baseline is the same for both species. Therefore, in order to produce an efficient and effective consultation/conference, the following sections discuss the mutual environmental baseline conditions for both species.

Louisiana's loss of wetlands and barrier islands to open water is now a well-documented fact in numerous studies. Since the 1930s Louisiana has lost 1,900 square miles of land (approximately 1.2 million acres). From 1990 to 2000, approximately 24 square miles of coastal land were lost each year. The 2004 Louisiana Coastal Area Ecosystem Restoration Study projected that 513 square miles of land would disappear by 2050, including a gain of 161 square miles from projects constructed under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) (USACE 2004). In Louisiana, barrier island erosion is attributable to increasing tidal prism, insufficient volumes of sediment supplied by littoral currents, land subsidence, and sea-level rise (Boesch 1982). Although increases in the tidal prism may be primarily responsible for enlargement of tidal passes, the insufficient supply of sand available to rebuild eroded areas has also contributed to increased tidal pass widths and shoreline retreat (Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority 1999). Where insufficient supplies of sand prevail, measures to maximize sand retention, such as sand fencing and vegetative planting, are used to effectively rebuild and maintain such eroded areas.

Louisiana barrier islands are part of a complex and dynamic coastal system that continually respond to tidal passes, tides, wind, waves, erosion and deposition, long-shore sediment transport and depletion, fluctuations in sea level, and weather events. During storm events, over-wash is common across the barrier islands, depositing sediments on the bay-side or landward side, clearing vegetation and increasing the amount of open, sandflat habitat ideal for shoreline dependent shorebirds. Winds move sediment across the dry beaches forming low dunes. The natural communities contain plants and animals that are subject to shoreline erosion and deposition, salt spray, wind, drought conditions, and sandy soils. Vegetative communities include fore dunes, occasional primary dunes, salt marsh, and black mangroves.

The Breton NWR, initially consisting of approximately 7,000 acres, was established on October 4, 1904, by Theodore Roosevelt, and is the second oldest refuge in the National Wildlife Refuge System. The refuge consists of a series of barrier islands including North Breton Island and the Chandeleur Island chain in Plaquemines and St. Bernard Parishes, Louisiana (Figure 1). Those islands were formed from the remnants of the Mississippi River's former St. Bernard Delta, which was last active approximately 2,000 years ago. Throughout history the islands have been continually reconfigured due to tidal action, winds, and tropical storms. Historically, Breton NWR was the site of a lighthouse station (destroyed by Hurricane Katrina in 2005), a quarantine station, a small fishing village, and an oil production facility (located on North Breton Island). In 1975 the refuge was established as a National Wilderness Area (except for North Breton Island because of the oil production facility). In 1990 the Louisiana Department of Wildlife and Fisheries (LDWF) entered into an agreement with the Service authorizing the Service management rights and law enforcement authority on the state-owned Old Harbor, New Harbor, South Gosier, Grand Gosier, Freemason, Curlew, and North Islands. Many of these islands have been washed away during recent tropical storms, but if they re-surface they will continue to be managed by the Service. The agreement increased the refuge size by an additional 11,350 acres for a total of 18,273 acres. However, today due to subsidence and storm events the islands comprise only a few thousand acres. For example, North Breton Island is the remnant of the "Breton Island" and/or "Breton Island chain" discussed throughout this section.

Breton NWR was established to: (1) provide sanctuary for nesting wading birds and sea birds as well as migrating and wintering shore birds and waterfowl; (2) protect and preserve the wilderness character of the islands; and (3) provide sand beach habitat for a variety of wildlife species. The islands within Breton NWR provide sandy barrier island beaches with vegetation comprised of black mangrove, groundsel bush, and wax myrtle. The shallow areas around the islands support beds of manatee grass, shoal weed, turtle grass, and widgeon grass. The refuge provides essential migration and wintering habitat for the threatened piping plover and red knot (proposed for listing), and most of the islands within the refuge are designated as critical habitat for the piping plover (described in detail in the **Status of the species within the action area** section below). The refuge also provides crucial habitat for 23 species of shore birds and sea birds including nesting grounds for 13 of those species. Common nesting species include royal, caspian, and sandwich terns, laughing gulls, brown pelicans, and black skimmers. During the winter large numbers of waterfowl such as redheads, canvasback, and scaup frequent the numerous islands and adjacent shallow water, marshes, and sounds for foraging and protection during inclement weather. The submerged aquatic grasses along the northern islands make this area one of the top four most important wintering areas for redhead ducks in the U.S. Frigate birds are also commonly observed flying over the refuge. Other wildlife species found on the refuge may include nutria, raccoons, and several species of sea turtles. The islands are also considered the first line of storm defense for eastern Louisiana (including New Orleans) and coastal Mississippi.

Because Breton NWR is a National Wilderness Area, management activities are limited. Bird colony and nest counts are performed yearly to determine population densities and dynamics. The banding of brown pelicans has also occurred as part of a management study to determine migrations and nesting characteristics of the species. The Service continues to work with our partners to respond to the problems created by storm damages to the islands. A series of sand fencing has been placed on the refuge to study the accumulation of Aeolian sand in an attempt to offer additional protection from storms and tidal action. However, we anticipate that it will take many years for the islands to recover naturally (if ever) from the effects of Hurricane Katrina, and we plan to restore the islands to the maximum extent practicable. In addition, Breton NWR was directly impacted by oil released from the Deepwater Horizon incident in 2010. While direct impacts to birds and other wildlife occurred, there

are ongoing studies through the NRDAR process to determine the extent of damages to habitat and long-term impacts to fish and wildlife populations.

Public use activities include only fishing and wildlife observation and photography. The refuge offers excellent fishing for redfish, speckled trout, flounder, sheephead, and numerous other saltwater species. Many anglers wade and fish in the shallow flats surrounding the islands. No hunting is allowed, and camping is no longer permitted due to the large amount of land lost (some estimates as high as 70 percent) as a result of Hurricane Katrina and possible impacts to nesting birds on the remaining habitat. To avoid disturbance to nesting seabird colonies, each colony is posted as a closed area during the nesting season. Visitors may continue to visit the refuge during the nesting season but are restricted from entering bird-posted areas. Visitor use is confined mainly to the spring, summer and early fall months, with approximately 2,500 visits per year. Visitors are encouraged to abide by "Leave No Trace" principles and practices in order to reduce the damage caused by outdoor activities, particularly non-motorized recreation. Specialized environmental education programs are also available upon request at the refuge for schools, universities, and professional groups, including opportunities to volunteer and assist with refuge activities for certain projects. Travel to the refuge is limited by its remote location and the need for a boat that can safely travel across open waters. There are no facilities of any kind on the islands. Access to and recreational use of the refuge resources are permitted in designated areas and in accordance with state and federal regulations<sup>3</sup>, subject to the following conditions:

- Recreational fishing and crabbing are permitted on the refuge year round and must be in accordance with all state and federal regulations.
- All fishing and crabbing equipment must be attended at all times. Anglers may not use trotlines, slat traps, or nets.
- Carrying, possessing, or discharging firearms on the refuge is prohibited.
- Refuge users should be aware of bird nesting colonies on the islands. The colonies are posted with "Area Closed" signs around them, and the entering or disturbing of bird colonies is strictly prohibited.

### **Status of the species within the action area**

Assessing the number of piping plovers and red knots within the action area during winter and migration periods is difficult for two main reasons: (1) the number of birds utilizing the island varies from year to year and throughout each migration and wintering season; and (2) the island is difficult to assess due to its remote location and generally poor winter weather conditions. Because winter generally produces inclement weather conditions, daily surveys over any length of time during the migration and wintering seasons are also difficult to coordinate. Consequently, surveys for non-breeding (e.g., over-wintering and migrating) plovers and red knots within the action area are sporadic and opportunistic, at best.

Because the 2005 hurricane season severely damaged much of the piping plover critical habitat across the state, the Service provided funding to the LDWF to conduct post-hurricane impact assessments of piping plovers and their habitat across the Louisiana coast for a three-year period. The LDWF conducted annual, one-day-count piping plover surveys between January 1 and February 18 from 2007 through 2011 (they were able to add two additional years with the funding provided). Due to lack of

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<sup>3</sup> These provisions supplement the regulations which govern recreational uses on national wildlife refuges set forth in Title 50, Code of Federal Regulations, Parts 25-32.6.

manpower and inclement weather (e.g., dangerous boating conditions) LDWF was unable to survey North Breton Island or the nearby Chandeleur Island chain. However, we have gained access to preliminary survey data for the Chandeleur Islands related to the Deepwater Horizon oil spill<sup>4</sup>. All known survey results for the islands in/near the action area are depicted in Table 12.

Table 12. Piping plover and red knot survey results within the action area and nearby available habitats.

	Chandeleur Islands <sup>a</sup>		Pass A Loutre <sup>b</sup>	
	PIPL <sup>c</sup>	REKN <sup>d</sup>	PIPL	REKN
<b>06/09/1988 survey of Breton Island</b> ( <i>eBird.org</i> )	0	25	NA <sup>e</sup>	NA
<b>1988 LDWF<sup>f</sup> Winter Survey</b>	80 <sup>g</sup>	-- <sup>h</sup>	NS <sup>i</sup>	NS
<b>1991 IPPC<sup>j</sup> Winter Survey</b>	353 <sup>g</sup>	--	NS	NS
<b>1996 IPPC Winter Survey</b>	99 <sup>g</sup>	--	0	--
<b>2001 IPPC Winter Survey</b>	NS	NS	0	--
<b>2006 IPPC Winter Survey</b>	NS	NS	0	0
<b>2007 LDWF Winter Survey</b>	NS	NS	8	0
<b>2008 LDWF Winter Survey</b>	NS	NS	70	0
<b>2009 LDWF Winter Survey</b>	NS	NS	NS	NS
<b>2010 LDWF Winter Survey</b>	NS	NS	6	0
<b>2011 LDWF Winter Survey</b>	NS	NS	0	0
<b>2011 DWH<sup>k</sup> Winter Survey</b>	194 <sup>g</sup>	--	NS	NS
<b>04/07/2011 survey of Breton NWR</b> ( <i>eBird.org</i> )	1	500	NA	NA

(a) The Chandeleur Islands are part of the Breton NWR and the southern end of the NWR includes the action area; (b) Pass A Loutre is the next closest area of known piping plover and red knot habitat; (c) PIPL = piping plover; (d) REKN = red knot; (e) NA = not applicable; (f) LDWF = Louisiana Department of Wildlife and Fisheries-Natural Heritage Program; (g) The data provided here represent all of the Breton and Chandeleur Islands that were included in the survey, which included North Breton Island (the action area); (h) No counts of red knot were provided in the survey data, so it is unknown whether they were observed as present or not; (i) NS = Not Surveyed; (j) IPPC = International Piping Plover Census; (k) DWH = Deepwater Horizon oil spill.

Of the 194 piping plovers observed across the Breton NWR during the 2011 Deepwater Horizon oil spill, 27 plovers were observed on North Breton Island (Catlin et al. 2011). Data from older surveys on the Chandeleur Islands cannot be assessed specific to North Breton Island because at those times (i.e., 1988, 1991, and 1996), North Breton Island was part of the larger “Breton Island” and counts often included all of the Breton Island chain. Similarly, for the red knot the most specific data available are the 25 knots observed on “Breton Island” in 1988 (*eBird.org*). Data specific to North Breton Island cannot be assessed for the April 7, 2011, *eBird.org* record because the record only describes the site as “Breton NWR”, which could include multiple islands or the Chandeleur Island chain or both.

The proposed project would be located within Unit LA-7 of piping plover critical habitat, which includes the Breton and Chandeleur Island chains in Plaquemines and St. Bernard Parishes. The Final Determinations of Critical Habitat for Wintering Piping Plovers (Service 2001b) describes critical habitat within the project action area as: “... Breton, Grand Gosier, and Curlew Islands and the Chandeleur Island chain. Those islands are part of the Breton National Wildlife Refuge or are state owned. The entire islands where primary constituent elements occur to MLLW are included in this unit.” At the time of designation approximately 24,964 acres of wintering habitat were designated in Louisiana, and Unit LA-7 consisted of approximately 7,700 acres of that total.

<sup>4</sup> The data depicted in Table 12 for the Deepwater Horizon oil spill were collected by members of the Virginia Tech NRDAR study team. The NRDAR study team followed specific survey protocols and surveys were conducted on January 18 and 19, 2011. The survey methodologies used in collecting the oil spill data are not the same as the survey methodology used in the IPPC, LDWF winter surveys, or individual observations posted on *eBird.org*. Any data comparisons should carefully note differences in survey methodologies before any conclusions can be drawn from such comparisons.



According to the DOI's BA, North Breton Island currently consists of 109 acres of intertidal zone, 88 acres of mud flat, 7 acres of salt scrub, 4 acres of salt marsh, 2 acres of *Spartina* salt marsh and 1 acre of bare sand, all of which encompasses approximately 10 square miles. Based on those acreages, most of the remnant island is over-wash and tidal mud flats that provide foraging habitat for piping plovers and red knots but little shoreline or loafing areas (1 acre estimated) to support large numbers of roosting birds. The entirety of the borrow area from which material would be dredged, as well as the pipeline right-of-way, access routes, and staging areas, encompasses approximately 35 square miles of predominantly open water and the underlying sediments. Thus, the action area contains a total of 198 acres of existing piping plover critical habitat (i.e., intertidal zone, mudflat, and bare sand) that would be affected by the NBIR project. That acreage is approximately 0.79 percent and 2.6 percent of the total acreage of wintering habitat in Louisiana and Unit LA-7, respectively. Those same habitats are also considered suitable for the red knot; however, no critical habitat has been proposed for the red knot at the time this document is being written.

### **Factors affecting species environment within the action area**

As mentioned previously, North Breton Island is only accessed by the public via boat and the Breton NWR is managed with "Leave No Trace" principles and practices. The Breton NWR receives approximately 2,500 visitors per year for fishing and wildlife observation and photography, which is generally restricted to spring, summer, and early fall months. The town of Venice is located approximately 16 miles southwest of the island on the west side of the Mississippi River, and there is regular boat and helicopter traffic to and from Venice and nearby support facilities for offshore oil and gas structures. However, such traffic does not generally pass in close proximity to North Breton Island and is restricted from disturbing nesting bird colonies on Breton NWR throughout the year. Nesting bird surveys (usually conducted by refuge or LDWF personnel) and nearby boat traffic from fishing and offshore oil and gas activities are the main sources of human disturbance in the general vicinity of the action area.

Raccoons are the only mammalian predator that may occur on North Breton Island, but the island is likely too small now to support enough shelter and forage to sustain a constant population. The island is also likely to be far enough from any adjacent land or marshes to allow mammalian predators to swim back and forth to the remnant island. Somewhat regular storm events (e.g., flooding) also tend to discourage mammals from persisting on the remnant island. Avian predators may also be present within the action area but their numbers are likely to peak during fall and spring migration periods.

In May 2010, the presence of oil from the Deepwater Horizon spill was confirmed on Breton NWR. The refuge was oiled repeatedly and Shoreline Cleanup Assessment Team (SCAT) reports throughout the duration of the spill documented various degrees of oiling on all of the Breton NWR islands. Legacy cleanup procedures are currently in place for the refuge; those procedures significantly reduce human disturbance from cleanup activities. At this time, it is unknown if there are any current or lasting effects to piping plovers and red knots migrating through or wintering in the action area (i.e., the number of oiled piping plovers or other shorebirds observed during NRDAR studies has not yet been released) or to the inter-tidal invertebrate food source used by piping plovers and red knots from either oil or oil dispersants and resulting cleanup activities within the action area. A greater impact to the piping plover, its critical habitat, and red knots might have occurred due to the prolonged human disturbance associated with cleanup activities, wildlife response, and damage assessment crews highly visible on the shorelines, as well as SCAT surveys and any future legacy cleanup activities. Except for

future legacy cleanup actions, no further disturbance is anticipated within the action area as a result of the Deepwater Horizon incident.

The only known sand placement project that occurred in proximity to the action area occurred from July 2010 through April 2011 on the Chandeleur Island chain (approximately 25 miles northeast of North Breton Island) as part of the Deepwater Horizon oil spill protective sand berm. Sand was mined from a nearby shoal north of the Chandeleur Island chain and pumped to the Gulf shoreline of the islands via a sediment delivery pipeline. Any temporary effects to piping plovers and their designated critical habitat or to red knots that normally utilized that area are likely to no longer be occurring at this time since there has been ample opportunity for the benthic community to recover. Shorebird monitoring surveys were conducted during sand berm construction; however, those surveys were sporadic due to weather conditions. Observers did note up to 6 piping plovers and 60 or more red knots utilizing bay-side intertidal habitat while the berm construction was occurring from August through November 2010 (Shaw Coastal, Inc. 2011). Additional unrelated surveys occurred within the construction window of the protective sand berm (i.e., Catlin et al. (2011) and eBird.org (2011) mentioned in the previous section; Table 12), which also noted both piping plovers and red knots utilizing available habitats in proximity to the sand berm construction area. While the work did cause disturbance on the Gulf shoreline side of the islands, the work did not preclude all birds from using available habitats in proximity to that major sand placement project. No work associated with the oil spill protective berm occurred on North Breton, Curlew, or the Gosier Islands.

## **EFFECTS OF THE ACTION**

Because the piping plover and red knot share similar foraging/roosting behaviors and utilize similar coastal habitats within Louisiana, the effects of the action are also very similar for both species. Therefore, in order to produce an efficient and effective consultation/conference, the following sections discuss the mutual effects of the action to both species.

The proposed action includes creation of 16,000 linear feet (76.2 acres) of beach, 138.7 acres of dune, and 137.3 acres of back barrier marsh habitat for a total of 352 additional acres of barrier island habitats. The proposed NBIR project intends to restore the island to its pre-Katrina shape and contours in order to prolong the existence of those habitat features and restore barrier island habitat, function, and morphology for nesting, migrating, and wintering water birds, waterfowl, and shorebirds. The proposed project would occur in habitat that is likely to be used by piping plovers and red knots and is designated as critical habitat for plovers. Construction of the NBIR project will overlap with multiple piping plover and red knot migrations and at least one wintering season. Short-term and temporary construction impacts to piping plovers and red knots will occur when the birds are roosting and feeding in the area. However, because only 1 acre of suitable loafing habitat (i.e., bare sand) is available to support approximately 197 acres of intertidal and mud flat foraging habitat, that existing habitat acreage within the proposed action area may not support a large number of loafing birds throughout those migration and wintering seasons.

The deposition of sand and marsh material will temporarily deplete the existing intertidal food base and temporarily disturb foraging and roosting birds during project construction on the island. The shaping and grading of the created beach, dune, and marsh would cause noise and visual disturbance and also remove wrack that has accumulated along the island's intertidal shoreline. This would affect feeding and roosting habitat for piping plovers and red knot, since they often use wrack for cover and foraging. Construction of the beach, dune, and marsh will also cover most of the existing intertidal flats used by foraging birds and will render that area unusable until natural processes re-work the

sediments and over-wash areas are again created by tidal and storm events and benthic prey species re-colonize those areas. Such temporary effects to benthic prey would extend for up to two years beyond construction until the benthic fauna recovers. Overall, however, project implementation would ultimately benefit piping plovers, their critical habitat, and red knots by creating new beach habitat and adding sediment to the Breton Islands system to be re-worked by natural forces.

The geomorphic characteristics of barrier islands, dunes, over-wash fans, and inlets are critical to a variety of natural resources and influence a barrier system's ability to respond to wave action, including storm over-wash and sediment transport. The protection or persistence of these important natural processes and wildlife resources are part of the goal of this restoration project. The newly created beach, dune, and marsh will not impede over-wash but may temporarily consist of less optimal roosting and foraging habitat until natural wrack is restored, the benthic prey base is able to recover from the construction activities, and over-wash areas are again created by natural tidal and weather events. The newly added sediment will be reworked by natural wind and wave processes which will, given time, create sand spits and flats on the ends and bay-side of the island. Thus, piping plover critical habitat and red knot foraging and roosting habitat will continue to be lost and created through the natural processes associated with daily tidal events and future storm events.

### **Factors to be considered**

#### *Proximity of the action*

Lack of regular surveys, fluctuation of use by piping plovers and red knots from year to year, and differences in numbers of birds migrating through versus those over-wintering, make it difficult to estimate the number of birds actually using the action area. Based on survey data depicted in Table 12, as many as 25 piping plovers and 27 red knots have been observed over-wintering within the action area; those estimates, however, are a snapshot in time and do not include peak numbers of migrating birds. We expect direct short-term effects in the form of: (1) disturbance due to human presence and equipment noise during pipeline construction activities, sediment placement, dune/beach construction, marsh creation, sand fence installation, and vegetative planting; and (2) a temporary loss of food base within the intertidal zone on both the island and its associated mudflats for up to two years following completion of sediment placement until the benthic community re-colonizes the project area. Approximately 198 acres of the existing island features contain PCEs of piping plover critical habitat within Unit LA-7, which would be temporarily disturbed until the benthic fauna recover.

#### *Distribution*

We expect direct effects to migrating and wintering piping plovers and red knots along the existing sandy beach, intertidal zone, and mudflats (approximately 198 acres) of North Breton Island as a result of human activity and ground disturbance. Although studies have shown that plovers tend to remain within a 2-mile wintering home range, it is unknown how far piping plovers and red knots will travel within specific areas during migration stopovers and within wintering areas due to local disturbance or to find a more abundant food source. The Gosier and Grand Gosier Islands located approximately five miles northeast of North Breton Island were the next closest islands to the NBIR project area; however, they have eroded below sea level and are now shallow water shoals. They may provide suitable foraging habitat at extremely low tides but they are mostly inundated. Small islands created from beneficial use of dredged material exist at the mouth of Baptist Collette, which is approximately 10 miles southwest of North Breton Island. However, it is unknown whether those islands provide suitable roosting and foraging shorebird habitat. The Chandeleur Island chain, which is located

approximately 27 miles north of the NBIR project area, would provide available habitat during project construction but would be beyond the estimated 2-mile range of wintering plovers. The next nearest suitable habitat consists of sand bars located at Pass a Loutre, approximately 20 miles south/southeast of the NBIR project area, which is also beyond the normal 2-mile range of wintering plovers.

### *Timing*

Construction of the NBIR project may overlap with multiple piping plover and red knot wintering/migrating seasons (mid-July to late April) pending the time of year construction is initiated, the duration of construction activities (i.e., six months up to a year or more), logistical challenges, and weather conditions. There may be ongoing construction related to several other barrier headland and island restoration projects along the Louisiana coast, but those would all be located in the central portion of the Louisiana Gulf coast greater than 30 miles west/southwest of the NBIR project area.

### *Nature of the adverse effect*

The effects to piping plovers and red knots may be direct and/or short-term or indirect. Activities that impact or alter the use of optimal habitat or increase disturbance to the species may directly decrease the survival and recovery potential of the piping plover and red knot by limiting the ability of birds to rest and replenish their fat reserves for spring migration and summer breeding. We expect direct, short-term impacts from human disturbance during project construction to both the birds and their habitats. We anticipate a temporary (i.e., up to two years post-construction) decrease in benthic prey species within all existing piping plover and red knot foraging habitat within the project footprint as a result of sand and marsh material placement and loss of natural wrack. Following one or two growing seasons, the dune portion of the project may become densely vegetated and would no longer be suitable roosting habitat for piping plovers and red knots until a storm event creates over-wash fans. Until the benthic community recovers and new over-wash fans are created, a temporary decrease in prey items and roosting habitat may result in a decrease in the survival of birds on migrating or wintering grounds due to lack of optimal habitat. That situation can contribute to decreased survival rates and may indirectly result in decreased productivity on the breeding grounds. Such effects may temporarily result in increased vulnerability to any of the three piping plover breeding populations and the red knot population.

The effects to 198 acres of critical habitat in Unit LA-7 result from activities that impact or alter the PCEs (disturbance to the species) which may decrease the survival and recovery potential of the piping plover. Such effects consist of temporary reductions in the value of the unit from disturbance to foraging and roosting piping plovers due to human activity during construction, temporary removal of wrack, and a temporary decrease in benthic prey species due to sand placement. Existing intertidal areas and mudflats would be covered by placement of new material until natural coastal processes (e.g., daily tidal events, storm events, etc.) are allowed to re-work the additional sediment to create new over-wash areas. That acreage (i.e., 198 acres) is approximately 0.79 percent and 2.6 percent of the total acreage of wintering habitat in Louisiana and Unit LA-7, respectively.

### *Duration*

The DOI's project engineering and design has not yet proceeded to the point of producing a detailed construction schedule. Construction could take from six months up to a year or more given potential logistics, equipment availability (e.g., dredging contractor), optimal planting times, and weather conditions. The DOI would plan construction windows with consideration of potential effects to fish

and wildlife resources and would adjust construction timing to the maximum extent practicable in coordination with the Service and NMFS. The DOI would also incorporate monitoring of fish and wildlife resources in the construction plan, which would include baseline (prior to construction), construction (to direct activities around resources), and post-construction (for a period after construction to evaluate physical and biological responses to project implementation) monitoring phases.

The activities associated with construction of the beach, dune, and marsh creation are a one-time occurrence and no renourishment events are proposed. Timing of construction activities may vary in duration depending on the amount of work needed, weather conditions, and equipment mobilization and maintenance. The DOI anticipates beginning construction on the NBIR project, should it be chosen as an early restoration project, as soon as funding is made available. The Service does not expect long-term, permanent alteration of the natural coastal processes, and the island would remain untouched after initial construction (e.g., ground disturbance, sand fencing, and vegetative plantings) is completed. The addition of sand material on 198 acres of piping plover critical habitat in Unit LA-7 is expected to temporarily decrease the quality of that existing foraging habitat for six months up to two years until the intertidal benthic fauna recovers to normal population levels and natural wrack returns to the newly created island shoreline.

#### *Disturbance frequency, intensity, and severity*

We anticipate that construction activities would have short-term, temporary effects on piping plover and red knot populations. We expect short-term disturbance to the birds and their habitats from construction activities and temporary effects to intertidal and mud flat habitats due to sand and marsh material placement. Direct effects to 198 acres of piping plover critical habitat in Unit LA-7 would include temporary removal of wrack, temporary smothering of intertidal benthic prey species, and the creation of a dune that may eventually become densely vegetated until new over-wash fans are created. We anticipate that: (1) piping plovers and red knots located within the construction area would move outside of the construction zone due to disturbance; (2) natural wrack would be deposited on the island shoreline following normal tidal events; (3) the intertidal benthic fauna would recover within six months up to two years following completion of material placement; and (4) the density of dune and marsh vegetation will ebb and flow as tidal and storm events naturally affect dune and marsh vegetation growth. We do not anticipate any permanent adverse changes to barrier island morphology because initial construction elevations would not prevent island over-wash during storm events and the created marsh platform would allow for natural island retreat or “rollover.”

All construction activities would occur during daylight hours. Because there would be no work activities during nighttime hours, all exposed habitats (e.g., existing and newly created) would be available for roosting birds between dusk and dawn. There would also be a lack of human disturbance during any weather-related shut-downs and/or delays throughout the duration of the project.

There would not be any increased or continual disturbance within piping plover critical habitat Unit LA-7 as a result of the NBIR project beyond normal NWR management activities as previously discussed in the **Environmental Baseline** section. Over the long-term the additional sediment would allow for creation of piping plover and red knot habitat on North Breton Island as natural processes re-work the sediment to create over-wash areas, sand flats, mud flats, and sand spits.

#### **Analysis for the effects of the action**

### *Direct effects*

Direct effects are those direct or immediate effects of a project on the species and/or its habitat. Implementation of the proposed action is not likely to directly kill piping plovers or red knots since the birds are highly mobile and can quickly move out of harm's way. The construction window will likely extend through one piping plover and red knot wintering season and more than one migration season. Heavy machinery and equipment (e.g., ORVs and bulldozers operating on project area beach and sand and mud flats, the placement of the dredge pipeline on/near the island, and sand and marsh material disposal) may directly affect migrating and wintering piping plovers and red knots in the project area by disturbance and disruption of normal activities such as roosting and foraging, and possibly forcing birds to expend valuable energy reserves to seek available habitat elsewhere.

Direct effects to critical habitat Unit LA-7 consist of sand and marsh material placement over 198 acres of existing sand, intertidal, and mud flat habitat which would result in temporary loss of wrack, temporary loss of over-wash areas, and burial and suffocation of intertidal benthic prey species. The natural wrack would be restored following normal tidal events. Over-wash areas would eventually be re-created during storm events. Burial and suffocation of invertebrate intertidal prey species will occur during initial sand and marsh material placement throughout the project area. Impacts will affect the project action area on and around North Breton Island. Timeframes projected for benthic recruitment and re-establishment following sand and marsh material placement are from six months up to two years.

### *Indirect effects*

Indirect effects are those that are caused by or result from the proposed action, are later in time, and are reasonably certain to occur. The short-term increase in human disturbance to normal piping plover and red knot foraging and roosting behavior, as well as to suitable foraging and roosting habitat, during construction and immediately post-construction is likely to result in indirect effects via increased energy expenditure and a potential lack of adequate food supplies which can then lead to temporarily reduced fitness, fecundity, and over-wintering survival. However, such effects would be temporary for those birds wintering in or migrating through the action area over the course of several wintering and migration seasons.

Reducing the potential for the formation of optimal habitats (such as over-wash or ephemeral pool formations) is a possible indirect effect to designated critical habitat. The piping plover's rapid response (within six months) to habitats formed by over-wash areas demonstrates the importance of over-wash created sand and mud flats for wintering and migrating piping plovers. Implementation of the proposed project will temporarily cover existing over-wash habitat within the entire action area. Given time, the intertidal zone along the newly created island footprint will re-establish and with daily tidal processes and occasional storm events natural over-wash and ephemeral pool habitat would again be created throughout the action area.

The project life does not increase the likelihood of long-term increased human disturbance on North Breton Island as it is currently managed under the Breton NWR. The Service manages and maintains North Breton Island as an important area for shorebird nesting, roosting, and foraging habitats with minimal human disturbance; public enjoyment of fishing and wildlife observation is a secondary management goal. North Breton Island's remote location and limited access from the mainland restricts regular use of the island to those who can safely cross open waters in an appropriate motorized vessel.

### *Beneficial effects*

Beneficial effects are wholly positive without any adverse effects. We expect the prolonged existence and restoration/creation of foraging and roosting habitat for piping plovers and red knots on North Breton Island and within Unit LA-7 of piping plover critical habitat as an overall result of the proposed NBIR project. The DOI has estimated that without the project there would be little or no piping plover critical habitat remaining on the island because sometime between 2014 and 2037 the island would erode below sea level. With the project, the DOI plans to restore approximately 214.9 acres of dune and beach complex. Much of the existing system is sediment-starved, and the proposed action would introduce sediment into that system that would be reworked and redistributed through the natural processes of wind and wave action and storm events. The additional sediment would allow for natural reformation of optimal piping plover and red knot habitat in the form of over-wash areas, sand flats, mud flats, and sand spits through those natural processes, thus maintaining and/or enhancing the features of piping plover critical habitat and suitable red knot habitat. The restoration and maintenance of such intertidal habitats are important for the restoration of piping plover and red knot populations to healthy levels.

### **Species response to the proposed action**

This biological and conference opinion addresses the direct and indirect effects that are anticipated to wintering and migrating piping plovers and their critical habitat and red knots, respectively, as a result of restoring beach, dune, and marsh on North Breton Island, as well as the temporary disruption of existing plover and red knot foraging and roosting habitat for the long-term benefit of maintaining existing barrier island habitat. Although survey data from Table 12 (page 69) indicate that up to 25 piping plovers and 27 red knots could be using the action area in any given year, it is difficult for the Service to estimate the number of birds migrating through or wintering within the proposed action area because piping plover and red knot numbers fluctuate daily, seasonally, and from year to year. Therefore, the Service anticipates that all migrating and wintering piping plovers and red knot utilizing the remnants of North Breton Island, and up to 198 acres of existing critical habitat will be impacted by: (1) disturbance due to human activity and equipment noise during construction within the action area; and (2) temporary habitat loss within the project footprint for the duration of construction activities (six months up to one year or more) and up to two years post-construction for the recovery of intertidal benthic prey species.

It is unknown how far piping plovers and red knots would move into nearby habitats due to disturbance or a lack of food source. The nearest available habitat may exist on small sand or mud flats that may be intermittently exposed during low tides in nearby shallow open water outside of the project footprint. Additional flats may be intermittently exposed on low tides on the remnants of Curlew and Gosier Islands (Figure 1), which are located approximately five miles away from North Breton Island. However, those small areas would only be available for foraging on a temporary basis during low tide. Suitable habitat may also exist on small dredge disposal islands at the mouth of Baptist Collette, which are located approximately 10 miles southwest of North Breton Island. The next nearest known available habitat is located on the Chandeleur Island chain (located 25 miles to the north), sand bars at Pass a Loutre (located 20 miles to the south/southeast), and the mud lumps at mouth of the South Pass of the Mississippi River (located greater than 30 miles to the south). The next closest suitable habitat areas to North Breton consist of Shell, Pelican, and Scofield Islands (located immediately west and east of the Empire jetties, respectively), Chaland Beach (near Grand Bayou), and the Grand Terre Islands (critical habitat Unit LA-5) to the west/southwest; all of which are greater

than 30 miles away from the action area. However, all of those areas were impacted by the Deepwater Horizon oil spill, and foraging and roosting habitat in those areas are still recovering from oil spill cleanup activities and NRDAR surveys and data collection. In addition, coastal restoration projects have been completed on the eastern end of Shell Island (i.e., Shell Island East) and Scofield and Pelican Islands within the last two years; therefore, those areas are still within the benthic recovery window.

The proposed action would involve anywhere from six months up to one year or more of disturbance activities for the construction period, plus an additional two years of recovery for the intertidal benthic community following material placement. The project would not, however, result in permanent changes to the natural processes that maintain the PCEs of piping plover critical habitat. Daily tidal processes and occasional storm events would re-work the additional sediment to recreate over-wash areas, sand and mud flats, and sand spits. Without the additional sediment from the project, critical habitat associated with North Breton Island would eventually erode below sea level.

Although restoration of North Breton Island would follow within a few years of the Deepwater Horizon oil spill and would result in temporary disturbance within the action area, in time the proposed action would ultimately benefit the piping plover and its critical habitat and red knots by restoring diverse barrier island habitats used by those species. The proposed action would also allow for the continued existence and creation of habitat within critical habitat Unit LA-7 throughout the project life.

## **CUMULATIVE EFFECTS**

The proposed project would occur on federally and State-owned lands and State-owned water bottoms. Cumulative effects include the effects of future State, tribal, local, or private actions that are reasonably certain to occur in the action area considered in this biological and conference opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the Act.

The proposed project would not contribute to increased human disturbance on North Breton Island because Breton NWR would continue to be managed under current NWR goals and objectives. In addition, the remoteness of the island limits human disturbance to those who can safely access it with a motorized vessel. Overall recreational use of North Breton Island is in the form of nearby fishing and bird watching and photography. Any future proposed actions that are within endangered or threatened species habitat will require section 7 or 10 permitting from the Service to be covered under the Act, and any future work on the Breton NWR would require a Special Use Permit.

Impacts to the action area from the Deepwater Horizon oil spill includes legacy cleanup actions and possibly ongoing NRDAR surveys and studies, as well as limited human disturbance from those cleanup and monitoring activities. Although the final breadth of the oil spill impacts to the Louisiana Gulf shoreline and shoreline-dependent species remains unknown, section 7 consultation is currently in progress with the lead Federal agency for the Deepwater Horizon incident, the U.S. Coast Guard.

## **CONCLUSION**

The survival and recovery of all breeding populations of piping plovers and red knots are fundamentally dependent on the continued availability of sufficient habitat in their coastal migration and wintering ranges, where those species spend more than two-thirds of their annual cycle. All piping plover and red knot populations are inherently vulnerable to even small declines in their most sensitive



vital rates (i.e., survival of adults and fledged juveniles). Mark-recapture analysis of resightings of uniquely banded piping plovers from seven breeding areas by Roche et al. (2010) found that apparent adult survival declined in four populations and increased in none over the life of the studies. Some evidence of correlation in year-to-year fluctuations in annual survival of Great Lakes and eastern Canada populations, both of which winter primarily along the southeastern U.S. Atlantic Coast, suggests that shared over-wintering and/or migration habitats may influence annual variation in survival. Further concurrent mark-resighting analysis of color-banded individuals across piping plover breeding populations has the potential to shed light on threats that affect survival in the migration and wintering range. Progress towards piping plover recovery (which is attained primarily through intensive protections to increase productivity on the breeding grounds) would be quickly slowed or reversed by even small sustained decreases in survival rates during migration and wintering. Similar data are not yet available for the red knot.

Implementation of the proposed action is not likely to directly kill any piping plovers or red knots since they are highly mobile and can move out of harm's way. The increased disturbance to normal piping plover and red knot foraging/roosting behaviors and suitable habitat would likely result in increased energy expenditure and a potential lack of food supply, which may indirectly affect fitness, fecundity, and over-wintering survival. Such effects to migrating and wintering piping plovers and red knots would be sporadic and temporary over the course of the construction window and the two-year recovery of benthic prey populations. After reviewing the current status of the piping plover wintering population of the northern Great Plains, the Great Lakes, and the Atlantic Coast; the current status of the red knot population; the environmental baseline for the action area; the effects of the proposed NBIR project; and cumulative effects, it is the Service's biological opinion that implementation of the NBIR project, as proposed, is not likely to jeopardize the continued existence of the piping plover or the red knot. As noted previously, the overall status of the piping plover species is stable, if not increasing. Similarly, the project-related effects to the red knot would be temporary and are not anticipated to affect the status of the overall wintering/migrating population of that species.

### *Critical Habitat*

Critical habitat for the piping plover has been designated within the project area and the action area. The project has been designed to mimic natural barrier island habitat and, in the long-term, would aid natural processes in creating and maintaining the PCEs of critical habitat on North Breton Island by providing sediment within the sediment-starved barrier island system. The amount of critical habitat in Unit LA-7 directly affected from the project is approximately 198 acres of bare sand and mud flat. The project area would be temporarily disturbed during construction activities which would impede piping plovers attempting to roost and forage in the area during the migration and wintering months that coincide with construction. Temporary disturbance to 198 acres of Unit LA-7 equates to 0.79 percent of designated critical habitat in Louisiana and 0.11 percent of all designated critical habitat throughout the Southeast (i.e., North Carolina to Texas). Because the effects to critical habitat would be temporary in nature and the overall project would be beneficial in the long-term, it is the Service's biological opinion that implementation of the NBIR project is not likely to destroy or adversely modify designated critical habitat in Unit LA-7. Please note that we have not relied on the regulatory definition of "destruction or adverse modification" of habitat at 50 Code of Federal Regulations (CFR) 402.02; instead, we have relied on the statutory provisions of the ESA.

## **INCIDENTAL TAKE STATEMENT**

Because the proposed action is likely to result in the taking of one listed and one proposed species incidental to that action, the Service has included an incidental take statement pursuant to section 7(b)(4) of the Act. Section 9 of the Act and Federal regulation pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by the Service to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Harass is defined by the Service as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are non-discretionary, and must be undertaken by the DOI so that they become binding conditions of any contract, grant, or permit issued to the DOI's contractor(s), as appropriate, for the exemption in section 7(o)(2) to apply. The DOI has a continuing duty to regulate the activity covered by this incidental take statement. If the DOI (1) fails to assume and implement the terms and conditions or (2) fails to require its contractor to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the contract, grant, or permit document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the DOI and/or its contractor(s) must report the progress of the action and its impact on the species to the Service as specified in the incidental take statement [50 CFR §402.14(I) (3)].

#### **AMOUNT OR EXTENT OF TAKE ANTICIPATED**

The Service expects incidental take of piping plover and red knot will be difficult to detect for the following reasons:

1. Migration and wintering bird survey data indicate that anywhere from one to 27 piping plovers and one to 25 red knots could be within the action area at any point in time. The number of birds within the action area for the duration of project construction and intertidal benthic recovery is difficult to detect because the remote project location makes consistent surveying problematic, wintering piping plover and red knot numbers within the action area vary from year to year, and migrating piping plover and red knot numbers vary between both fall and spring migrations from year to year.
2. Harassment to the level of harm may only be apparent on the breeding grounds the following year as a result of reduced fitness or fecundity, or as lack of over-wintering survival. It would be difficult to detect because of our inability to track individual birds from their wintering grounds to their breeding grounds.
3. Over-wintering survival would be difficult to detect because it is difficult to detect birds that do not survive migration back to the breeding grounds. This is also difficult to detect because we would need to track individually marked birds between wintering and breeding grounds.

However, the following level of take of this species can be expected by disturbance to the affected acreage of bare sand, mud flat, and intertidal habitats because disturbance to suitable habitat within the action area would affect the ability of piping plovers and red knots to find foraging and roosting habitat

throughout the migrating and wintering periods for the duration of project construction and intertidal benthic recovery. The Service anticipates that directly and indirectly all piping plovers and red knots using the affected 198 acres (all of which is also designated piping plover critical habitat) of suitable habitat on North Breton Island could be taken in the form of harm and harassment as a result of the proposed action.

The level (i.e., all piping plovers and red knots using the 198 acres of bare sand, mud flat, and intertidal habitats) of take of these species can be anticipated by the proposed activities because:

1. Piping plovers and red knots are known to winter in and migrate through the action area.
2. The placement of sand is expected to temporarily affect (e.g., in the form of increased human disturbance during construction, temporary loss of benthic prey, and temporary loss of wrack) 198 acres of bare sand, mud flat, and intertidal habitats over multiple migrating and wintering seasons until construction is complete and until the benthic fauna recover.
3. Temporarily increased levels of human disturbance are expected for the duration of construction activities which would make the 198 acres of bare sand, mud flat, and intertidal habitats less desirable habitat for piping plovers and red knots, which may cause increased energy expenditure as birds move away from construction activities.
4. A temporary reduction of food base (up to two years following construction) will occur due to sand placement which would affect the piping plover's and red knot's ability to forage and store enough fat reserves for migration back to the breeding grounds for multiple wintering seasons. Such an effect could result in reduced fitness or fecundity.

The Service has reviewed the biological information and other information relevant to this action. The take is expected in the form of harm and harassment because of: (1) temporarily decreased fitness and survivorship of wintering piping plovers and red knots; (2) temporarily decreased fitness and survivorship of piping plovers and red knots attempting to migrate to breeding grounds, due to temporary loss of and disturbance to foraging and roosting habitat; and (3) an indirect temporary reduction of fecundity on the breeding grounds due to the temporary decrease in fitness and survivorship of wintering and migrating piping plovers and red knots. This Incidental Take Statement covers take of the species within the action area. If the DOI expands the action outside of the action area then consultation must be reinitiated.

## **EFFECT OF THE TAKE**

In the accompanying biological/conference opinion, the Service determined that this level of anticipated take is not likely to result in jeopardy to the piping plover and red knot species or destruction or adverse modification of piping plover critical habitat. Incidental take of up to 27 piping plovers and 25 red knots utilizing the affected 198 acres of bare sand, mud flat, and intertidal habitats is anticipated to occur during project construction, up to two years following construction until the intertidal benthic community recovers, and sporadically for up to one or more years following construction for vegetative plantings.

## **REASONABLE AND PRUDENT MEASURES**

The Service believes the following reasonable and prudent measures (RPMs) are necessary and appropriate to monitor and minimize take on non-breeding piping plovers during implementation of the proposed NBIR project within the action area. The prohibitions against taking red knot found in section 9 of the Act do not apply until the red knot is listed. However, the Service advises the DOI to

consider implementing the following RPMs for the red knot as well. If this conference opinion for red knot is adopted as a biological opinion following listing or designation, these measures, with their implementing terms and conditions, will be nondiscretionary.

1. The DOI should carefully mark and stake the boundaries of the entire project footprint on/near North Breton Island and ensure that those markers are maintained for the duration of project construction activities. Should the project actions (e.g., personnel, equipment, etc.) affect suitable habitat outside of those boundary markers and beyond the action area as described in the biological opinion, then the level of incidental take (i.e., all piping plovers using the existing 198 acres of bare sand, mud flat, and intertidal habitats) for this project would be exceeded and the DOI should reinitiate section 7 consultation with the Service as soon as possible.
2. A baseline survey for piping plovers and red knots should be conducted within the migrating and wintering season immediately prior to initial construction in order to determine each species' preferred habitat use within the action area. Such information could then be used as an aid to determine whether specific project actions require slight modifications in order to minimize the effects of the take for future migrating and wintering seasons. For example, initial bird surveys may aid in locating and marking appropriate access routes for ORVs and other work-related equipment, as well as equipment staging areas, in order to reduce disturbance to foraging and roosting birds to the maximum extent practicable.
3. A simple diversity and abundance survey of the intertidal benthic prey species community should be conducted within the migration and wintering seasons immediately prior to initial construction (preferably at the same time as the bird distribution surveys) in order to establish a baseline of benthic prey species diversity and abundance (e.g., biomass). Again, such information could then be used as an aid to determine whether specific project actions require slight modifications in order to minimize the effects of the take for future migrating and wintering seasons. For example, initial surveys could locate areas of abundant benthic prey where birds may tend to congregate for foraging, and those areas could be flagged for avoidance by regular personnel traffic to reduce disturbance to foraging piping plovers and red knots.
4. Piping plover and red knot monitoring surveys should be conducted during the migrating and wintering seasons throughout initial project construction in order to determine whether access routes are working or whether they need to be adjusted, and for three consecutive years following completion of initial construction to determine whether birds are still utilizing the project area during the benthic recovery period. The frequency of surveys will be determined in coordination with the Service (see #6 below).
5. To determine if incidental take exceeds the anticipated recovery time (i.e., up to two years) of suitable foraging habitat on North Breton Island for migrating and wintering piping plovers and red knots, monitoring surveys of the intertidal benthic prey species community should be conducted each year following completion of initial construction for three consecutive years. Such information could also be used to determine whether corrective actions (that may be necessary to achieve the DOI's NRDAR success criteria) require slight modifications in order to minimize the effects of the take.
6. Due to the remoteness of the project area, weather conditions, potential logistical constraints, and the need to closely coordinate with Breton NWR staff, the DOI should meet with the Service within six months of the date of this biological opinion to coordinate and develop a detailed monitoring plan and schedules for bird and benthic surveys.
7. Due to the duration between receiving construction funds and letting out contracts, the Service should be notified in writing at least six months prior to mobilization when construction will be initiated so that the DOI and the Service can coordinate and exchange updated species and project information to ensure that reinitiation of consultation is not necessary.

8. A comprehensive report describing the actions taken to implement the RPMs and terms and conditions associated with this incidental take statement shall be submitted to the Service by June 30 of the year following completion of all required surveys.

## **TERMS AND CONDITIONS**

In order to be exempt from the prohibitions of section 9 of the Act, the DOI shall execute the following terms and conditions, which implement the RPMs described above and outline required reporting/monitoring requirements. These terms and conditions are nondiscretionary.

### *Marking Project Boundaries*

1. The DOI should carefully survey and mark the boundaries of the entire project footprint on/near North Breton Island.
2. Boundary markers should be semi-permanent such that they should be maintained throughout construction activities and should persist until all construction-related activities are completed. Those markers may be the same ones used by contractors to determine appropriate elevations for material placement.
3. The Service's Louisiana Ecological Services Office (337/291-3108) should be notified immediately if any work or project-related actions exceed the boundary markers in existing suitable habitat on North Breton Island, beyond the action area described in the biological opinion, so that reinitiation of section 7 consultation can proceed as quickly and efficiently as possible to avoid delay in the project schedule.

### *Monitoring Requirements*

1. Requirements for piping plover and red knot surveys
  - a) A tentative survey schedule (with dates) is listed in Appendix D and the recommendation is for at least 3 survey dates per month; this schedule will be followed as closely as possible and would be finalized prior to initiating pre-construction surveys. The Service recognizes that given the remoteness of the project area and the potential for inclement weather conditions during the piping plover and red knot migration and wintering season, three survey dates per month may be difficult to achieve in Louisiana. If conditions require a deviation from the recommended survey schedule, such information should be carefully documented in a detailed monitoring plan, including an explanation why any deviation from the recommended schedule was deemed necessary.
  - b) Piping plover and red knot identification, especially when in non-breeding plumage, can be difficult. Qualified personnel with shorebird/habitat survey experience must conduct the required survey work. Piping plover and red knot monitors must be capable of detecting and recording locations of roosting and foraging birds, and documenting observations in legible, complete field notes. Aptitude for monitoring includes keen powers of observation, familiarity with avian biology and behavior, experience observing birds or other wildlife for sustained periods, tolerance for adverse weather, experience in data collection and management, and patience.
  - c) At a minimum, binoculars, a global positioning system (GPS) unit, a 10-60x spotting scope with a tripod, and the Service datasheet (Appendix D) should be used to conduct the surveys.
  - d) Negative (i.e., no plovers or knots seen) and positive survey data shall be recorded and reported.

- e) Piping plover and red knot locations shall be recorded with a GPS unit set to record in decimal degrees in universal transverse mercator (UTM) North American Datum 1983 (NAD83).
  - f) Habitat, landscape, and substrate features used by piping plovers and red knots when seen shall be recorded. Such features are outlined on the Service data sheet in Appendix D.
  - g) Behavior of piping plovers and red knots (e.g., foraging, roosting, preening, bathing, flying, aggression, walking) shall be documented on the Service data sheet in Appendix D.
  - h) Any bands/flags seen on piping plovers and red knots shall also be carefully documented, and should also be reported according to the information found at the following websites. Information regarding piping plover band/flag observations can be found at: [http://www.fishwild.vt.edu/piping\\_plover/Protocols\\_final\\_draft.pdf](http://www.fishwild.vt.edu/piping_plover/Protocols_final_draft.pdf), [http://www.waterbirds.umn.edu/Piping\\_Plovers/piping2.htm](http://www.waterbirds.umn.edu/Piping_Plovers/piping2.htm), and <http://www.fws.gov/northeast/pipingplover/pdf/BahamasBandReporting2010.pdf>. Information regarding red knot band/flag observations can be found at: <http://www.bandedbirds.org/Reporting.html>, <http://www.flshorebirdalliance.org/resources-pages/bands.html>, and <http://www.pwrc.usgs.gov/bbl/>.
2. Requirements for surveying benthic prey species
- a) Qualified personnel with sediment/macroinvertebrate sampling experience must conduct the benthic prey species surveys.
  - b) A baseline macroinvertebrate survey is recommended to be conducted during the migration/wintering season immediately prior to construction. Additional surveys will be conducted during the migration/wintering season each year post-construction for three consecutive years to determine benthic prey species recovery.
  - c) Sampling will be conducted using a basic before and after control and impact design method. Sampling will be coordinated with piping plover and red knots foraging observations based on low tide surveys.
  - d) In addition to recording benthic species abundance and diversity, a qualitative measure of sediment characteristics (sand, shell, mud) should also be recorded.
  - e) An appropriate detailed sampling methodology and schedule should be developed in coordination with the Service prior to initiating pre-construction surveys.

### *Reporting Requirements*

1. Due to the duration between receiving construction funds and letting out contracts, the remoteness of the project area, weather conditions, potential logistical constraints, and the need to closely coordinate with Breton NWR staff, the DOI should meet with the Service within six months of the date of this biological opinion (no later than the end of calendar year 2014) to coordinate and develop a detailed monitoring plan, including sampling methodologies and a project-specific schedule for the bird and benthic surveys.
2. Incorporate all data collected into an appropriate database, preferably one for plovers and knots, and one for benthic prey species.
3. Annual update reports should be provided to the Service by June 30 of each calendar year once construction begins. Annual update reports should include data sheets, maps, a copy of the database, and the progress and initial findings of piping plover, red knot, and benthic community surveys, as well as any problematic issues that may hinder future survey efforts.
4. If the DOI foresees any problematic issues that would require a change in the recommended survey schedule due to work conditions or project delays, the DOI should immediately notify the Service (337/291-3108) so that we can resolve/correct any such issues.

5. A final comprehensive report should be provided to the Service by June 30 following the third year of surveys. That final report should include an analysis of all data results from the piping plover, red knot, and benthic community surveys.
6. At least six months prior to mobilization of construction equipment, the DOI should notify the Service in writing. That notification should include whether there are any changes in the anticipated project footprint or design details and confirmation of a finalized detailed monitoring plan.

Upon locating a dead or injured piping plover or red knot that may have been harmed or destroyed as a direct or indirect result of the proposed project, the DOI and/or contractor shall be responsible for notifying the Service's Lafayette, Louisiana, Field Office (337/291-3100) and the LDWF's Natural Heritage Program (225/765-2821). Care shall be taken in handling an injured piping plover or red knot to ensure effective treatment or disposition and in handling dead specimens to preserve biological materials in the best possible state for later analysis.

## **COORDINATION OF INCIDENTAL TAKE STATEMENT WITH OTHER LAWS, REGULATIONS, AND POLICIES**

### **Migratory Bird Treaty Act (MBTA)**

The MBTA implements various treaties and conventions between the U.S., Canada, Japan, Mexico, and the former Soviet Union for the protection of migratory birds. Under the provisions of the MBTA it is unlawful "by any means or manner to pursue, hunt, take, capture or kill any migratory bird except as permitted by regulations issued by the Service. The term "take" is not defined in the MBTA, but the Service has defined it by regulation to mean to pursue, hunt, shoot, wound, kill, trap, capture or collect any migratory bird, or any part, nest or egg or any migratory bird covered by the conventions or to attempt those activities.

In order to comply with the MBTA and potential for this project to impact nesting shorebirds, the DOI should follow the Service and LDWF's guidelines (Appendix E) to protect against impacts to nesting shorebirds during implementation of this project. Please note that a bird abatement plan may be necessary to avoid disturbance to nesting water birds and shorebirds.

The Service will not refer the incidental take of piping plovers or red knots associated with this project for prosecution under the Migratory Bird Treaty Act of 1918, as amended (16 U.S.C. 703-712), if such take is in compliance with the terms and conditions specified here.

## **CONSERVATION RECOMMENDATIONS**

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

1. The DOI should consider retro-fitting all sand fencing poles with pointy tops or caps to reduce avian predation.

2. We encourage the DOI to continue to coordinate with the Service during the pre-planning phases of future Deepwater Horizon NRDAR Early Restoration projects (including any sand placement projects) within piping plover designated critical habitat.
3. We encourage the DOI to incorporate follow-up winter surveys for piping plovers and red knots during future NRDAR monitoring activities associated with the NRDAR success criteria for the NBIR project. Such data would facilitate our knowledge of the biology of those species and their wintering habitats within Breton NWR.
4. We encourage the DOI to participate in and/or fund a benthic study (or studies) along coastal Louisiana, west of the Mississippi River. Information is needed regarding the effects of sand placement and dredging projects on benthic prey species and their potential recovery time following such actions. That information would benefit our knowledge regarding piping plover and red knot foraging biology and aid in future section 7 consultation during project planning for future restoration actions.

In order for the Service to be kept informed of actions that minimize or avoid adverse effects or that benefit listed and proposed species or their habitats, the Service requests notification of the implementation of any conservation recommendations.

#### **REINITIATION NOTICE**

This concludes consultation for the piping plover on the proposed action. You may ask the Service to confirm the conference opinion as a biological opinion issued through formal consultation of the red knot is listed; that request must be in writing. If the Service reviews the proposed action and finds that there have been no significant changes in the action as planned or in the information used during the conference, the Service will confirm the conference opinion and the biological opinion on the project and no further section 7 consultation will be necessary for the red knot.

As provided in 50 CFR §402.16, reinitiation of formal consultation for the piping plover (and its critical habitat) and the red knot (after it is listed as endangered or threatened) is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take (i.e., the 198 acres of bare sand, mud flat, and intertidal habitats described herein) is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this biological/conference opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take shall cease pending reinitiation.

The incidental take statement for the red knot provided in this biological/conference opinion does not become effective until the species is listed and the conference opinion is adopted and the biological opinion issued through formal consultation. At that time, the project will be reviewed to determine whether any take of the red knot has occurred. Modifications of the opinion and incidental take statement may be appropriate to reflect that take. No take of the red knot may occur between the listing of the red knot and the adoption of the conference opinion through formation consultation, or the completion of a subsequent formal consultation.



The above findings and recommendations constitute the report of the Department of the Interior. If you have any questions about this final biological opinion, please contact Ms. Brigitte Firmin of this office at 337/291-3108.

cc: FWS, Atlanta, GA (Attn: Jerry Ziewitz and Holly Herod)  
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## LITERATURE CITED

- American Bird Conservancy. 2007. Pesticide Profile – Fenthion. Accessed on 27 February 2009 at <http://www.abcbirds.org/abcprograms/policy/pesticides/Profiles/fenthion.html>.
- 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.
- 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.
- Anders, F.J., and S.P. Leatherman. 1987. Disturbance of beach sediment by off-road vehicles. *Environmental Geology and Water Sciences* 9:183-189.
- Anderson, D.M. 2007. The ecology and oceanography of harmful algal blooms: Multidisciplinary approaches to research and management. IOC Technical Series 74. United Nations Educational, Scientific and Cultural Organization, Paris, available at <http://unesdoc.unesco.org/images/0016/001631/163114e.pdf>.
- Andres, B.A. 2009. Analysis of shorebird population trend datasets. Unpublished report by the U.S. Fish and Wildlife Service, Denver, CO.
- Antas, P.T.Z., and I.L.S. Nascimento. 1996. Analysis of red knot *Calidris canutus rufa* banding data in Brazil. *International Wader Studies* 8:63-70.
- 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. Page 5.
- Atlantic States Marine Fisheries Commission (ASMFC). 1998. Interstate fishery management plan for horseshoe crab. Fishery management report no. 32, available at <http://http://www.asmfc.org>.
- Atlantic States Marine Fisheries Commission (ASMFC). 2009. Horseshoe crab stock assessment for peer review. Stock assessment report no. 09-02 (Supplement A). Unpublished report by ASMFC, available at <http://http://www.asmfc.org>.
- Atlantic States Marine Fisheries Commission (ASMFC). 2012. 2012 review of the Fishery Management Plan in 2011 for horseshoe crab (*Limulus polyphemus*). Unpublished report by ASMFC, available at <http://http://www.asmfc.org>.
- Aubry, Y., and R. Cotter. 2001. Using trend information to develop the Quebec Shorebird Conservation Plan. *Bird Trends* 8:21-24.
- Audubon, J.J. 1844. Audubon images: The octavo editions. Plate 328: Red breasted sandpiper, available at [http://audubonimages.org/b301-400/328\\_red\\_breasted\\_sand.htm](http://audubonimages.org/b301-400/328_red_breasted_sand.htm).

- Baker, A.J., P.M. González, I.L. Serrano, R.T.J. Wallace, M.A. Efe, S. Rice, V.L. D'Amico, M.C. Rocha, and M.E. Echave. 2005. Assessment of the wintering area of red knots in Maranhao, northern Brazil. *Wader Study Group Bulletin* (107):10-18.
- Baker, A.J., P.M. González, T. Piersma, L.J. Niles, d.N. de Lima Serrano, P.W. Atkinson, N.A. Clark, C.D.T. Minton, M.K. Peck, G. Aarts, and et al. 2004. Rapid population decline in red knots: Fitness consequences of decreased refueling rates and late arrival in Delaware Bay. *Proceedings of the Royal Society Biological Sciences, Series B* 271(1541):875-882.
- Bandedbirds.org. 2012. Bandings and resightings, available at <http://www.bandedbirds.org>.
- Barber Beach Cleaning Equipment. 2009. Information accessed from website at [http://www.hbarber.com/cleaners/beach\\_cleaning\\_equipment.aspx](http://www.hbarber.com/cleaners/beach_cleaning_equipment.aspx).
- Barnes, B.M., and B.R. Truitt editors. 1997. *Seashore chronicles. Three centuries on the Virginia Barrier Islands*. University of Virginia Press, Charlottesville, VA.
- Bart, J., and V. Johnston editors. 2012. *Arctic shorebirds in North America: A decade of monitoring*. University of California Press, Berkeley, CA.
- Bent, A.C. 1927. Life histories of North American shore birds: Order Limicolae (Part 1). *Smithsonian Institution United States National Museum Bulletin* (142):131-145.
- Bent, A.C. 1929. Life histories of North American Shorebirds (Part 2). *Smithsonian Institution United States National Museum Bulletin* (146):236-246.
- Blomqvist, S., N. Holmgren, S. Åkesson, A. Hedenström, and J. Pettersson. 2002. Indirect effects of lemming cycles on sandpiper dynamics: 50 years of counts from southern Sweden. *Oecologia* 133(2):146-158.
- Boesch, D. F. 1982. Proceedings of the conference on coastal erosion and wetland modification in Louisiana: causes, consequences, and options. U.S. Fish and Wildlife Service, Biological Services Program, Washington, D.C. FWS/OBS-82/59. 256 pp.
- Botton, M.L., R.E. Loveland, and T.R. Jacobsen. 1988. Beach erosion and geochemical factors: Influence on spawning success of horseshoe crabs (*Limulus polyphemus*) in Delaware Bay. *Marine Biology* 99(3):325-332.
- Botton, M.L., R.E. Loveland, and T.R. Jacobsen. 1994. Site selection by migratory shorebirds in Delaware Bay, and its relationship to beach characteristics and abundance of horseshoe crab (*Limulus polyphemus*) eggs. *The Auk* 111(3):605-616.
- Braut, 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.
- Breese, G. 2010. Compiled by Gregory Breese from notes and reports. Unpublished report to U.S. Fish and Wildlife Service, Shorebird Technical Committee.

- Buehler, D.M. 2002. Shorebird counts in Panama during emphasize the need to monitor and protect the Upper Panama Bay. Wader Study Group Bulletin 99:41-44.
- Buehler, D.M., B.I. Tieleman, and T. Piersma. 2010. Indices of immune function are lower in red knots (*Calidris canutus*) recovering protein than in those storing fat during stopover in Delaware Bay. The Auk 127:394-401.
- Burger, J. 1986. The effect of human activities on shorebirds in two coastal bays in the Northeastern United States. Environmental Conservation 13:123-130.
- Burger, J. 1991. Foraging behavior and the effect of human disturbance on the piping plover (*Charadrius melodus*). Journal of Coastal Research 7:39-52.
- Burger, J. 1994. The effect of human disturbance on foraging behavior and habitat use in piping plover (*Charadrius melodus*). Estuaries 17:695-701.
- Burger, J. 1997. Effects of oiling on feeding behavior of sanderlings (*Calidris alba*) and semipalmated plovers (*Charadrius semipalmatus*) in New Jersey. Condor 99:290-298.
- Burger, J., and L. Niles. (in press). Effects of beach closure and human activities on shorebirds at a New Jersey coastal beach. Prepublication draft manuscript: 25.
- Burger, J., D. Caldwell Hahn, and J. Chase. 1979. Aggressive interactions in mixed-species flocks of migrating shorebirds. Animal Behaviour 27:459-469.
- Burger, J., C. Jeitner, K. Clark, and K.J. Niles. 2004. The effect of human activities on migrant shorebirds: Successful adaptive management. Environmental Conservation 31(4):283-288.
- Burger, J., L.J. Niles, R.R. Porter, A.D. Dey, S. Koch, and C. Gordon. 2012. Migration and overwintering of red knots (*Calidris canutus rufa*) along the Atlantic coast of the United States. The Condor 114(2):1-12.
- Burton, N.H.K., P.R. Evans, and M.A. Robinson. 1996. Effects on shorebirds numbers of disturbance, the loss of a roost site and its replacement by an artificial island at Hartlepool, Cleveland. Biological Conservation 77:193-201.
- Cairns, W.E., and I. McLaren. 1980. Status of the piping plover on the east coast of North America. American Birds 34:206-208.
- 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*) in eastern Canada. Avian Conservation and Ecology 1(3):4. <http://www.ace-eco.org/vol1/iss3/art4>.
- Camfield, F.E. and C.M. Holmes. 1995. Monitoring completed coastal projects. Journal of Performance of Constructed Facilities 9:169-171.

- Carlos, C.J., C.E. Fedrizzi, A.A. Campos, H. Matthews-Cascon, C.X. Barroso, S.G. Rabay, L.E.A. Bezerra, C.A.O. Meirelles, Meireles, Antônio Jeovah de Andrade, and P.R.L. Thiers. 2010. Migratory shorebirds conservation and shrimp farming in NE Brazil: Final report, agreement #BR-N11. Unpublished report prepared for U. S. Fish and Wildlife Service.
- Carmona, R., N. Arce, V. Ayala, A.H. Alvarez, J.B. Buchanan, L.J. Salzer, P. Tomkovich, J.A. Johnson, R.E. Gill Jr., B.J. McCaffery, and et al. (in press). Overview of migration connectivity by red knots (*Calidris canutus roselaari*) along the eastern Pacific coast of the Americas. Wader Study Group Bulletin.
- Catlin, D.H., J.D. Fraser, M. Stantial, J.H. Felio, K. Gierdes, and S. Karpanty. 2011. Operations report – Virginia Tech Chandeleur piping plover survey. Unpublished report prepared for U.S. Fish and Wildlife Service under Permit TE19418A-0. 2pp.
- 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.
- Chase, S. 2006. Sand back-passing with land-based equipment, a cost-effective approach for beach restoration. *Shore and Beach* 74(2):19-25.
- Chasten, M.A., and J.D. Rosati. 2010. Townsends Inlet to Cape May Inlet, NJ. Evaluation of sediment back-passing along the Avalon shoreline. U.S. Army Corps of Engineers, Philadelphia District, Philadelphia, PA.
- Clark, Ralph R. 1993. Beach Conditions in Florida: a statewide inventory and identification of the beach erosion problem areas in Florida, in Florida Department of Environmental Protection. 5<sup>th</sup> Edition, December 1993. Beaches and Shores Technical and Design Memorandum 89-1.
- Clark, K.E., L.J. Niles, and J. Burger. 1993. Abundance and distribution of migrant shorebirds in Delaware Bay. *The Condor* 95:694-705.
- Clark, K.E., R.R. Porter, and J.D. Dowdell. 2009. The shorebird migration in Delaware Bay. *New Jersey Birds* 35(4):85-92.
- 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.
- Climate Change Science Program (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.
- Coastal Protection and Restoration Authority of Louisiana. 2012. Louisiana's comprehensive master plan for a sustainable coast. Louisiana Office of Coastal Protection and Restoration, Baton Rouge, LA, available at <http://www.coastalmasterplan.louisiana.gov>.

- 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. 2008a. Winter ecology of piping plovers at Oregon Inlet, North Carolina. *Waterbirds* 31:472-479.
- Cohen, J. B., E. H. Wunker, and J. D. Fraser. 2008b. Substrate and vegetation selection by nesting piping plovers (*Charadrius melodus*) in New York. *Wilson Journal of Ornithology* 120:404-407.
- Cohen, J.B., S.M. Karpanty, J.D. Fraser, B. Watts, and B. Truitt. 2008c. Red knot stopover ecology in Delaware Bay and Virginia. Unpublished PowerPoint presentation.
- Cohen, J.B., S.M. Karpanty, J.D. Fraser, B.D. Watts, and B.R. Truitt. 2009. Residence probability and population size of red knots during spring stopover in the mid-Atlantic region of the United States. *Journal of Wildlife Management* 73(6):939-945.
- Cohen, J.B., S.M. Karpanty, J.D. Fraser, and B.R. Truitt. 2010. The effect of benthic prey abundance and size on red knot (*Calidris canutus*) distribution at an alternative migratory stopover site on the US Atlantic Coast. *Journal of Ornithology* 151:355-364.
- Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2007. COSEWIC assessment and status report on the red knot *Calidris canutus* in Canada. COSEWIC, Gatineau, QC, available at [http://www.sararegistry.gc.ca/virtual\\_sara/files/cosewic/sr\\_calidris\\_canutus\\_e.pdf](http://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_calidris_canutus_e.pdf).
- Connor, P.F.Jr., S.P. Penland, A.D. Beall, M.A. Kulp, S. Fearnley, S.J. Williams, and A.H. Sallenger, Jr. 2004. Long-term shoreline change history of Louisiana's gulf shoreline: 1800's to 2002. Pontchartrain Institute for Environmental Sciences, PIES\_CRL Technical Report Series 04001.
- Coutu, S.D., J.D. Fraser, J.L. McConnaughey, and J.P. Loegering. 1990. Piping plover distribution and reproductive success on Cape Hatteras National Seashore. Unpublished report to the National Park Service.
- Cross, R.R. 1990. Monitoring, management and research of the piping plover at Chincoteague National Wildlife Refuge. Unpublished report. Virginia Department of Game and Inland Fisheries, Richmond, Virginia.
- Cross, R.R. 1996. Breeding ecology, success, and population management of the piping plover at Chincoteague National Wildlife Refuge, Virginia. M.S. Thesis. College of William and Mary, Virginia.
- Cuthbert, F.J. and E.A. Roche. 2006. Piping plover breeding biology and management in the Great Lakes, 2006. Report submitted to the US Fish and Wildlife Service, East Lansing, Michigan.
- Cuthbert, F.J. and E.A. Roche. 2007. Estimation and evaluation of demographic parameters for recovery of the endangered Great Lakes piping plover population. Unpublished report submitted to the US Fish and Wildlife Service, East Lansing, Michigan.
- Davis, T.H. 1983. 1, Loons to sandpipers. Pages 372-375 *In* J. Farrand, ed. The Audubon Society master guide to birding, Knopf, New York.

- 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(2009):1-12.
- Dey, A., K. Kalasz, and D. Hernandez. 2011a. Delaware Bay egg survey: 2005-2010. Unpublished report to ASMFC.
- Dey, A., L. Niles, H. Sitters, K. Kalasz, and R.I.G. Morrison. 2011b. Update to the status of the red knot *Calidris canutus* in the Western Hemisphere, April, 2011, with revisions to July 14, 2011. Unpublished report to New Jersey Department of Environmental Protection, Division of Fish and Wildlife, Endangered and Nongame Species Program.
- 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.
- Douglas, B.C., Kearney, M., and S. Leatherman. 2001. *Sea-level rise: History and consequences*. New York, New York: Academic Press, Inc.
- Drake, K.R. 1999a. Movements, habitat use, and survival of wintering piping plovers. M.S. Thesis. Texas A&M University-Kingsville, Kingsville, TX. 82 pp.
- Drake, K. L. 1999b. Time allocation and roosting habitat in sympatrically wintering piping and snowy plovers. M.S. Thesis. Texas A&M University-Kingsville, Kingsville, TX. 59 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(2):259-267.
- Duerr, A.E., B.D. Watts, and F.M. Smith. 2011. Population dynamics of red knots stopping over in Virginia during spring migration. Center for Conservation Biology technical report series. College of William and Mary & Virginia Commonwealth University, CCBTR-11-04, Williamsburg, VA.
- Dugan, J.E., D.M. Hubbard, M.D. McCrary, and M.O. Pierson. 2003. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. *Estuarine, Coastal and Shelf Science* 58:25-40.
- Dugan and Hubbard. 2006. Ecological responses to coastal armoring on exposed sandy beaches. *Journal of the American Shore and Beach Preservation Association*. Winter Volume 74, No. 1.
- Eaton, E.H. 1910. *Birds of New York*. University of the State of New York, Albany, NY, available at <http://www.biodiversitylibrary.org/item/74037#page/7/mode/1up>.
- eBird.org. 2012. eBird: An online database of bird distribution and abundance (web application). Cornell Lab of Ornithology, Ithaca, New York. , available at <http://www.ebird.org/>.
- Ecological Associates, Inc. 2009. Report to Martin County, "Piping plover surveys-St. Lucie Inlet Area". Jensen Beach, Florida. 7 pp and appendices.

- Elias-Gerken, S.P. 1994. Piping plover habitat suitability on central Long Island, New York barrier islands. M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.
- Elliott, L.F. and T. Teas. 1996. Effects of human disturbance on threatened wintering shorebirds. In fulfillment of Texas Grant number E-1-8. Project 53. 10 pp.
- 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 p.
- Emanuel, K. 2005. Increasing destructiveness of tropical cyclones over the past 30 years. *Nature*, Volume 436(4):686-688.
- 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>.
- Escudero, G., J.G. Navedo, T. Piersma, P. De Goeij, and P. Edelaar. 2012. Foraging conditions 'at the end of the world' in the context of long-distance migration and population declines in red knots. *Austral Ecology* 37:355-364.
- Fabry, V.J., B.A. Seibel, R.A. Feely, and J.C. Orr. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science* 65:414-432.
- Farrell, J.G., and C.S. Martin. 1997. Proceedings of the Horseshoe Crab Forum: Status of the resource. University of Delaware, Sea Grant College Program, Newark, Delaware.
- Feng, S., C. Ho, Q. Hu, R.J. Oglesby, and S. Jeong. 2012. Evaluating observed and projected future climate changes for the Arctic using the Koppen-Trewartha climate classification. *Climate Dynamics* 38:1359-1373.
- Fenster, M., and R. Dolan. 1996. Assessing the impact of tidal inlets on adjacent barrier island shorelines. *Journal of Coastal Research* 12(1):294-310.
- Ferland, C.L., and S.M. Haig. 2002. 2001 International piping plover census. U.S. Geological Survey, forest and Rangeland Ecosystem Science Center. Corvallis, Oregon.
- Florida Department of Environmental Protection (FDEP). 2008. Critically eroded beaches in Florida. Bureau of Beaches and Coastal Systems. 77 pp.
- Florida Fish and Wildlife Conservation Commission (FFWCC). 2011. Red tides in Florida, available at <http://myfwc.com/research/redtide/information/general/redtides-fl/>.
- Florida Oceans and Coastal Council (FOCC). 2010. Climate change and sea-level rise in Florida: An update of "The effects of climate change on Florida's ocean and coastal resources". FOCC, Tallahassee, FL, available at [http://www.floridaoceanscouncil.org/reports/Climate\\_Change\\_and\\_Sea\\_Level\\_Rise.pdf](http://www.floridaoceanscouncil.org/reports/Climate_Change_and_Sea_Level_Rise.pdf).
- Food and Agriculture Organization of the United Nations (FAO). 2004. Marine biotoxins. FAO food and nutrition paper 80. FAO, Rome, available at <http://www.fao.org/docrep/007/v5486e/v5486e00.HTM>.



- Forbush, E.H. 1912. Knot (*Tringa canutus*). Page 262 In A history of the game birds, wild-fowl and shore birds of Massachusetts and adjacent states, Massachusetts State Board of Agriculture, Boston, MA, available at <http://www.biodiversitylibrary.org/item/115411#page/9/mode/1up>.
- Forys, B. 2011. An evaluation of existing shorebird management techniques' success at locations in Pinellas County. Final Report. Unpublished report by Eckerd College, St. Petersburg, FL.
- Foster, C., A. Amos, and L. 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.D., S.M. Karpanty, J.B. Cohen, and B.R. Truitt. 2013. The red knot (*Calidris canutus rufa*) decline in the western hemisphere: Is there a lemming connection? *Canadian Journal of Zoology* 91:13-16.
- 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.
- Gebert, J. 2012. 2012 Status report on USACE-Philadelphia district beaches and inlets in New Jersey. In 25-years of New Jersey coastal studies, February 15, 2012, The Richard Stockton College Coastal Research Center, Galloway, NJ, available at [http://intraweb.stockton.edu/eyos/coastal/25yrConference/2012\\_Status\\_Report.pdf](http://intraweb.stockton.edu/eyos/coastal/25yrConference/2012_Status_Report.pdf).
- Gerasimov, K.B. 2009. Functional morphology of the feeding apparatus of red knot *Calidris canutus*, great knot *C. tenuirostris* and surfbird *Aphriza virgate*. In International Wader Study Group Annual Conference, September 18-21, 2009, International Wader Study Group, Norfolk, UK.
- Gibbs, J.P. 1986. Feeding ecology of nesting piping plovers in Maine. Unpublished report to Maine Chapter, The Nature Conservancy, Topsham, Maine.
- 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. Volume 41, No.1, p. 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.
- Giraud, J.P., Jr. 1844. Birds of Long Island. Wiley & Putman, New York, available at <http://www.biodiversitylibrary.org/item/68875#page/7/mode/1up>.
- Godfrey, P.J., S.P. Leatherman, and P.A. Buckley. 1978. Impact of off-road vehicles on coastal ecosystems. Pages 581-599 in Coastal Zone 1978 Symposium on Technical, Environmental Socioeconomic and Regulatory Aspects of Coastal Zone Management. Volume II, San Francisco, California.

- Godfrey, P.J., S.P. Leatherman, and P.A. Buckley. 1980. ORVs and barrier beach degradation. *Parks* 5:2, 5-11.
- 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.
- Goldin, M.R., C. Griffin, and S. Melvin. 1990. Reproductive and foraging ecology, human disturbance, and management of piping plovers at Breezy Point, Gateway National Recreational Area, New York, 1989. Progress report for U.S. Fish and Wildlife Service, Newton Corner, Massachusetts.
- González, P.M. 2005. Report for developing a red knot status assessment in the U.S. Unpublished report by Fundacion Inalafquen, Rio Negro, Argentina.
- González, P.M., M. Carbajal, R.I.G. Morrison, and A.J. Baker. 2004. Tendencias poblacionales del playero rojizo (*Calidris canutus rufa*) en el sur de Sudamérica. *Ornitología Neotropical* 15(Suppl.):357-365.
- Goossen, J.P., D.L. Amirault, J. Arndt, R. Bjorge, S. Boates, J. Brazil, S. Brechtel, R. Chiasson, G.N. Corbett, R. Curley, M. Elderkin, S.P. Flemming, W. Harris, L. Heyens, D. Hjertaas, M. Huot, B. Johnson, R. Jones, W. Koonz, P. Laporte, D. McAskill, R.I.G. Morrison, S. Richard, F. Shaffer, C. Stewart, L. Swanson and E. Wiltse. 2002. National Recovery Plan for the Piping Plover (*Charadrius melodus*). National Recovery Plan No. 22. Recovery of Nationally Endangered Wildlife. Canadian Wildlife Service, Ottawa, Canada. 47 pp.
- Goss-Custard, J.D., R.T. Clarke, S.E.A. le V. dit Durell, R.W.G. Caldow, and B.J. Ens. 1996. Population consequences of winter habitat loss in migratory shorebird. II. Model predictions. *Journal of Applied Ecology* 32:337-351.
- Gratto-Trevor, C., D. Amirault-Langlais, D. Catlin, F. Cuthbert, J. Fraser, S. Maddock, E. Roche, and F. Shaffer. 2009. Winter distribution of four different piping plover breeding populations. Report to U.S. Fish and Wildlife Service. 11 pp.
- 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.
- Griffin, C.R. and S.M. Melvin. 1984. Research plan on management, habitat selection, and population dynamics of piping plovers on outer Cape Cod, Massachusetts. University of Massachusetts. Research proposal submitted to U.S. Fish and Wildlife Service, Newton Corner, Massachusetts.
- Guilfoyle, M.P., R.A. Fischer, D.N. Pashley, and C.A. Lott editors. 2006. Summary of first regional workshop on dredging, beach nourishment, and birds on the south Atlantic coast. ERDC/EL TR-06-10. U.S. Army Corps of Engineers, Washington, DC, available at <http://www.fws.gov/raleigh/pdfs/ES/trel06-10.pdf>.
- Guilfoyle, M.P., R.A. Fischer, D.N. Pashley, and C.A. Lott editors. 2007. Summary of second regional workshop on dredging, beach nourishment, and birds on the north Atlantic coast.

ERDC/EL TR-07-26. U.S. Army Corps of Engineers, Washington, DC, available at <http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA474358>.

Hafner, S. 2012. Beach stabilization - Structure and beach nourishment alternatives. *In* 25-years of New Jersey coastal studies, February 15, 2012, The Richard Stockton College Coastal Research Center, Galloway, NJ, available at <http://inraweb.stockton.edu/eyos/coastal/25yrConference/Beach-Stabilization.pdf>.

Haig, S.M. 1992. Piping Plover *in* The Birds of North America, No. 2 (A. Poole, P. Stettenheim, & F. Gill, eds). Philadelphia: The academy of Natural Sciences; Washington DC: The American Ornithologists' Union. 17 pp.

Haig, S.M., and E. Elliott-Smith. 2004. Piping Plover *in* The Birds of North America Online (A. Poole, eds.). Ithaca: Cornell Laboratory of Ornithology; Retrieved from The Birds of North American Online database: [http://bna.birds.cornell.edu/BNA/account/Piping\\_Plover](http://bna.birds.cornell.edu/BNA/account/Piping_Plover).

Haig, S.M., and L.W. Oring. 1985. The distribution and status of the piping plover throughout the annual cycle. *Journal of Field Ornithology* 56:334-345.

Haig, S.M., and L.W. Oring. 1987. The piping plover. *Audubon Wildlife Report*. Pp. 509-519.

Haig, S.M., C.L. Ferland, F.J. Cuthbert, J. Dingleline, J.P. Goossen, A. Hecht, and N. McPhillips. 2005. A complete species census and evidence for regional declines in piping plovers. *Journal of Wildlife Management*. 69(1): 160-173.

Hake, M. 1993. 1993 summary of piping plover management program at Gateway NRA Breezy Point district. Unpublished report. Gateway National Recreational Area, Long Island, New York.

Harrington, B.A. 1996. The flight of the red knot: A natural history account of a small bird's annual migration from the Arctic Circle to the tip of South America and back. W. W. Norton & Company, New York.

Harrington, B.A. 2001. Red knot (*Calidris canutus*). *In* A. Poole, and F. Gill, eds. The birds of North America, No. 563, The Birds of North America, Inc., Philadelphia, PA.

Harrington, B.A. 2005a. Unpublished information on red knot numbers and distribution in the eastern United States: Based largely on ongoing projects and manuscripts under development at the Manomet Center for Conservation Sciences and the Georgia Department of Natural Resources.

Harrington, B.A. 2005b. Studies of disturbance to migratory shorebirds with a focus on Delaware Bay during north migration. Unpublished report by Manomet Center for Conservation Sciences, Manomet, MA.

Harrington, B.A. 2008. Coastal inlets as strategic habitat for shorebirds in the southeastern United States. DOER technical notes collection. ERDC TN-DOERE25. U.S. Army Engineer Research and Development Center, Vicksburg, MS, available at <http://el.ercd.usace.army.mil/elpubs/pdf/doere25.pdf>.

- Harrington, B.A., J.M. Hagen, and L.E. Leddy. 1988. Site fidelity and survival differences between two groups of New World red knots (*Calidris canutus*). *The Auk* 105:439-445.
- Harrington, B.A., N.P. Hill, and N. Blair. 2010a. Changing use of migration staging areas by red knots: An historical perspective from Massachusetts. *Waterbirds* 33(2):188-192.
- Harrington, B.A., S. Koch, L.K. Niles, and K. Kalasz. 2010b. Red knots with different winter destinations: Differential use of an autumn stopover area. *Waterbirds* 33(3):357-363.
- Hayes, M.O., and J. Michel. 2008. A coast for all seasons: A naturalist's guide to the coast of South Carolina. Pandion Books, Columbia, South Carolina. 285 pp.
- Hecht, A., and S. M. Melvin. 2009. Expenditures and effort associated with recovery of breeding Atlantic Coast piping plovers. *Journal of Wildlife Management* 73(7):1099-1107.
- Hellmayr, C.E., and B. Conover. 1948. Subfamily Erolinae. Sandpipers. Genus *Calidris*. Pages 166-169 *In* Catalogue of birds of the Americas zoological series. Part 1, no. 3. Field Museum of Natural History, Chicago, available at <http://www.biodiversitylibrary.org/item/20854#page/8/mode/1up>.
- Helmers, D.L. 1992. Shorebird management manual. Western Hemisphere Shorebird Reserve Network, Manomet, Massachusetts, USA.
- Herrington, T.O. 2003. Manual for costal hazard mitigation. New Jersey Sea Grant Consortium, Fort Hancock, NJ, 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. Chapter 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.M. 1993. Relationships between human recreation and piping plover foraging ecology and chick survival. M.S. Thesis. University of Massachusetts, Amherst, Massachusetts.
- Hoopes, E.M., C.R. Griffin, and S.M. Melvin. 1992. Relationships between human recreation and piping plover foraging ecology and chick survival. Unpublished report. University of Massachusetts, Amherst, Massachusetts.
- 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.
- 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.
- Hutt, M.B., and H. Hutt. 1992. The birds of Barbados West Indies: An annotated checklist. (Unpublished manuscript):70-71.
- Ims, R.A., and E. Fuglei. 2005. Trophic interaction cycles in tundra ecosystems and the impact of climate change. *BioScience* 55(4):311-322.

- Intergovernmental Panel on Climate Change (IPCC). 2007. Climate change 2007: Synthesis report, summary for policymakers. IPCC Plenary XXVII. Valencia, Spain, 12-17 November 2007.
- International Atomic Energy Agency. 2004. The algae's toxic brews, available at <http://www.iaea.org/newscenter/features/algabloom/algae.html>.
- Johnson, C.M. and G.A. Baldassarre. 1988. Aspects of the wintering ecology of piping plovers in coastal Alabama. *Wilson Bulletin* 100:214-233.
- Jones, S.J., F.P. Lima, and D.S. Wetthey. 2010. Rising environmental temperatures and biogeography: Poleward range contraction of the blue mussel, *Mytilus edulis* L., in the western Atlantic. *Journal of Biogeography* 37:2243-2259.
- Kalasz, K. 2008. Delaware shorebird conservation plan. Version 1.0. Delaware Natural Heritage and Endangered Species Program Division of Fish and Wildlife, Delaware Department of Natural Resources & Environmental Control, Smyrna, DE.
- Kana, T. 2011. Coastal erosion control and solutions: A primer, 2nd ed. Coastal Science & Engineering, Columbia, SC, available at <http://coastalscience.com/cses-coastalerosion-and-solutions-a-primer-2nd-edition-now-available/>.
- Kaplan, J.O., N.H. Bigelow, P.J. Bartlein, T.R. Christiansen, W. Cramer, S.M. Harrison, N.V. Matveyeva, A.D. McGuire, D.F. Murray, I.C. Prentice, and et al. 2003. Climate change and Arctic ecosystems II: Modeling, paleodata-model comparisons, and future projections. *Journal of Geophysical Research* 108(D17):8171.
- Karpanty, S.M., J.D. Fraser, J. Berkson, L. Niles, A. Dey, and E.P. Smith. 2006. Horseshoe crab eggs determine distribution of red knots in the Delaware Bay. *Journal of Wildlife Management* (70):1704-1710.
- Karpanty, S.M., J.D. Fraser, J.B. Cohen, S. Ritter, B. Truitt, and D. Catlin. 2012. Update of red knot numbers and prey counts in Virginia using ground survey methods. Unpublished report to the Delaware Bay Technical Committee and the Atlantic States Marine Fisheries Commission, Department Fish and Wildlife Conservation.
- 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.
- Lamont, M.M., H.F. Percival, L.G. Pearlstine, S.V. Colwell, W.M. Kitchens, and R.R. Carthy. 1997. The Cape San Blas ecological study. U.S. Geological Survey -Biological Resources Division. Florida Cooperative Fish and Wildlife Research Unit, Technical Report No. 57.
- Lanctot, R. 2009. Third meeting: Western Hemisphere Shorebird Group. Introduction. Pages 93-136 *In* Third meeting: Western Hemisphere Shorebird Group, March 9-13, 2009, International Wader

Study Group, Norfolk, UK, available at

<http://www.shorebirdplan.org/wpcontent/uploads/2013/01/ShorebirdScienceConference2009.pdf>.

- Larson, S. 1960. On the influence of the arctic fox *Alopex lagopus* on the distribution of arctic birds. *Oikos* 11:276-305.
- 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.
- Lathrop, R.G., Jr. 2005. Red knot habitat in Delaware Bay: Status and trends. Unpublished report by the Department of Ecology, Evolution & Natural Resources, Center for Remote Sensing & Spatial Analysis, Rutgers University, New Brunswick, NJ.
- Laursen, K., J. Frikke, and J. Kahlert. 2008. Accuracy of 'total counts' of waterbirds from aircraft in coastal waters. *Wildlife Biology* 14:165-175.
- Leatherman, S.P. 1989. National assessment of beach nourishment requirements associated with accelerated sea level rise *In* The potential effects of global climate change on the United States. Report to Congress. Appendix B: Sea level rise. U.S. Environmental Protection Agency, EPA 230-05-89-052, Washington, DC, available at <http://nepis.epa.gov>.
- LeBlanc, D. 2009. Electronic mail dated 29 January 2009 from Darren LeBlanc, Service, Daphne, Alabama, Ecological Services Office to Patricia Kelly, Service, Panama City, Florida, Field Office regarding habitat changes along Alabama coast from hurricanes.
- 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.
- LeDee, O.E., K.C. Nelson, and F.J. Cuthbert. 2010. The challenge of threatened and endangered species management in coastal areas. *Coastal Management* 38:337-353.
- Lee, C. 2009. Electronic mail dated 6 February 2009 from Clare Lee, USFWS Corpus Christi, Texas Field Office to Robyn Cobb, USFWS Corpus Christi, Texas Field Office regarding oil spills, area committees, contingency plans and the contents of containers washing up on Texas' beaches.
- Lindquist, N., and L. Manning. 2001. Impacts of beach nourishment and beach scraping on critical habitat and productivity of surf fishes. Final report. North Carolina Sea Grant, NC State University, 98EP-05, Raleigh, NC, available at [http://www.ncsu.edu/ncsu/CIL/sea\\_grant/FRG/PDF/98EP05.PDF](http://www.ncsu.edu/ncsu/CIL/sea_grant/FRG/PDF/98EP05.PDF).
- Lindström, Å., and J. Agrell. 1999. Global change and possible effects on the migration and reproduction of Arctic-breeding waders. *Ecological Bulletins* 47:145-159.
- Loegering, J.P. 1992. Piping plover breeding biology, foraging ecology and behavior on Assateague Island National Seashore, Maryland. M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

- Lott, C.A., P.A. Durkee, W.A. Gierhart, and P.P. Kelly. 2007 in review. Florida coastal engineering and bird conservation geographic information system (GIS) manual. U.S. Army Corps of Engineers, Dredging Operations and Environmental Research Program, Engineer Research and Development Center, Technical Report.
- Lott, C.A., C.S. Ewell Jr., and K.L. Volanky. 2009. 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. 1999. Coast 2050: toward a sustainable coastal Louisiana, the appendices. Appendix E - region 3 supplemental information. Louisiana Department of Natural Resources. Baton Rouge, LA. 173 pp.
- Lowery Jr., G.H. 1974. Red knot *Calidris canutus*. Pages 308-310, 602 *In* Louisiana birds, Louisiana State University Press.
- Luckenbach, M. 2007. Potential interactions between clam aquaculture and shorebird foraging in Virginia, U.S.A. Unpublished report by Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA.
- MacIvor, L.H. 1990. Population dynamics, breeding ecology, and management of piping plovers on outer Cape Cod, Massachusetts. M.S. Thesis. University of Massachusetts, Amherst, Massachusetts.
- Mackay, G.H. 1893. Observations on the knot (*Tringa canutus*). *The Auk* 10:25-35, available at <http://www.istor.org/stable/4067895>.
- Maddock, S. B. 2008. Wintering piping plover surveys 2006-2007, East Grand Terre, LA to Boca Chica, TX, 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., 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.
- Massachusetts Audubon. 2003-2009. Buzzard's Bay oil spill: What lies beneath? Accessed on 26 February 2009 at <http://www.massaudubon.org/news/newsarchive.php?id=63&type=news>.
- McBride, R.A., S. Penland, M. Hiland, S.J. Williams, K.A. Westphal, B. Jaffe, and A.H. Sallenger, Jr. 1992. Analysis of barrier shoreline change in Louisiana from 1853 to 1989 *In* Williams, S.J., S. Penland, and A.H. Sallenger (eds), *Atlas of Barrier Island Changes in Louisiana from 1853 to 1989*. Miscellaneous Investigations Series 1-2150-A, U.S. Geological Survey, pp 36-97.
- McConnaughey, J.L., J.D. Fraser, S.D. Coutu, and J.P. Loegering. 1990. Piping plover distribution and reproductive success on Cape Lookout National Seashore. Unpublished report to National Park Service.

- McGowan, C.P., J.E. Hines, J.D. Nichols, J.E. Lyons, D.R. Smith, K.S. Kalasz, L.J. Niles, A.D. Dey, N.A. Clark, P.W. Atkinson, and et al. 2011. Demographic consequences of migratory stopover: Linking red knot survival to horseshoe crab spawning abundance. *Ecosphere* 2(6):1-22.
- Meltofte, H., T. Piersma, H. Boyd, B. McCaffery, B. Ganter, V.V. Golovnyuk, K. Graham, C.L. Gratto-Trevor, R.I.G. Morrison, E. Nol, and et al. 2007. Effects of climate variation on the breeding ecology of Arctic shorebirds. *Meddelelser om Grønland, Bioscience* 59. Danish Polar Center, Copenhagen, available at [http://www.worldwaders.org/dokok/literature/125/effects\\_of\\_climate\\_on\\_arctic\\_shorebirds\\_mog\\_biosci\\_59\\_2007.pdf](http://www.worldwaders.org/dokok/literature/125/effects_of_climate_on_arctic_shorebirds_mog_biosci_59_2007.pdf).
- Melvin, S.M., C.R. Griffin, and L.H. MacIvor. 1991. Recovery strategies for piping plovers in Managed coastal landscapes. *Coastal Management* 19: 21-34.
- Melvin, S.M., and J.P. Gibbs. 1994. Viability analysis for the Atlantic Coast Population of piping plovers. Unpublished report to the U.S. Fish and Wildlife Service, Sudbury, Massachusetts.
- Melvin, S.M., and J.P. Gibbs. 1996. Viability analysis for the Atlantic Coast population of piping plovers. Pp. 175-186 in *Piping plover (Charadrius melodus)*, Atlantic Coast population, revised recovery plan. U.S. Fish and Wildlife Service, Hadley, Massachusetts.
- Meyer, S.R., J. Burger, and L.J. Niles. 1999. Habitat use, spatial dynamics, and stopover ecology of red knots on Delaware Bay. Unpublished report to the New Jersey Endangered and Nongame Species Program, Division of Fish and Wildlife, Trenton, NJ.
- Morrier, A., and R. McNeil. 1991. Time-activity budget of Wilson's and semipalmated plovers in a tropical environment. *Wilson Bulletin* 103:598-620.
- Morrison, R.I.G. 2006. Body transformations, condition, and survival in red knots *Calidris canutus* travelling to breed at Alert, Ellesmere Island, Canada. *Ardea* 94(3):607-618.
- Morrison, R.I.G., and B.A. Harrington. 1992. The migration system of the red knot *Calidris canutus* in the New World. *Wader Study Group Bulletin* 64:71-84.
- Morrison, R.I.G., and R.K. Ross. 1989. Atlas of Nearctic shorebirds on the coast of South America in two volumes. Canadian Wildlife Service, Ottawa, Canada.
- Morrison, R.I.G., C. Downes, and B. Collins. 1994. Population trends of shorebirds on fall migration in eastern Canada 1974-1991. *Wilson Bulletin* 106(3):431-447.
- Morrison, R.I.G., Y. Aubry, R.W. Butler, G.W. Beyersbergen, G.M. Donaldson, C.L. Gratto-Trevor, P.W. Hicklin, V.H. Johnston, and R.K. Ross. 2001. Declines in North American shorebird populations. *Wader Study Group Bulletin* 94:34-38.
- Morrison, R.I.G., K. Ross, and L.J. Niles. 2004. Declines in wintering populations of red knots in southern South America. *The Condor* 106:60-70.



- Morrison, R.I.Guy, B.J. McCaffery, R.E. Gill, S.K. Skagen, S.L. Jones, W. Gary, C.L. Gratto-Trevor, and B.A. Andres. 2006. Population estimates of North American shorebirds. Wader Study Group Bulletin 111:67-85.
- Morrison, R.I.G., D.S. Mizrahi, R.K. Ross, O.H. Ottema, N. de Pracontal, and A. Narine. 2012. Dramatic declines of semipalmated sandpipers on their major wintering areas in the Guianas, northern South America. *Waterbirds* 35(1):120-134.
- Morton, R.A. 2003. An overview of coastal land loss: With emphasis on the southeastern United States. USGS Open File Report 03-337. U.S. Geological Survey Center for Coastal and Watershed Studies, St. Petersburg, FL, available at <http://pubs.usgs.gov/of/2003/of03-337/pdf.html>.
- Morton, R.A., and T.L. Miller. 2005. National assessment of shoreline change: Part 2: Historical shoreline changes and associated coastal land loss along the U.S. Southeast Atlantic Coast. Open-file report 2005-1401. U.S. Geological Survey, Center for Coastal and Watershed Studies, St. Petersburg, FL, available at <http://pubs.usgs.gov/of/2005/1401/>.
- Morton, R., G. Tiling, and N. Ferina. 2003. Causes of hot-spot wetland loss in the Mississippi delta plain. *Environmental Geosciences* 10(2):71-80.
- Morton, R.A., T.L. Miller, and L.J. Moore. 2004. National assessment of shoreline change: Part 1: Historical shoreline changes and associated coastal land loss along the U.S. Gulf of Mexico. Open-file report 2004-1043. U.S. Geological Survey Center for Coastal and Watershed Studies, St. Petersburg, FL, available at <http://pubs.usgs.gov/of/2004/1043/>.
- Musmeci, L., A.J. Gatto, M.A. Hernández, L.O. Bala, and J.A. Scolaro. 2011. Plasticity in the utilization of beaches by the red knots at Peninsula Valdés, Patagonia Argentina: Diet and prey selection. *In* Western Hemisphere Shorebird Group: Fourth meeting, August 11-15, 2011, International Wader Study Group, Norfolk, UK, available at <http://www.sfu.ca/biology/wildberg/4WHSG/WHSGProgramFinal.pdf>.
- Myers, J.P., and L.P. Myers. 1979. Shorebirds of coastal Buenos Aires Province, Argentina. *Ibis* 121:186-200.
- National Park Service (NPS). 2007. Cape Hatteras National Seashore 2007 annual piping plover (*Charadrius melodus*) report. Cape Hatteras National Seashore, Manteo, North Carolina.
- National Research Council. 2010. Advancing the science of climate change. The National Academies Press, Washington, DC, available at [http://www.nap.edu/catalog.php?record\\_id=12782](http://www.nap.edu/catalog.php?record_id=12782).
- 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.
- Nebel, S. 2011. Notes & news: Shooting of whimbrels sparks calls for regulation of shorebird hunting in the Caribbean. Wader Study Group Bulletin 118(1):217.

- New Jersey Department of Environmental Protection (NJDEP). 2011. New Jersey Coastal Management Program Section 309 Assessment for 2011-2015. NJDEP, Trenton, NJ, available at <http://www.state.nj.us/dep/cmp/nj2011-309assessment.pdf>.
- Newstead, D.J., L.J. Niles, R.R. Porter, A.D. Dey, and J. Burger. (in press). Geolocation reveals mid-continent migratory routes and Texas wintering areas of red knots (*Calidris canutus rufa*). Wader Study Group Bulletin.
- 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.
- Nicholls, J.L. and G.A. Baldassarre. 1990a. Habitat selection and interspecific associations of piping plovers along the Atlantic and Gulf Coasts of the United States. M.S. Thesis. Auburn University, Auburn, Alabama.
- Nicholls, J.L. and G.A. Baldassarre. 1990b. Habitat associations of piping plover wintering in the United States.
- Niles, L. 2009. Red knots wintering on the Florida Gulf Coast 2005-2009. Unpublished final report (Report on Red Knot Surveys in Florida 2008-2009) Neotropical Migrant Bird Conservation Act. Project #3556, Agreement #NJ-N31.
- Niles, L.J. 2012a. Blog - a rube with a view: Unraveling the Texas knot, available at <http://arubewithaview.com/2012/05/01/unraveling-the-texas-knot/>.
- Niles, L.J. 2012b. Blog - a rube with a view: The challenge of the rice fields of Mana, available at <http://arubewithaview.com/2012/08/26/the-challenge-of-the-rice-fields-of-mana/>.
- Niles, L.J., H.P. Sitters, A.D. Dey, P.W. Atkinson, A.J. Baker, K.A. Bennett, R. Carmona, K.E. Clark, N.A. Clark, and C. Esposito. 2008. Status of the red knot (*Calidris canutus rufa*) in the Western Hemisphere. *Studies in Avian Biology* 36:1-185.
- Niles, L.J., H.P. Sitters, D. Newstead, J. Sitters, A.D. Dey, and B. Howe. 2009. Shorebird project on the gulf coast of Texas: Oct 3-11, 2009. Unpublished report.
- Niles, L.J., J. Burger, R.R. Porter, A.D. Dey, C.D.T. Minton, P.M. González, A.J. Baker, J.W. Fox, and C. Gordon. 2010. First results using light level geolocators to track red knots in the Western Hemisphere show rapid and long intercontinental flights and new details of migration pathways. *Wader Study Group Bulletin* 117(2):123-130.
- Niles, L., A. Dey, D. Mizrahi, L. Tedesco, and K. Sellers. 2012. Second report: Damage from superstorm Sandy to horseshoe crab breeding and shorebird stopover habitat on Delaware Bay. Unpublished report to New Jersey Natural Lands Trust, available at <http://wetlandsinstitute.org/wp-content/uploads/2013/03/2nd-report-impact-Sandycrabs-and-shorebirds-7dec12.pdf>.
- Niles, L., L. Tedesco, D. Daly, and T. Dillingham. 2013. Restoring Reeds, Cooks, Kimbles and Pierces Point Delaware Bay beaches, NJ, for shorebirds and horseshoe crabs. Unpublished draft project proposal.

- Niles, L.J., J. Burger, R.R. Porter, A.D. Dey, S. Koch, B. Harrington, K. Iaquinto, and M. Boarman. (in press). Migration pathways, migration speeds and non-breeding areas used by northern hemisphere wintering red knots *Calidris canutus* of the subspecies *rufa*. Wader Study Group Bulletin.
- Noel, B.L., C.R. Chandler, and B. Winn. 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.
- 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.
- 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.
- Nordstrom, K.F. 2000. Beaches and dunes of developed coasts. Cambridge University Press, Cambridge, UK.
- Nordstrom, K.F., and M.N. Mauriello. 2001. Restoring and maintaining naturally functioning landforms and biota on intensively developed barrier islands under a no-retreat alternative. *Shore & Beach* 69(3):19-28.
- Nordstrom, K.F. N.L. Jackson, A.H.F. Klein, D.J. Sherman, and P.A. Hesp. 2006. Offshore aeolian transport across a low fore dune on a developed barrier island. *Journal of Coastal Research*. Volume 22, No. 5:1260-1267.
- Normandeau Associates Inc. 2011. New insights and new tools regarding risk to roseate terns, piping plovers, and red knots from wind facility operations on the Atlantic Outer Continental Shelf. Final report. U.S. Department of the Interior, Bureau of Ocean Energy Management (BOEMRE), BOEMRE 048-2011, New Orleans, LA, available at <http://www.data.boem.gov/PI/PDFImages/ESPIS/4/5119.pdf>.
- Nudds, R.L. and D.M. Bryant. 2000. The energetic cost of short flight in birds. *Journal of Experimental Biology* 203:1561-1572.
- Operational Science Advisory Team (OSAT-2). 2011. Summary report for fate and effects of remnant oil remaining in the beach environment. Gulf Coast Incident Management Team for the Deepwater Horizon MC252 oil spill. 37pp.
- Palmer, R.S. 1967. Piping plover in Stout, G.D. (editor). *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 Resources* 6:323-342.
- Peters, K.A., and D.L. Otis. 2007. Shorebird roost-site selection at two temporal scales: Is human disturbance a factor? *Journal of Applied Ecology* 44:196-209.

- 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 a 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.
- 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.
- Philippart, C.J.M., H.M. van Aken, J.J. Beukema, O.G. Bos, G.C. Cadée, and R. Dekker. 2003. Climate-related changes in recruitment of the bivalve *Macoma balthica*. *Limnology and Oceanography* 48(6):2171-2185.
- Piersma, T., and A.J. Baker. 2000. Life history characteristics and the conservation of migratory shorebirds. Pages 105-124 *In* L.M. Gosling, and W.J. Sutherland, eds. *Behaviour and Conservation*, Cambridge University Press, Cambridge, UK.
- Piersma, T., and Å. Lindström. 2004. Migrating shorebirds as integrative sentinels of global environmental change. *Ibis* 146 (Suppl.1):61-69.
- Piersma, T., and J.A. van Gils. 2011. *The flexible phenotype. A body-centered integration of ecology, physiology, and behavior.* Oxford University Press Inc., New York.
- Piersma, T., R. Hoekstra, A. Dekinga, A. Koolhaas, P. Wolf, P. Battley, and P. Wiersma. 1993. Scale and intensity of intertidal habitat use by knots *Calidris canutus* in the western Wadden Sea in relation to food, friends and foes. *Netherlands Journal of Sea Research* 31(4):331-357.
- Piersma, T., G.A. Gudmundsson, and K. Lilliendahl. 1999. Rapid changes in the size of different functional organ and muscle groups during refueling in a long-distance migrating shorebird. *Physiological and Biochemical Zoology* 72(4):405-415.
- Pilkey, O.H., and J.D. Howard. 1981. *Saving the American beach.* Skidaway Institute of Oceanography, Savannah, GA.
- Pilkey, O.H., and H.L. Wright III. 1988. Seawalls versus beaches. *Journal of Coastal Research* 4:41-64.
- 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 the Service's Corpus Christi, Texas, Field Office. July 2004. One page plus maps and tables.
- Plissner, J.H., and S.M. Haig. 1997. 1996 International Piping Plover Census. Report to U.S. Geological Survey, Biological Resources Division, Forest and Rangeland Ecosystem Science Center, Corvallis, Oregon.
- Plissner, J.H. and S.M. Haig. 2000. Viability of piping plover *Charadrius melodus* metapopulations. *Biological Conservation* 92:163-173.

- Pompei, V. D., and F. J. Cuthbert. 2004. Spring and fall distribution of piping plovers in North America: implications for migration stopover conservation. Report the U.S. Army Corps of Engineers. University of Minnesota, St. Paul.
- 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. *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.
- Rehfisch, M.M., and H.Q.P. Crick. 2003. Predicting the impact of climatic change on Arctic-breeding waders. *Wader Study Group Bulletin* 100:86-95.
- Rice, T.M. 2009. Best management practices for shoreline stabilization to avoid and minimize adverse environmental impacts. Unpublished report prepared for the USFWS, Panama City Ecological Services Field Office, available at <http://www.fws.gov/charleston/pdf/PIPL/BMPs%20For%20Shoreline%20Stabilization%20To%20Avoid%20And%20Minimize%20Adverse%20Environmental%20Impacts.pdf>.
- Rice, T.M. 2012a. The status of sandy, oceanfront beach habitat in the coastal migration and wintering range of the piping plover (*Charadrius melodus*). Appendix 1C in: Draft comprehensive conservation strategy for the piping plover (*Charadrius melodus*) coastal migration and wintering range. USFWS, available at <http://www.fws.gov/charleston/pdf/PIPL/The%20Status%20of%20Sandy%20Oceanfront%20Beach%20Habitat%20In%20The%20Coastal%20Migration%20And%20Wintering%20Range%20Of%20The%20Piping%20Plover.pdf>.
- Rice, T.M. 2012b. Inventory of habitat modifications to tidal inlets in the coastal migration and wintering range of the piping plover (*Charadrius melodus*). Appendix 1B in: Draft comprehensive conservation strategy for the piping plover (*Charadrius melodus*) coastal migration and wintering range. USFWS, available at <http://www.fws.gov/charleston/pdf/PIPL/Inventory%20Of%20Habitat%20Modifications%20To%20Tidal%20Inlets%20In%20The%20Coastal%20Migration%20And%20Wintering%20Range%20Of%20The%20Piping%20Plover.pdf>.
- Ridgway, R. 1919. *Canutus Canutus* (Linnaeus). Knot. Pages 232-238 *In* The birds of North and Middle America : A descriptive catalogue of the higher groups, genera, species, and subspecies of birds known to occur in North America, from the Arctic lands to the Isthmus of Panama, the West Indies and other islands of the Caribbean sea, and the Galapagos Archipelago. Bulletin of the United States National Museum. No. 50. Part VIII, Government Printing Office, Washington, DC,

available at

[http://books.google.com/books?hl=en&lr=&id=mIZ5LU47jUQC&oi=fnd&pg=PA1&dq=info:tM8K7NpXf2sJ:scholar.google.com&ots=iqUMGZ65fg&sig=45\\_FRHcwdx6dwLTcPWbOL-BELf4#v=onepage&q&f=false](http://books.google.com/books?hl=en&lr=&id=mIZ5LU47jUQC&oi=fnd&pg=PA1&dq=info:tM8K7NpXf2sJ:scholar.google.com&ots=iqUMGZ65fg&sig=45_FRHcwdx6dwLTcPWbOL-BELf4#v=onepage&q&f=false).

Roche, E.A., J.B. Cohen, D.H. Catlin, D.L. Amirault, F.J. Cuthbert, C.L. Gratto-Trevor, J., Felio, and J.D. Fraser. 2010. Range-wide estimation of apparent survival in the piping plover. *Journal of Wildlife Management* 74:1784-1791.

Roosevelt, R.B. 1866. *The game birds of the coasts and lakes of the northern states of America*. Carleton Publisher, New York, available at <http://www.biodiversitylibrary.org/item/117197#page/9/mode/1up>.

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., 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.

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.

Schekkerman, H., I. Tulp, T. Piersma, and G.H. Visser. 2003. Mechanisms promoting higher growth rate in arctic than in temperate shorebirds. *Oecologia* 134:332-342.

Schlacher, T.A., and L.M.C. Thompson. 2008. Physical impacts caused by off-road vehicles (ORVs) to sandy beaches: Spatial quantification of car tracks on an Australian barrier island. *Journal of Coastal Research* 24:234-242.

Schmidt, N.M., R.A. Ims, T.T. Høye, O. Gilg, L.H. Hansen, J. Hansen, M. Lund, E. Fuglei, M.C. Forchhammer, and B. Sittler. 2012. Response of an arctic predator guild to collapsing lemming cycles. *Proceedings of the Royal Society B* 279:4417-4422.

Schmitt, M.A. and A. C. Haines. 2003. Proceeding of the 2003 Georgia Water Resources Conference, April 23-24, 2003, at the University of Georgia.

Schneider, T.M., and B. Winn. 2010. Georgia species account: Red knot (*Calidris canutus*). Unpublished report by the Georgia Department of Natural Resources, Wildlife Resources Division, Nongame Conservation Section, available at [http://www.georgiawildlife.com/sites/default/files/uploads/wildlife/nongame/pdf/accounts/birds/calidris\\_canutus.pdf](http://www.georgiawildlife.com/sites/default/files/uploads/wildlife/nongame/pdf/accounts/birds/calidris_canutus.pdf).

Shaw Coastal, Inc. 2011. State of Louisiana barrier berm: oil spill protection. Project No. 139551. Survey report prepared for the U.S. Fish and Wildlife Service's Louisiana Ecological Services Office, Lafayette, Louisiana.

- Shriner, C.A. 1897. Knot, robin snipe, or gray snipe. Page 94 *In* The Birds of New Jersey, New Jersey Fish and Game Commission, available at <http://www.biodiversitylibrary.org/item/32639>.
- Shuster, C.N., Jr., R.B. Barlow, and J.H. Brockmann editors. 2003. The American horseshoe crab. Harvard University Press, Cambridge, MA.
- Siok, D., and B. Wilson. 2011. Using dredge spoils to restore critical American horseshoe crab (*Limulus polyphemus*) spawning habitat at the Mispillion Inlet. Delaware Coastal Program, Dover, DE.
- Skagen, S.K., P.B. Sharpe, R.G. Waltermire, and M.B. Dillon. 1999. Biogeographical profiles of shorebird migration in midcontinental North America. Biological Science Report 2000-0003, U.S. Geological Survey, available at [http://www.fort.usgs.gov/products/publications/pub\\_abstract.asp?PubID=555](http://www.fort.usgs.gov/products/publications/pub_abstract.asp?PubID=555).
- Smith, B.S. 2007. 2006-2007 Nonbreeding shorebird survey, Franklin and Wakulla Counties, Florida. Final report to the Service in fulfillment of Grant #40181-7-J008. Apalachicola Riverkeeper, Apalachicola, Florida. 32 pp.
- Smith, B.S. 2010. Patterns of nonbreeding snowy plover (*Charadrius alexandrinus*), piping plover (*C. melodus*), and red knot (*Calidris canutus*) distribution in northwest Florida. Florida Field Naturalist 38(2):43-54.
- Smith, D.R., and S.F. Michels. 2006. Seeing the elephant: Importance of spatial and temporal coverage in a large-scale volunteer-based program to monitor horseshoe crabs. Fisheries 31(10):485-491.
- Smith, P.A., H.G. Gilchrist, M.R. Forbes, J. Martin, and K. Allard. 2010. Inter-annual variation in the breeding chronology of arctic shorebirds: Effects of weather, snow melt and predators. Journal of Avian Biology 41:292-304.
- Smith, D.R., N.L. Jackson, K.F. Nordstrom, and R.G. Weber. 2011. Beach characteristics mitigate effects of onshore wind on horseshoe crab spawning: Implications for matching with shorebird migration in Delaware Bay. Animal Conservation 14:575-584.
- Spaans, A.L. 1978. Status and numerical fluctuations of some North American waders along the Surinam coast. Wilson Bulletin 90:60-83.
- Sprandell, G.L., J.A. Gore, and D.T. Cobb. 1997. Winter shorebird survey. Final performance report. Florida Game and Fresh Water Fish Commission, Tallahassee, FL, available at [http://www.flshorebirdalliance.org/pdf/Sprandel\\_Gore\\_Cobb-1994\\_Winter\\_Shorebirds.pdf](http://www.flshorebirdalliance.org/pdf/Sprandel_Gore_Cobb-1994_Winter_Shorebirds.pdf).
- Staine, K.J., and J. Burger. 1994. Nocturnal foraging behavior of breeding piping plovers (*Charadrius melodus*) in New Jersey. Auk 111:579-587.
- Stearns, W.A., and E. Coues. 1883. New England bird life: Being a manual of New England ornithology, Part II. Lee and Shepard Publishers, Boston, MA, available at <http://www.biodiversitylibrary.org/item/115807#page/236/mode/1up>.

- Stillman, R.A., A.D. West, J.D. Goss-Custard, S. McGrorty, N.J. Frost, D.J. Morrisey, A.J. Kenny, and A.L. Drewitt. 2005. Predicting site quality for shorebird communities: A case study on the Humber Estuary, UK. *Marine Ecology Progress Series* 305:203-217.
- Stone, W. 1937. *Bird studies at Old Cape May: An ornithology of coastal New Jersey*. Dover Publications, New York.
- Stucker, J.H. and F.J. Cuthbert. 2004. Piping plover breeding biology and management in the Great Lakes, 2004. Report submitted to the US Fish and Wildlife Service, East Lansing, Michigan.
- Stucker, J.H., and F.J. Cuthbert. 2006. Distribution of non-breeding Great Lakes piping plovers along Atlantic and Gulf of Mexico coastlines: 10 years of band resightings. Final Report to U.S. Fish and Wildlife Service.
- Stucker, J.H., F.J. Cuthbert and C.D. Haffner. 2003. Piping plover breeding biology and management in the Great Lakes, 2003. Report submitted to the U.S. Fish and Wildlife Service, East Lansing, Michigan.
- Summers, R.W., and L.G. Underhill. 1987. Factors related to breeding production of Brent Geese *Branta b. bernicla* and waders (*Charadrii*) on the Taimyr Peninsula. *Bird Study* 34:161-171.
- Tarr, N.M. 2008. Fall migration and vehicle disturbance of shorebirds at South Core Banks, North Carolina. North Carolina State University, Raleigh, NC.
- 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.
- Taylor, A.L. 1981. Adventitious molt in red knot possibly caused by *Actornithophilus* (Mallophaga: Menoponidae). *Journal of Field Ornithology* 52(3):241.
- Thomas, K., R.G. Kvitek, and C. Bretz. 2002. Effects of human activity on the foraging behavior of sanderlings (*Calidris alba*). *Biological Conservation* 109:67-71.
- Titus, J.G. 1990. Greenhouse effect, sea level rise, and barrier islands: Case study of Long Beach Island, New Jersey. *Coastal Management* 18:65-90.
- Titus, J.G. 2000. Does the U.S. government realize that the sea is rising? How to restructure federal programs so that wetland and beaches survive. *Golden Gate University Law Review* 30(4):717-778, available at <http://digitalcommons.law.ggu.edu/cgi/viewcontent.cgi?article=1797&context=ggulrev>.
- 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, and et al. 2009. State and local governments plan for development of most land vulnerable to rising sea level along the US Atlantic coast. *Environmental Research Letters* 4(4):044008.



- 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.
- Truitt, B.R., B.D. Watts, B. Brown, and W. Dunstan. 2001. Red knot densities and invertebrate prey availability on the Virginia barrier islands. Wader Study Group Bulletin 95:12.
- U.S. Army Corps of Engineers (USACE). 2002. Coastal engineering manual. Engineer manual 1110-2-1100. USACE, Washington, DC, available at <http://chl.erdc.usace.army.mil/cem>.
- U.S. Army Corps of Engineers (USACE). 2004. Louisiana Coastal Area – Ecosystem Restoration Study, Final Report. U.S. Army Corps of Engineers, New Orleans District. 506 pp.
- U.S. Army Corps of Engineers (USACE). 2006. Coastal Engineering Manual, EM 1110-2-1100, Part V.
- U.S. Army Corps of Engineers (USACE). 2009a. April 24, 2009, Biological assessment of the proposed Louisiana Coastal Area – Barataria Basin Barrier Shoreline Restoration project. U.S. Army Corps of Engineers, New Orleans District. 41 pp plus appendices.
- U.S. Army Corps of Engineers (USACE). 2009b. 2008 Annual Report; Biological Opinion on the Operation of the Missouri River Main Stem System, Operation and Maintenance of the Missouri River Bank Stabilization and Navigation Project, and Operation of the Kansas River Reservoir System. U.S. Army Corps of Engineers, Omaha District, Kansas City District.
- U.S. Army Corps of Engineers (USACE). 2010. August 9, 2010, Biological Assessment of the proposed Louisiana Coastal Area – Barataria Basin Barrier Shoreline Restoration project. U.S. Army Corps of Engineers, New Orleans District. 88 pp plus appendices.
- U.S. Army Corps of Engineers (USACE). 2011. June 3, 2011, Biological Assessment of the proposed Louisiana Coastal Area – Barataria Basin Barrier Shoreline Restoration project. U.S. Army Corps of Engineers, New Orleans District. 88 pp plus appendices.
- U.S. Army Corps of Engineers (USACE). 2012. Project factsheet: Delaware Bay coastline, DE & NJ, Reeds Beach and Pierces Point, NJ , available at <http://www.nap.usace.army.mil/Missions/Factsheets/FactSheetArticleView/tabid/4694/Article/6442/delaware-bay-coastline-de-nj-reeds-beach-and-pierces-pointnj.aspx>.
- U.S. Department of the Interior (DOI). 2013. Biological assessment for the proposed North Breton Island Restoration, Chandeleur Islands Barrier System, Louisiana. 26pp.
- U.S. Fish and Wildlife Service (Service). 1985. Determination of endangered and threatened status for the piping plover. Federal Register 50:50726-50734.
- U.S. Fish and Wildlife Service (Service). 1988. 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.

- U.S. Fish and Wildlife Service (Service). 1994. Revised Draft - Recovery plan for piping plovers - Breeding on the Great Lakes and Northern Great Plains. U.S. Fish and Wildlife Service, Twin Cities, Minnesota. 99 pp.
- U.S. Fish and Wildlife Service (Service). 1996. Piping plover (*Charadrius melodus*), Atlantic Coast population, revised recovery plan. Hadley, Massachusetts.
- U.S. Fish and Wildlife Service (Service). 2001a. Final determination of critical habitat for the Great Lakes breeding population of the piping plover. Federal Register 66:22938-22969.
- U.S. Fish and Wildlife Service (Service). 2001b. Final determination of critical habitat for wintering piping plovers. Federal Register 66:36037-36086.
- U.S. Fish and Wildlife Service (Service). 2002. Final designation of critical habitat for the Northern Great Plains breeding population of the piping plover. Federal Register 67:57637-57717.
- U.S. Fish and Wildlife Service (Service). 2003. Recovery plan for the Great Lakes piping plover (*Charadrius melodus*). U.S. Fish and Wildlife Service, Fort Snelling, Minnesota.
- U.S. Fish and Wildlife Service (Service). 2008. Revised designation of critical habitat for the wintering population of the piping plover (*Charadrius melodus*) in North Carolina. Federal Register 73:62816-62841.
- U.S. Fish and Wildlife Service (Service). 2009a. Revised designation of critical habitat for the wintering population of the piping plover (*Charadrius melodus*) in Texas. Federal Register 74:23476-23524.
- U.S. Fish and Wildlife Service (Service). 2009b. Piping plover (*Charadrius melodus*) 5-year review: summary and evaluation. U.S. Fish and Wildlife Service, Hadley, Massachusetts. 214 pp.
- U.S. Fish and Wildlife Service (Service). 2011a. Abundance and productivity estimates: Atlantic Coast piping plover population, 1986-2009. Sudbury, Massachusetts. 4 pp.
- U.S. Fish and Wildlife Service (Service). 2011b. Species assessment and listing priority assignment form. Scientific name: *Calidris canutus ssp. rufa*. USFWS, Hadley, MA, available at [http://ecos.fws.gov/docs/candidate/assessments/2012/r5/B0DM\\_V01.pdf](http://ecos.fws.gov/docs/candidate/assessments/2012/r5/B0DM_V01.pdf).
- U.S. Fish and Wildlife Service (Service). 2011c. Draft biological opinion on the effects of back-passing on the federally listed (threatened) piping plover (*Charadrius melodus*) and sea-beach amaranth (*Amaranthus pumilus*) in Avalon Borough, Cape May County, New Jersey, 2011 to 2017. USFWS New Jersey Field Office, Pleasantville, NJ.
- U.S. Fish and Wildlife Service (Service). 2012a. Comprehensive conservation strategy for the piping plover (*Charadrius melodus*) in its coastal migration and wintering range in the continental United States. USFWS, East Lansing, MI, available at [http://www.fws.gov/midwest/endangered/pipingplover/pdf/CCSpipI\\_NoApp2012.pdf](http://www.fws.gov/midwest/endangered/pipingplover/pdf/CCSpipI_NoApp2012.pdf).

- U.S. Fish and Wildlife Service (Service). 2013. Proposed rule for the threatened status for the Rufa Red Knot (*Calidris canutus rufa*). Federal Register 78:60023-60098.
- U.S. Fish and Wildlife Service (Service), and Conserve Wildlife Foundation of New Jersey. 2012. Cooperative agreement. Project title: Identify juvenile red knot wintering areas.
- U.S. Fish and Wildlife Service (Service) and Town of Kiawah Island. 2006. Unpublished data.
- Unified Area Command. 2010. October 6, 2010, weekly update for the Deepwater Horizon MC252 oil spill. [www.RestoreTheGulf.gov](http://www.RestoreTheGulf.gov).
- Urner, C.A., and R.W. Storer. 1949. The distribution and abundance of shorebirds on the North and Central New Jersey Coast, 1928-1938. The Auk 66(2):177-194.
- van Deventer, M. 2007. Brevetoxins in marine birds: Evidence of trophic transfer and the role of prey fish as toxin vector. University of South Florida, Tampa, FL, available at <http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=3391&context=etd>.
- van Deventer, M., K. Atwood, G.A. Vargo, L.J. Flewelling, J.H. Landsberg, J.P. Naar, and D. Stanek. 2011. *Karenia brevis* red tides and brevetoxin-contaminated fish: A high risk factor for Florida's scavenging shorebirds? Botanica Marina 55(1):31-37.
- van Gils, J.A., P.F. Battley, T. Piersma, and R. Drent. 2005a. Reinterpretation of gizzard sizes of red knots world-wide emphasis overriding importance of prey quality at migratory stopover sites. Proceedings of the Royal Society of London, Series B 272:2609-2618.
- van Gils, J.A., A. Dekinga, B. Spaans, W.K. Vahl, and T. Piersma. 2005b. Digestive bottleneck affects foraging decisions in red knots (*Calidris canutus*). II. Patch choice and length of working day. Journal of Animal Ecology 74:120-130.
- Ward, J.R., and K.D. Lafferty. 2004. The elusive baseline of marine disease: Are diseases in ocean ecosystems increasing? PLoS Biology 2(4):542-547.
- Watts, B.D. 1998. An investigation of waterbirds within the Panama Canal Zone and the upper Bay of Panama. Center for Conservation Biology, College of William and Mary. CCBR-98-04.
- 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.
- Westbrock, M., E.A. Roche, F.J. Cuthbert and J.H. Stucker. 2005. Piping plover breeding biology and management in the Great Lakes, 2005. Report submitted to the US Fish and Wildlife Service, East Lansing, MI.
- 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.

Western Hemisphere Shorebird Reserve Network (WHSRN). 2012. Site profiles, available at <http://www.whsrn.org/sites/list-sites>.

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. UM-NPSCRU Report No. 28. [Also submitted as a M.S. Thesis entitled "Off-road vehicle (ORV) effects on representative infauna and a comparison of predator-induced mortality by *Polinices duplicatus* and ORV activity on *Mya arenaria* at Hatches Harbor, Provincetown, Massachusetts" to the University of Massachusetts, Amherst, Massachusetts.]

Wilcox, L. 1959. A twenty year banding study of the piping plover. *Auk* 76: 129-152.

Wilkinson, P.M., and M. Spinks. 1994. Winter distribution and habitat utilization of piping plovers in South Carolina. *Chat* 58:33-37.

Williams, S.J., S. Penland, and A.H. Sallenger, Jr., editors. 1992. Louisiana Barrier Island Erosion Study: Atlas of shoreline changes in Louisiana from 1853 to 1989. Prepared by the U.S. Geological Survey in cooperation with the Louisiana Geological Survey. 103p.

Williams, T. 2001. Out of control. *Audubon Magazine* October 2001. Accessed on 26 February 2009, at <http://www.audubonmagazine.org/incite/incite0109.html>.

Wilson, A. 1829. Species 7. *Tringa rufa*. Red-breasted sandpiper; *Tringa cinerea*. Ashcoloured sandpiper. Pages 140-148 *In American ornithology; or the natural history of the birds of the United States*, Collins & Co., New York, available at <http://digicoll.library.wisc.edu/cgi-bin/DLDecArts/DLDecArtsidx?id=DLDecArts.AmOrnWil04>.

Wilson, J., E. Aubry, C. Buidin, Y. Rochepault, and A.J. Baker. 2010. Three records of red knots *Calidris canutus* possibly changing flyways. *Wader Study Group Bulletin* 117(3):192-193.

Winstead, N. 2008. Letter dated 8 October 2008 from Nick Winstead, Mississippi Department of Wildlife, Fisheries and Parks, Museum of Natural Science to Patty Kelly, Service, Panama City, Florida Field Office regarding habitat changes in Mississippi from hurricanes and estimates of shoreline miles of mainland and barrier islands.

Woods Hole Oceanographic Institution (Woods Hole). 2012. Harmful algae: What are harmful algal blooms (HABs)?, available at <http://www.whoi.edu/redtide/home>.

Zivojnovich, M. 1987. Habitat selection, movements and numbers of piping plovers wintering in coastal Alabama. Alabama Department of Conservation and Natural Resources. Project Number W-44-12. 16 pp.

Zöckler, C., and I. Lysenko. 2000. Water birds on the edge: First circumpolar assessment of climate change impact on Arctic breeding water birds. World Conservation Press, Cambridge, UK, available at [http://www.unep-wcmc.org/biodiversity-series-11\\_114.html](http://www.unep-wcmc.org/biodiversity-series-11_114.html).

- Zonick, C. 1997. The use of Texas barrier island washover pass habitat by piping plovers and other coastal waterbirds. National Audubon Society. A Report to the Texas Parks and Wildlife Department and the U.S. Fish and Wildlife Service. 19 pp.
- 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. 1995. 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. 49pp.
- 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.
- Zwarts, L., and A.M. Blomert. 1992. Why knot *Calidris canutus* take medium-sized *Macoma balthica* when six prey species are available. Marine Ecology Progress Series 83:113-128.

### ***Personal Communications***

- Adams, T. 2009. Electronic mail dated 10 February 2009 from Trish Adams, USFWS, Vero Beach, Florida, Field Office to Patricia Kelly, USFWS, Panama City, Florida Office regarding USFWS-issued permit conditions for raccoon eradication to Indian River County staff in Florida as part of a coastal Habitat Conservation Plan.
- Amos, A. 2009. Telephone conversation on 3 April 2009 between Tony Amos, University of Texas Marine Science Institute, and Robyn Cobb, USFWS Corpus Christi, Texas Field Office regarding injured and oiled piping plovers on the central Texas coast.
- Bimbi, M. 2012. Biologist. E-mails of September 12, and November 1, 2012. U.S. Fish and Wildlife Service, Recovery and Endangered Species, South Carolina Field Office. Charleston, SC.
- Bimbi, M. 2013. Biologist. E-mails of January 31, June 27, and July 2, 2013. U.S. Fish and Wildlife Service, Recovery and Endangered Species, South Carolina Field Office, Charleston, SC.
- Breese, G. 2013. Project Leader. E-mails of March 11, 12, 25, and April 26 and 29, 2013. US Fish & Wildlife Service, Delaware Bay Estuary Project. Smyrna, Delaware.
- Clark, K. 2012. Senior Zoologist Biologist. Phone interview of April 11, 2012; E-mail of October 25, 2012. New Jersey Department of Environmental Protection, Division of Fish and Wildlife, Endangered and Nongame Species Program. Tuckahoe, New Jersey.
- Clark, K. 2013. Senior Zoologist Biologist. E-mails of January 21, February 11, and March 4, 2013. New Jersey Department of Environmental Protection, Division of Fish and Wildlife, Endangered and Nongame Species Program. Tuckahoe, New Jersey.
- Cobb, R. 2009. Electronic mail dated 10 February 2009 from Robyn Cobb, USFWS, Corpus Christi, Texas, Field Office to Patricia Kelly, USFWS, Panama City, Florida, Field Office regarding predator control programs used for waterbird islands in Texas.

- 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 Regional Office.
- Dey, A. 2012. Principal Zoologist. E-mails of August 9, 13, 20; October 12, 29; November 19; and December 3, 2012. New Jersey Department of Environmental Protection, Division of Fish and Wildlife, Endangered & Nongame Species Program. Millville, NJ.
- Dey, A. 2013. Principal Zoologist. E-mails of February 08 and April 26, 2013. New Jersey Department of Environmental Protection, Division of Fish and Wildlife, Endangered & Nongame Species Program. Millville, NJ.
- Farley, R. 2009. Phone conversation on 11 February 2009 between Robert Farley, Planning and Landscape Architecture, Post, Buckley, Schuh, and Jernigan, Inc. and Patricia Kelly, Service, Panama City, Florida, Field Office regarding status of beach vitex on northwest Florida beaches.
- Hall, H. 2009. Electronic mail dated 17 July 2009 from Howard Hall, USFWS Raleigh, North Carolina, Field Office to Patricia Kelly, USFWS, Panama City, Florida, Field Office regarding estimates on beach nourishment coverage in NC.
- Hanlon, H. 2012. Biologist. E-mail of November 22, 2012. U.S. Fish and Wildlife Service, Cape May National Wildlife Refuge. Cape May Court House, NJ.
- Harrington, B. 2006. Biologist. E-mail of March 31, 2006. Manomet Center for Conservation Sciences. Manomet, MA.
- Harrington, B. 2012. Biologist. E-mail of November 12, 2012. Manomet Center for Conservation Sciences. Manomet, MA.
- Hunter, C. 2012. Chief. E-mail of September 20, 2012. Division of Strategic Resource Management, U.S. Fish and Wildlife Service, National Wildlife Refuge System. Atlanta, GA.
- Jeffery, M. 2013. Program Manager. E-mail of February 13, 2013. National Audubon Society, International Alliances Program. Washington, DC.
- Kalasz, K. 2011. Biologist. Interview of November 17, 2011. Delaware Department of Natural Resources and Environmental Control, Delaware Shorebird Project. Dover, DE.
- Kalasz, K. 2012. Biologist. E-mail of November 26, 2012. Delaware Department of Natural Resources and Environmental Control, Delaware Shorebird Project. Dover, DE.
- Kalasz, K. 2013. Biologist. E-mails of February 8, and March 29, 2013. Delaware Department of Natural Resources and Environmental Control, Delaware Shorebird Project. Dover, DE.
- Koch, S. 2012. Wildlife Biologist. E-mail of November 19, 2012. U.S. Fish and Wildlife Service, Eastern Massachusetts National Wildlife Refuge Complex. Sudbury, MA.

LeBlanc, D. 2009. Electronic mail dated 29 January 2009 from Darren LeBlanc, USFWS, Daphne, Alabama, Ecological Services Office to Patricia Kelly, USFWS, Panama City, Florida, Field Office regarding habitat changes along Alabama coast from hurricanes.

Lee, C. 2009. Electronic mail dated 6 February 2009 from Clare Lee, USFWS Corpus Christi, Texas Field Office to Robyn Cobb, USFWS Corpus Christi, Texas Field Office regarding oil spills, area committees, contingency plans and the contents of containers washing up on Texas' beaches.

Levesque, A. 2011. Biologist. E-mail of October 11, 2011. National Hunting and Wildlife Agency. Guadeloupe, FWI.

Mizrahi, D. 2011. Vice-president. E-mail of October 16, 2011. New Jersey Audubon Society, Research and Monitoring. Cape May Court House, NJ.

Mizrahi, D. 2012. Vice-president. E-mail of November 17, 2012. New Jersey Audubon Society, Research and Monitoring. Cape May Court House, NJ.

Newstead, D. 2012. Manager, Coastal Waterbird Program. E-mails of August 20, 29, and September 14; Conference call of September 14, 2012. Coastal Bend Bays & Estuaries Program, Corpus Christi TX.

Nicholas, M. 2005. Electronic mail dated 8 March 2005 from Mark Nicholas, Gulf Islands National Seashore, Gulf Breeze, Florida to Patricia Kelly, Service, Panama City, Florida Field Office providing documentation of Great Lakes piping plover sightings post-hurricane.

Niles, L. 2008. Consulting Biologist/Leader. Interviews of September 3 and 4, 2008. International Shorebird Project Leader, Conserve Wildlife Foundation of New Jersey. Greenwich, NJ.

Niles, L. 2012. Consulting Biologist/Leader. E-mails of November 19 and 20, 2012. International Shorebird Project, Conserve Wildlife Foundation of New Jersey. Greenwich, NJ.

Niles, L. 2013. Consulting Biologist/Leader. E-mails of January 4, 8, and 25, and March 15, 2013. International Shorebird Project, Conserve Wildlife Foundation of New Jersey. Greenwich, NJ.

Patrick, L. 2012. Biologist. E-mails of August 31, and October 22, 2012. U.S. Fish and Wildlife Service, Southeast Region. Panama City, FL.

Perkins, S. 2008. "South Beach PIPLs", 29 September 2008, electronic correspondence (30 September 2008) NEFO *see 4/27 email from Susi*.

Pover, T. 2012. Project Manager. E-mail of December 9, 2012. Conserve Wildlife Foundation of New Jersey, Beach Nesting Bird Program. Trenton, NJ.

Rabon, D. 2009. Electronic mail dated 10-11 February 2009 from David Rabon, Service, Raleigh, North Carolina, Field Office to Patricia Kelly, Service, Panama City, Florida Field Office on regarding NPS lands and individual state parks in North Carolina that participate in predator control programs.

- Rice, T.M. 2013. Research Associate. E-mails of January 3, 28, and 29, 2013. Terwilliger Consulting, Inc. Locustville, VA.
- Schwarzer, A. 2013. Fish/Wildlife Technician. E-mails of March 25 and June 17, 2013. Florida Fish and Wildlife Conservation Commission. Gainesville, FL.
- Sitters, H. 2008. Editor, Wader Study Group Bulletin. Interview of September 4, 2008. Wader Study Group Bulletin. Seaton. Devon, UK.
- Suiter, D. 2009. Electronic mail dated 2 February 2009 from Dale Suiter, Service, Raleigh, North Carolina Field Office to Patricia Kelly, Service, Panama City, Florida Field Office on February 2, 2009 regarding status of beach vitex and control measures along the North Carolina, South Carolina, and Georgia coast.
- Tuttle, P. 2012. Project Leader. E-mail of November 08, 2012. U.S. Fish & Wildlife Service, Natural Resource Damage Assessment and Restoration. Montrose, Alabama.
- Watts, B.D. 2012. Director/Professor. E-mails of August 16 and 28; October 4; and November 15, 2012. The Center for Conservation Biology, College of William and Mary. Williamsburg, VA.



**APPENDIX A**

**Standard Conditions for In-water Work in the Presence of Manatees**

### **Guidelines for Activities in Proximity to Manatees and Their Habitat**

- A. All personnel associated with the project should be informed of the potential presence of manatees, manatee speed zones, and the need to avoid collisions with and injury to manatees. Such personnel instruction should also include a discussion of the civil and criminal penalties for harming, harassing, or killing manatees, which are protected under the Marine Mammal Protection Act of 1972 and the Endangered Species Act of 1973.
- B. All contract and/or construction personnel are responsible for observing water-related activities for the presence of manatee(s).
- C. Temporary signs should be posted prior to and during all construction/dredging activities to remind personnel to be observant for manatees during active construction/dredging operations or within vessel movement zones (i.e., work area), and at least one sign should be placed where it is visible to the vessel operator.
- D. Siltation barriers, if used, should be made of material in which manatees could not become entangled, and should be properly secured and regularly monitored. Barriers should not impede manatee movement.
- E. If a manatee is sighted within 100 yards of the active work zone, special operating conditions should be implemented, including: no operation of moving equipment within 50 feet of a manatee; all vessels should operate at no wake/idle speeds within 100 yards of the work area; and siltation barriers, if used, should be re-secured and monitored. Once the manatee has left the 100-yard buffer zone around the work area on its own accord, special operating conditions are no longer necessary, but careful observations would be resumed.
- F. Any manatee sighting should be immediately reported to the Fish and Wildlife Service's (Service) Lafayette, Louisiana, Field Office (337-291-3100) and the Louisiana Department of Wildlife and Fisheries (LDWF), Natural Heritage Program (225-765-2821).

**APPENDIX B**

**FIGURES**

Figure 1. The proposed action would be located at the southern end of the Chandeleur Islands barrier island system in Plaquemines Parishes, Louisiana.

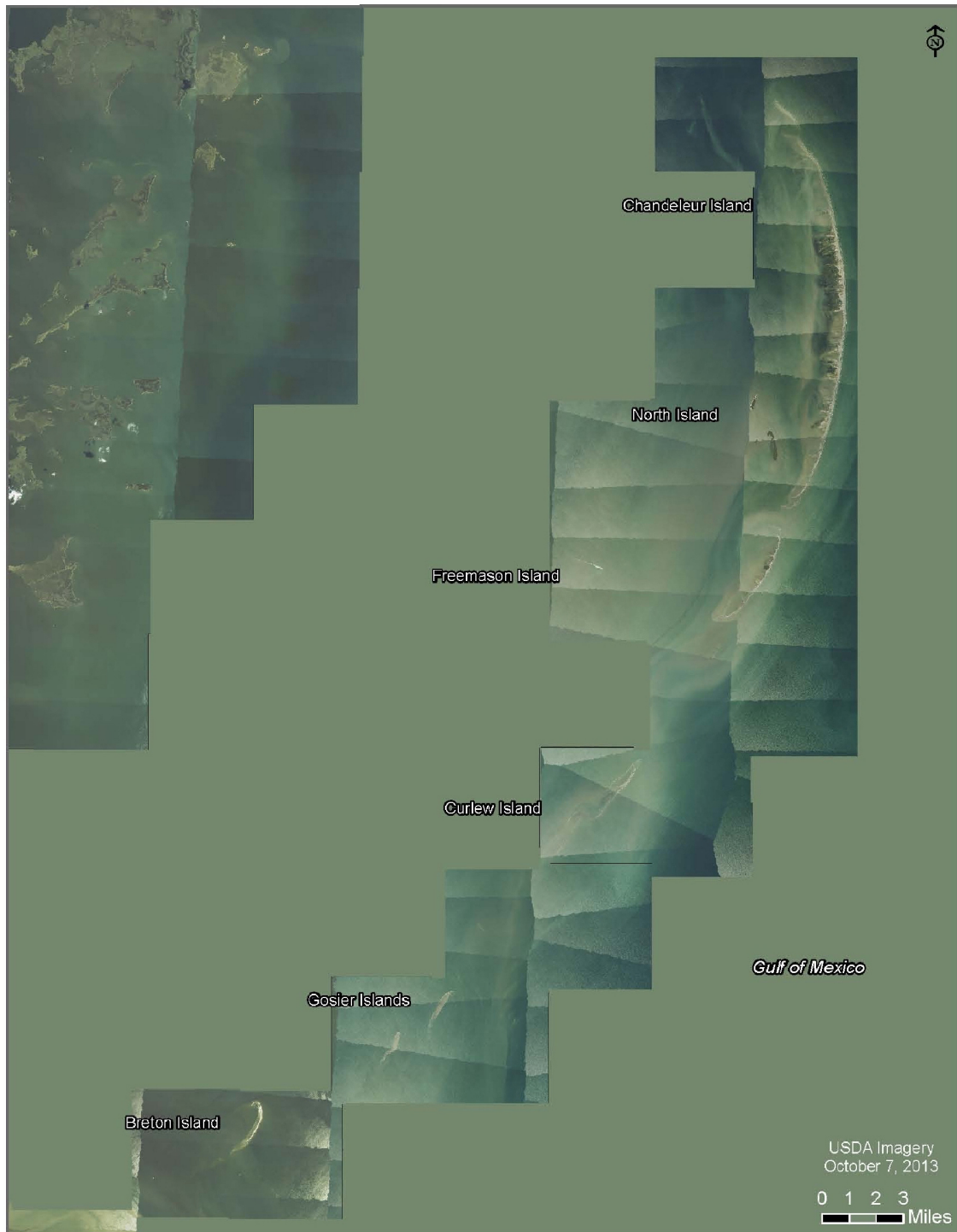


Figure 2. The conceptual design for the North Breton Island Restoration Project is based upon the pre-Hurricane Katrina island footprint (DOI 2013).



Figure 3. The approximate location of the offshore shoal that is the target borrow area for the North Breton Island Restoration project.

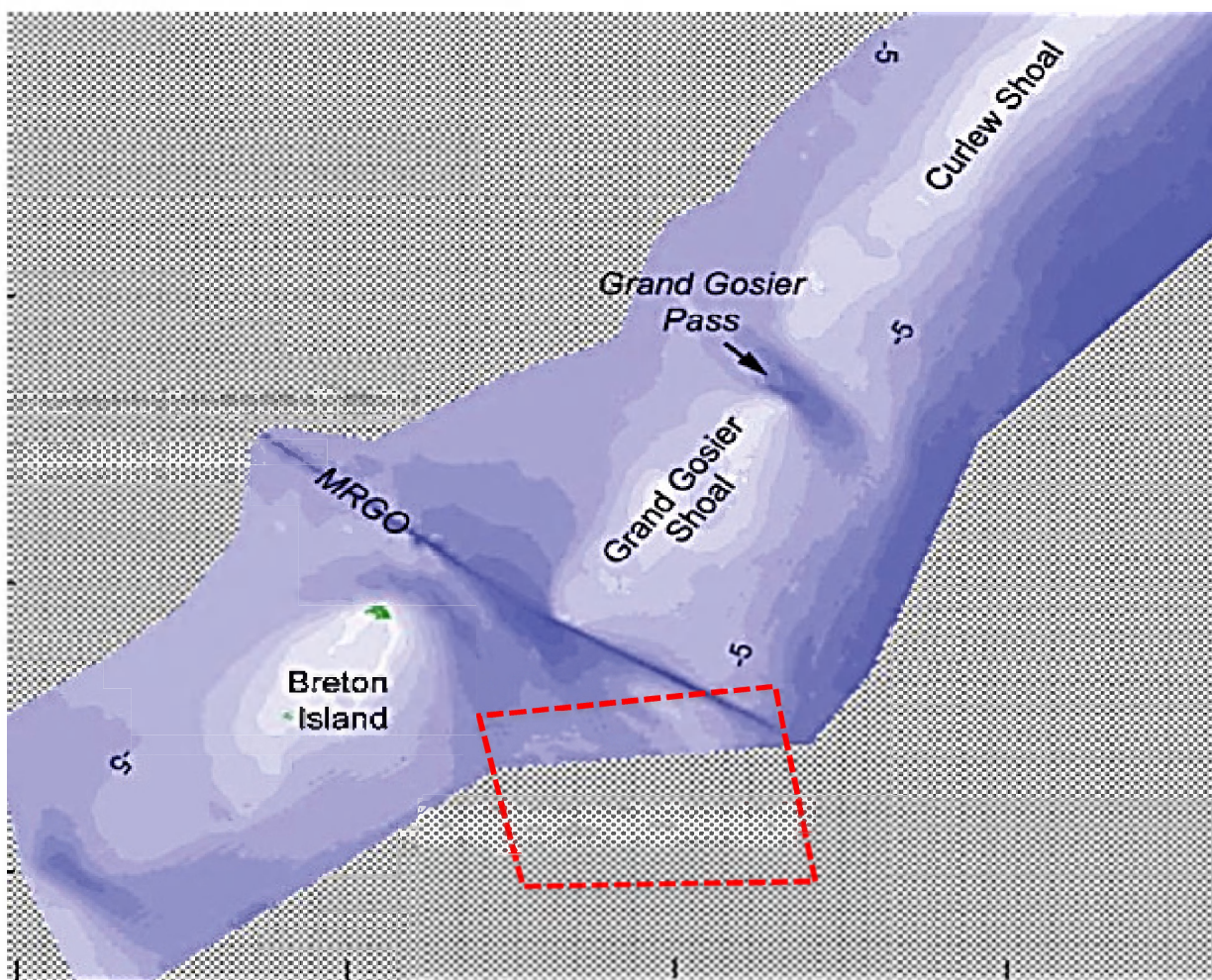
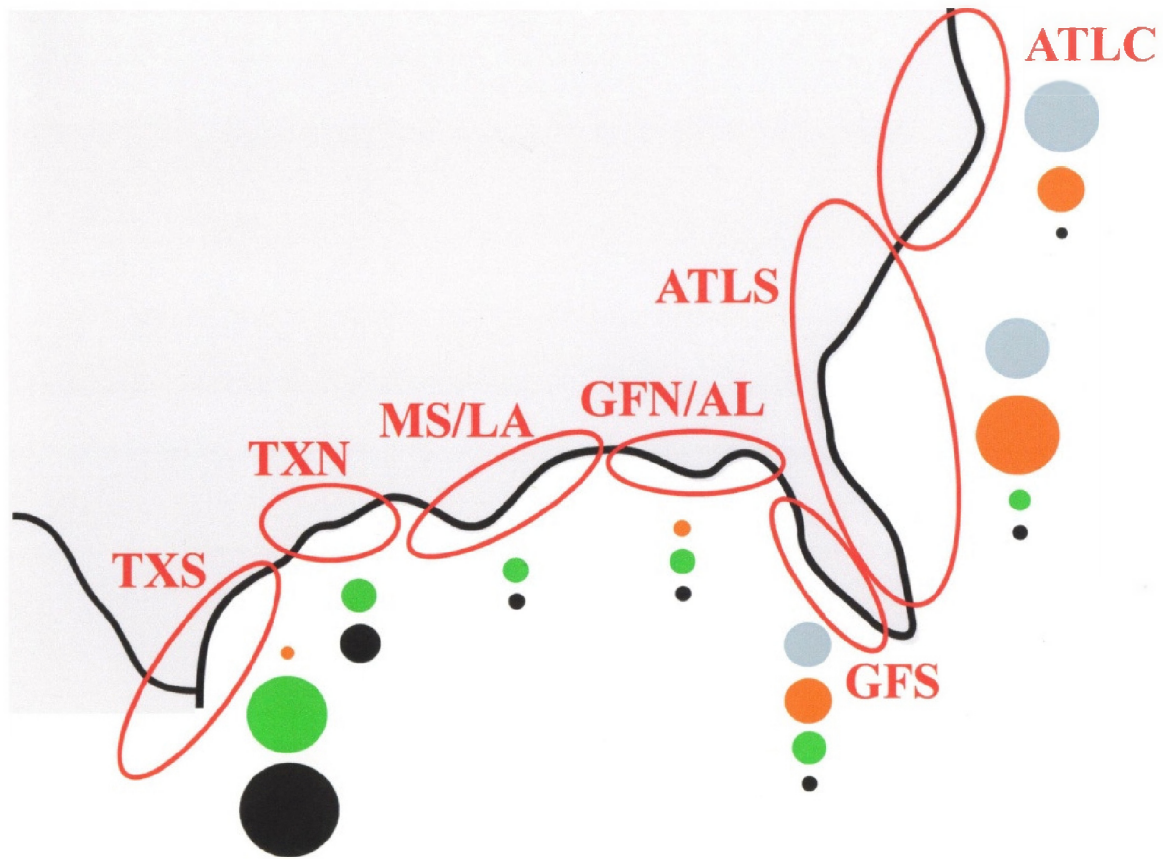


Figure 4. Breeding population distribution\* in the wintering/migration range (from Gratto-Trevor et al. 2009, reproduced by permission).



\*Regions: ATLC=Atlantic (eastern) Canada; ATLS=Atlantic U.S.; GFS=Gulf Coast of southern Florida; GFN=Gulf Coast of north Florida; AL=Alabama; MS/LA=Mississippi and Louisiana; TXN=northern Texas; and TXS=southern Texas. For each breeding population, circles represent the percentage of individuals reported wintering along the eastern coast of the U.S. from the central Atlantic to southern Texas/Mexico up to December 2008. Each individual was counted only once. Grey circles represent Eastern Canada birds, orange circles for U.S. Great Lakes, green circles for the U.S. Great Plains, and black circles for Prairie Canada. The relative size of the circle represents the percentage from a specific breeding area seen in that winter region. Total number of individuals observed on the wintering grounds was 46 for Eastern Canada, 150 for the U.S. Great Lakes, 169 for the U.S. Great Plains, and 356 for Prairie Canada.

Figure 5. The known wintering range of rufa red knot (78 FR Number 189).

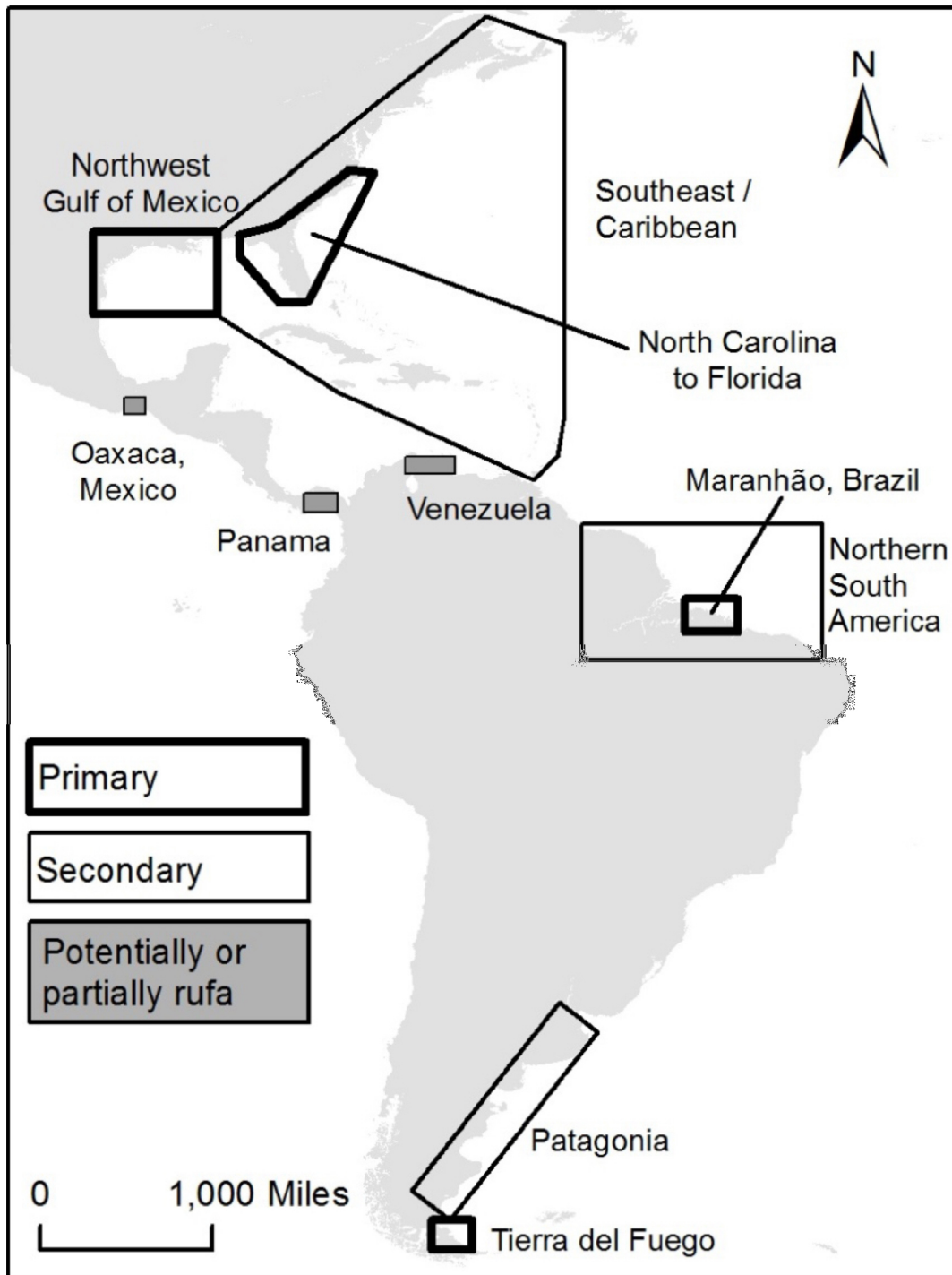




Figure 6. The known stopover areas along the rufa red knot's migration route (Service 2013).



## **APPENDIX C**

### **Non-breeding Piping Plover and Red Knot Survey Guidelines**



## Louisiana Piping Plover and Red Knot Non-Breeding Season Survey Guidelines

The purpose of these guidelines is to assess and/or monitor piping plover and red knot use of coastal restoration features related to the North Breton Island Restoration Project. Survey locations should include the project footprint plus existing adjacent suitable shorebird habitat (i.e., intertidal beaches, mud flats, sand flats, algal flats, wash-over passes, and associated dunes and flats above annual high tide). Monitoring should be conducted July 15 through May 15 to follow the International Shorebird Survey (ISS) census dates listed below. The ISS schedule usually results in three surveys per month. If this is not feasible, try to do at least two surveys per month on the ISS census dates. Surveys should be conducted on ISS dates plus or minus two days. For example, a survey scheduled for the 15<sup>th</sup> could be conducted on any day between the 13<sup>th</sup> through the 17<sup>th</sup> of that month.

### Spring Migration

February 25  
March 5  
March 25  
April 5  
April 15  
April 25  
May 5  
May 15

### Fall Migration

July 15  
July 25  
August 5  
August 15  
August 25  
September 5  
September 15  
September 25  
October 5

### Winter

October 15  
October 25  
November 5  
November 15  
November 25  
December 5  
December 15  
December 25  
January 5  
January 15  
January 25  
February 5  
February 15

To the extent possible, surveys should be conducted when birds are foraging. The best time is at low tide, but surveys can also be conducted on a falling or rising tide provided that the foraging areas are not completely covered. During high tide, birds will be roosting. Although piping plovers often roost near foraging areas, the birds will be more difficult to locate. Avoid conducting surveys during poor weather conditions (e.g., high winds, rain).

### Methods

In most cases surveys will be conducted by foot. All terrain vehicles (ATVs) may be used to expedite the transport of observers over long stretches of linear routes ("leapfrogging" teams down a beach in 0.5 to 1 mile increments), but all bird counting will be conducted while walking. **[Driving on vegetated areas shall not be permitted. Any ATV use should be coordinated with the Breton National Wildlife Refuge management staff.]** Birds on exposed mudflats that may be inaccessible by foot should be counted from boats. Each survey crew should use their best professional judgment on the most efficient way to conduct the survey and should document in detail if any deviations to these guidelines are deemed necessary.

Observers should work in teams of two to four people, depending on the width of the beach and beach/tidal interface. Wide coastal beaches will require a greater number of observers in order to assure that birds are not missed on the back (aft) side of the dune. Observers working on beaches that contain moderate to high dunes should climb them every 0.5 to 1 mile and look for wash-over flats and pools that may not be visible from the beach. Coastal islands will be surveyed on both the Gulf and bay sides (this may require multiple teams of observers in order to finish the surveys in a timely manner).

Piping plover and red knot locations will be recorded with global positioning system (GPS) units. GPS locations will be recorded in universal transverse mercator (UTM) map datum NAD 83 CONUS. Each survey team should carry aerial photography of the survey route so that new breaks (cuts) in the beach or island can be noted on the survey maps. Habitat data will also be collected and will include foraging substrate, portion of the beach used and side of the island on which the birds are found (see attached data sheet). These habitat criteria have been adapted from the 2006 International Winter Piping Plover Census organized by the U.S. Geological Survey. Behavioral data (e.g., foraging, roosting, preening, bathing, flying, aggression, walking) of piping plovers and red knots when seen should also be documented.

Negative data is as important as positive data. Indicate when surveys have been done and no birds were observed. Although piping plovers and red knots are the target species, any additional observations of other species would help the Fish and Wildlife Service to identify shorebird concentration areas and management needs.

**Louisiana Piping Plover and Red Knot Survey Form**

(Note: Most criteria adopted from the 2006 Wintering Piping Plover Census Form)

A. Total # Piping Plovers Observed: \_\_\_\_\_

Total # Red Knots Observed: \_\_\_\_\_

B. Location Description (Name): \_\_\_\_\_

1. Parish: \_\_\_\_\_

2. UTM location NAD 83 CONUS (center):

    Northing \_\_\_\_\_ Easting \_\_\_\_\_

3. Land Ownership:

    \_\_\_Federal \_\_\_State \_\_\_Municipal \_\_\_Private \_\_\_County \_\_\_Tribal

C. Date of survey: \_\_\_\_\_ Time survey conducted: \_\_\_\_\_ to \_\_\_\_\_

D. Weather Conditions:

1. Tide stage(s): \_\_\_Low \_\_\_Mid \_\_\_High (\_\_\_Rising / \_\_\_Falling)

2. General weather: \_\_\_Sunny \_\_\_Partly cloudy \_\_\_Overcast \_\_\_Rain \_\_\_Fog  
    \_\_\_Other (describe): \_\_\_\_\_

3. Approximate temperature: \_\_\_\_\_ Celsius / Fahrenheit (circle one)

4. Wind speed: \_\_\_\_\_ miles/hr Wind direction: \_\_\_\_\_

E. Description of Habitat Surveyed (check as many as apply). The Code designation will be used in Section F table below:

• **Body of Water Type:**

    \_\_\_I. Ocean \_\_\_II. Protected bay, harbor, cove, lagoon \_\_\_III. Gulf of Mexico  
    \_\_\_IV. Ocean Inlet \_\_\_V. Other (describe) \_\_\_\_\_

• **Shoreline Type:**

    \_\_\_A. Mainland \_\_\_B. Barrier Island \_\_\_C. Spoil Island \_\_\_D. Bar  
    \_\_\_E. Other Island \_\_\_F. Over-wash area \_\_\_G. Other  
    (describe) \_\_\_\_\_

• **Specific Description:**

    \_\_\_1. Sand beach \_\_\_2. Sand spit \_\_\_3. Sand flat \_\_\_4. Sand bar  
    \_\_\_5. Salt flat \_\_\_6. Gravel shore \_\_\_7. Oyster reef \_\_\_8. Mudflat  
    \_\_\_9. Vegetation (algal) mat \_\_\_10. Vegetated shoreline  
    \_\_\_11. Other (describe) \_\_\_\_\_

• **Location Description** (criteria for islands only):

    \_\_\_i. Gulf-side of island \_\_\_ii. Bay-side of island  
    \_\_\_a. Tidal interface \_\_\_b. Fore dune \_\_\_c. Top of dune \_\_\_d. Aft dune



K. Additional species encountered (for flying flocks lump as peeps and estimate number).  
 Species of special interest are listed below; please add any additional species.

<b>OTHER SPECIES</b>	<b>TOTAL#</b>	<b>OTHER SPECIES</b>	<b>TOTAL#</b>
Reddish Egret			
Marbled Godwit			
Western Sandpiper			
Stilt Sandpiper			
Short-billed Dowitcher			
Snowy Plover			
Wilson's Plover			
Long-billed Curlew			
American Oystercatcher			

**APPENDIX D**

**Louisiana Guidelines for Minimizing Disturbance to Colonial Nesting Birds**





## **Louisiana Guidelines for Minimizing Disturbance to Colonial Nesting Birds**

Nesting colonies may be present that are not currently listed in the database maintained by the Louisiana Department of Wildlife and Fisheries (LDWF). That database is updated primarily by monitoring the colony sites that were previously surveyed during the 1980s. Until a new, comprehensive coast-wide survey is conducted to determine the location of newly-established nesting colonies, we recommend that a qualified biologist inspect the proposed work site for the presence of undocumented nesting colonies during the nesting season. In addition, we recommend that on-site contract personnel be informed of the need to identify colonial nesting birds and their nests, and should avoid affecting them during the breeding season.

To minimize disturbance to colonial nesting birds, the following restrictions on activity should be observed:

1. For colonies containing nesting brown pelicans, all activity occurring within 2,000 feet of a rookery should be restricted to the non-nesting period (i.e., September 15 through March 31). Nesting periods vary considerably among Louisiana's brown pelican colonies, however, so it is possible that this activity window could be altered based upon the dynamics of the individual colony. The Louisiana Department of Wildlife and Fisheries' Fur and Refuge Division should be contacted to obtain the most current information about the nesting chronology of individual brown pelican colonies. Brown pelicans are known to nest on barrier islands and other coastal islands in St. Bernard, Plaquemines, Jefferson, Lafourche, and Terrebonne Parishes, and on Rabbit Island in lower Calcasieu Lake, in Cameron Parish.
2. For colonies containing nesting wading birds (i.e., herons, egrets, night-herons, ibis, and roseate spoonbills), anhingas, and/or cormorants, all activity occurring within 1,000 feet of a rookery should be restricted to the non-nesting period (i.e., September 1 through February 15, exact dates may vary within this window depending on species present).
3. For colonies containing nesting gulls, terns, and/or black skimmers, all activity occurring within 650 feet of a rookery should be restricted to the non-nesting period (i.e., September 16 through April 1, exact dates may vary within this window depending on species present).

Below is a table explaining the nesting chronology of species that are known to nest in Louisiana. The table is an excerpt from page 31 of:

Martin, R.P., and G.D. Lester. 1990. The Atlas and Census of Wading Bird and Seabird Nesting Colonies of Louisiana: 1990. Louisiana Department of Wildlife and Fisheries – Louisiana Natural Heritage Program. Special Publication No. 3 for the U.S. Department of Interior – Fish and Wildlife Service. Contract No. 14-16-0004-89-963.



Table 8. Nesting chronology for colonial-nesting waterbirds in Louisiana with suggested activity windows.<sup>a</sup>

Species	Incubation Season	Incubation Period (days)	Days to Fledging	Activity <sup>b</sup> Window
Brown Pelican	1 Nov to 15 Jun	28-30	74-76	1 Aug to 31 Oct
Olivaceous Cormorant	15 Mar to 15 Apr	23-26	35-42	1 Jul to 1 Mar
American Anhinga	15 Mar to 15 Apr	25-28	?	1 Jul to 1 Mar
Great Blue Heron	1 Mar to 30 Apr	25-29	58-62	1 Aug to 15 Feb
Great Egret	1 Mar to 31 May	23-24	40-44	1 Aug to 15 Feb
Snowy Egret	16 Mar to 15 Jun	17-19	20-25	1 Aug to 1 Mar
Little Blue Heron	16 Mar to 15 Jun	22-24	28-32	1 Aug to 1 Mar
Tricolored Heron	16 Mar to 15 Jun	20-22	?	1 Aug to 1 Mar
Reddish Egret	16 Mar to 15 Jun	23-26	?	1 Aug to 1 Mar
Cattle Egret	16 Apr to 30 Jun	21-24	35-40	1 Sep to 1 Apr
Green-backed Heron	1 Apr to 30 Jun	19-21	16-17	1 Sep to 15 Mar
Black-crowned Night-Heron	16 Mar to 15 Jun	24-26	40-42	1 Sep to 1 Mar
Yellow-crowned Night-Heron	1 Apr to 15 Jun	?	?	1 Sep to 15 Mar
White Ibis	16 Apr to 30 Jun	21-23	35-42	1 Sep to 1 Apr
Glossy/White-faced Ibis	16 Apr to 30 Jun	21-23	42-49	1 Sep to 1 Apr
Roseate Spoonbill	16 Apr to 15 Jun	23-24	49-56	1 Aug to 1 Apr
Laughing Gull	16 Apr to 15 Jun	23-25	35-45	1 Aug to 1 Apr
Gull-billed Tern	16 May to 15 Jul	22-23	28-35	16 Sep to 1 May
Caspian Tern	1 May to 15 Jul	26-28	36-48	16 Sep to 15 Apr
Royal Tern	1 May to 15 Jul	28-31	36-48	16 Sep to 15 Apr
Sandwich Tern	1 May to 15 Jul	23-25	22-33	16 Sep to 15 Apr
Common Tern	1 May to 15 Jul	21-25	23-27	16 Sep to 15 Apr
Forster's Tern	1 Apr to 31 May	25-29	23-27	1 Aug to 15 Mar
Least Tern	1 May to 15 Jul	20-25	19-23	16 Sep to 15 Apr
Sooty Tern	16 May to 15 Jul	22-23	30-35	16 Sep to 15 Apr
Black Skimmer	16 May to 15 Jul	22-23	30-35	16 Sep to 1 May

<sup>a</sup> Data are compiled from Bent (1921), Bent (1926), Palmer (1962), Harrison (1975), Portnoy (1977) and Terres (1980).

<sup>b</sup> Suggested project initiation and completion dates to minimize disturbance to nesting birds.

The Fish and Wildlife Service realizes that the proposed barrier island restoration work most likely would be constructed during one or more colonial waterbird nesting seasons because construction would likely extend over 1 or more years. In order to minimize disturbance to nesting pelicans, gulls, terns, and/or black skimmers, the Service would like to coordinate with the DOI to develop a migratory bird abatement plan. Please contact Ms. Patti Holland (337-291-3121) of the Louisiana Ecological Services Office for further information and coordination associated with the development of a migratory bird abatement plan.