APPENDIX E

USFWS Biological Opinion

Wrightsville Beach Coastal Storm Risk Management Emergency Repair – Evaluation of Borrow Area Alternatives

New Hanover County, North Carolina

JANUARY 2023

Prepared by:

Environmental Resources Section
U.S. Army Corps of Engineers, Wilmington District

Biological Opinion

U.S. Army Corps of Engineers

Wrightsville Beach Coastal Storm Risk Management Emergency Repairs Using Offshore Borrow Area

New Hanover County, North Carolina

USFWS Project Number # 2022-0077818

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January 5, 2023

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CONSULTATION HISTORY

The U.S. Fish and Wildlife Service (Service) has been in coordination with the U.S. Army Corps of Engineers (Corps) on the Wrightsville Beach Coastal Storm Risk Management (CSRM) project for at least five decades. This section lists key events and correspondence during the course of this current consultation. A complete administrative record of this consultation and previous coordination/consultations is on file in the Raleigh Ecological Service's Field Office.

Multiple Dates throughout 2021 – The Service participated in multiple Project Delivery Team meetings for development of the future 50-year plan for the Wrightsville Beach CSRM project. During those meetings, the Corps indicated that it was investigating the use of one or more offshore borrow areas for future sand placement projects, including emergency repairs.

05/24/2022 – The Service participated in a virtual meeting with the Corps, other agencies, and multiple stakeholders to discuss the concerns for derelict tires in one or more of the offshore borrow areas, identified for use during the emergency repair project.

Multiple dates in July and August 2022 – In virtual meetings, and by phone and email, the Service discussed with the Corps and Bureau of Ocean Energy Management (BOEM) various aspects of project coordination and potential issues with tires in the offshore borrow areas for the project.

08/18/2022 – The Corps requested initiation of formal consultation and provided a biological assessment (BA) and supporting information. Formal consultation was initiated by letter on September 7, 2022.

09/21/2022 – The Service provided a draft Incidental Take Statement (ITS) to the Corps for review. The Service also provided the draft ITS to BOEM on September 28, 2022 for its review.

09/28/2022 – By phone, the Corps responded to the Service with input on the draft ITS. BOEM responded by email with input on the draft ITS on September 29, 2022.

12/09/2022- The Service and Corps discussed the draft BO and revised the project description to reflect the Corps' intent to complete work during the winter work window (November 15-April 30).

BIOLOGICAL OPINION

1. INTRODUCTION

A biological opinion (BO) is the document that states the findings of the U.S. Fish and Wildlife Service (Service) required under section 7 of the Endangered Species Act of 1973, as amended (ESA), as to whether a Federal action is likely to:

- jeopardize the continued existence of species listed as endangered or threatened; or
- result in the destruction or adverse modification of designated critical habitat.

The Federal action addressed in this BO is the U.S. Army Corps of Engineers' (Corps) proposed emergency repairs under the Wrightsville Beach Coastal Storm Risk Management (CSRM) Project, including the use of an offshore borrow area (the Action). This BO considers the effects of the Action on piping plover, red knot, seabeach amaranth, and the loggerhead, leatherback, green, hawksbill, and Kemp's ridley sea turtles. The Action does not affect designated critical habitat; therefore, this BO does not address critical habitat.

By letter dated September 7, 2022, the Service previously concurred with the Corps' determination that the Action is not likely to adversely affect the West Indian manatee. This concurrence fulfilled the Corps' responsibilities for the Action under §7(a)(2) of the ESA for these species. We do not address further these species in this BO.

BO Analytical Framework

A BO that concludes a proposed Federal action is *not* likely to *jeopardize the continued existence* of listed species and is *not* likely to result in the *destruction or adverse modification* of critical habitat fulfills the Federal agency's responsibilities under §7(a)(2) of the ESA.

> *"Jeopardize the continued existence* means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 CFR §402.02).
>
> "*Destruction or adverse modification* means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species" (50 CFR §402.02).

The Service determines in a BO whether we expect an action to satisfy these definitions using the best available relevant data in the following analytical framework (see 50 CFR §402.02 for the regulatory definitions of *action, action area, environmental baseline, effects of the action*, and *cumulative effects*).

a. *Proposed Action*. Review the proposed Federal action and describe the environmental changes its implementation would cause, which defines the action area.
b. *Status*. Review and describe the current range-wide status of the species or critical habitat.
c. *Environmental Baseline*. Describe the condition of the species or critical habitat in the action area, without the consequences to the listed species caused by the proposed action. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all

proposed Federal projects in the action area that have already undergone formal or early consultation, and the impacts of State or private actions which are contemporaneous with the consultation.

d. *Effects of the Action*. Predict all consequences to species or critical habitat caused by the proposed action, including the consequences of other activities caused by the proposed action, which are reasonably certain to occur. Activities caused by the proposed action would not occur but for the proposed action. Effects of the action may occur later in time and may include consequences that occur outside the action area.
e. *Cumulative Effects*. Predict all consequences to listed species or critical habitat caused by future non-Federal activities that are reasonably certain to occur within the action area.
f. *Conclusion*. Add the effects of the action and cumulative effects to the environmental baseline, and in light of the status of the species, formulate the Service's opinion as to whether the action is likely to jeopardize species or adversely modify critical habitat.

2. PROPOSED ACTION

2.1. Sand Placement

The proposed action includes emergency repair (sand placement) consistent with the currently authorized CSRM project using borrow sources offshore of Wrightsville Beach. The existing CSRM project consists of a dune with a base generally bordering at or near the building line together with an integral shoreline berm for a total distance of 15,650 feet, which includes a 2,000-foot northern transition. The Wrightsville Beach CSRM project is authorized by the Flood Control Act of 1962, Water Resources Development Act (WRDA) of 1986, and WRDA of 2020. The 2020 Wrightsville Beach Validation report was authorized to allow an increase in the total maximum/Section 902 project cost limit, so Federal participation in periodic renourishment could continue through FY 2036. Emergency restoration is authorized by Public Law 84-99, Emergency Response to Natural Disasters. The next CSRM periodic renourishment was planned for FY 2022, but the search for a new borrow area has delayed the planned periodic renourishment to FY 2023. In 2019, Hurricane Dorian caused significant sand loss to Wrightsville Beach, ultimately resulting in changing the immediate scope of this sand placement event to an emergency repair.

The Corps is the lead federal agency. Pursuant to 40 CFR 1501, the Bureau of Ocean Energy Management (BOEM) is serving as a cooperating agency as the project proposes to utilize a series of potential borrow areas in federal waters adjacent to the project site. BOEM will also serve as a cooperating agency for consultation requirements related to ESA Section 7 (50 CFR 402).

The authorized plan for the Wrightsville Beach CSRM consists of a dune having a crown width of 25 feet at 12.5 feet NAVD88, together with a beach berm, having a crown width of 50 feet at 9.5 feet NAVD88, and a construction berm, having a crown width of 205 feet at 5.0 feet NAVD88. The dune and berms extend north 13,650 linear feet (lf) from Masonboro Inlet North Jetty. The FY23 renourishment extends from Station 70+00 to 140+00 with a 2,000-foot transition to station 160+00, with a maximum of 15,560 lf of sand placement.

The emergency repairs will be completed with one placement and will require an estimated 780,000 cubic yards of material. The Corps intends to complete sand placement within the winter work window (November 15 to April 30).

Placement of beach quality sand is accomplished by pumping a mixture of beach quality sand and water through a pipeline leading to the recipient beach. The placement operations typically employ a spreader that is attached to the discharge end of the pipeline. Temporary shore-parallel containment dikes are constructed in front of the onshore beach discharge points to facilitate sediment settling and to reduce turbidity in the nearshore environment. As placement activities progress, the onshore pipeline is extended along the beach by adding new sections of pipe. Pipeline placement is typically on the upper beach, but seaward of the dunes and any upper beach vegetation. Booster pumps may be required along the pipelines as they are extended along the beach. The location where the pipeline emerges onto the subaerial beach may also shift incrementally as renourishment progresses along the beach. Throughout the renourishment process, front-end loaders or other heavy equipment are used to transport and position the onshore pipeline sections.

Renourishment of Wrightsville Beach may be accomplished by a hopper dredge with a hopper pump-out station with direct placement on the beach or by a hydraulic cutterhead dredge with direct placement on the beach. The hopper dredge would pump the material out of the hopper into a pumpout location approximately 2,500 to 3,000 ft. offshore and a submerged pipeline would approach the beach at a given area and extend to the placement area.

Subsurface investigations using a combination of boring data and geophysical surveys were used to identify and define borrow areas for the Wrightsville Beach CSRM project. Based on these investigations, two borrow areas were identified (Borrow Areas C and D) located between approximately 2-4 miles offshore of Wrightsville Beach.

Analysis of the side scan sonar data for Borrow Areas C and D identified thousands of tires in the area surveyed. Based on historical research, approximately 650,000 un-ballasted tires and other materials were deployed by the North Carolina Division of Marine Fisheries in the 1970s and 1980s to create a system of artificial reefs in North Carolina’s ocean waters. The reef in closest proximity to the borrow source is known as AR-370 and is located to the northwest of the borrow site. In addition to tires, AR-370 also contains materials such as concrete pipe sections and sunken vessels / barges. It is speculated, over several decades, the steel cable, nylon rope, and polypropylene rope that bound tires together have deteriorated and failed. Storms and natural currents have swept these tires and binding materials well outside of the AR-370 vicinity and have redistributed orphaned tires over much of the borrow site. Concentrations of tires and magnetic anomalies associated with the reef render much of the borrow site unusable; however, the Corps has identified suitable areas of the borrow site for renourishment that will minimize encounters with debris and provide adequate beach quality material to complete the emergency repairs (**Figure 2-1**). The Corps intends to use portions of the borrow site that appear to have no tires on the surface and minimal subsurface magnetic anomalies.

The Corps offers the following Conservation Measures for sand placement:

1. The Corps proposes to buffer magnetic anomalies by approximately 100 feet to minimize risk of transport to the beach, as well as damage to the dredge.
2. Regardless of the type of dredge plant used for the project, if the contractor encounters a pocket of material that contains tires/debris, they will stop dredging in that area and move. Mechanical raking of the beachfill area during/after beachfill placement (i.e., Using a front-end loader, bobcat type, or similar mechanical equipment outfitted with a specialized bucket containing a rake and screen with screen opening size no larger than 2"X2") will be a contractual option that will be exercised if needed.
3. Depending on the dredge plant employed, the Corps will implement several measures to avoid and minimize the placement of tires or other borrow area debris on the beach:

   Hopper Dredge. Any work done with a hopper dredge would incorporate screens, as described below, at three different locations to prevent the placement of tires or pieces of tires and borrow area debris on the beach.

   a. A screen (4 inch (in) by 4 in) attached to the underside of the draghead. A screen at this location will substantially reduce the number of tires and debris sucked up by the dredge.
   b. A screen (4 in by 4 in) installed on the hopper inflow boxes. Screens on the inflow boxes will capture debris that surpassed the screen on the draghead, further reducing debris in the dredged material. Debris collected inside the inflow boxes will be collected and disposed of properly in an approved landfill or recycling center.
   c. A screen (2 in by 2 in or smaller as feasible) at the end of the discharge pipe on the beach. The smallest screen sized opening will be attached to the end of the discharge pipe on the beach to capture tire pieces or debris that made it past the first two screens. Debris collected inside the inflow boxes will be collected and disposed of properly in an approved landfill or recycling center.

   Visual observers would be stationed at the inflow box and on the beach to quickly identify and remove unacceptable material. All debris will be discarded in an on-site dumpster (on the dredge and on the beach) and disposed of at an approved off-site disposal facility. Additionally, the Corps will frequently inspect operations on the beach to monitor the quality of material being transported to the beach and take action as necessary to address any concerns with the quality of material being placed.

   Hydraulic Cutterhead Dredge. Any work done with a pipeline dredge will incorporate screens at two locations to prevent the placement of tires or pieces of tires and borrow area debris on the beach.

   a. A screen (4 in by 4 in) attached in front of the cutterhead suction. This will substantially reduce the number of tires/debris sucked up by the dredge.
   b. A screen (2 in by 2 in or smaller as feasible) at the end of the discharge pipe on the beach to capture tire pieces or debris that made it past the first screens. Debris collected inside screen box will be collected and disposed of properly in an approved landfill or recycling center.

Contractor Observers will be stationed at the beachfill area and will discard all debris as described above. The Corps will also frequently inspect operations on the beach to monitor the quality of material being transported to the beach and take action as necessary to address any concerns with the quality of material being placed.

4. Post- renourishment tilling and/or escarpment leveling may be conducted as needed based on North Carolina Wildlife Resources Commission (NCWRC) recommendations. Tilling and leveling are accomplished by heavy equipment similar to that employed in redistribution and grading operations. Compacted beach fill areas between the toe of the dune and the mean high water (MHW) line are typically tilled to a depth of 24 inches using a series of overlapping passes to ensure thorough decompaction. Chain-linked fencing or a similar apparatus may be dragged over the tilled areas as necessary to eliminate any ruts and furrows created by the tilling process. Escarpments are regraded according to the original berm design specifications.
5. Staging areas for equipment and pipes are generally located off the beach to the extent practicable. When necessary, staging areas on the beach are generally positioned as far landward as possible without impacting established vegetation on the upper beach or the frontal dune system. Beach access for construction equipment is typically provided by existing public beach access points.
6. For projects where lighting is a concern for sensitive organisms, ample lighting can be obtained without impacting a large area by using light shields and appropriate angling of lights. In addition to lighting in the renourishment area, the vehicles used for transport, as well as the bulldozers moving sediment will have lights on the front and back of the equipment.

2.2. Other Activities Caused by the Action

A BO evaluates all consequences to species or critical habitat caused by the proposed Federal action, including the consequences of other activities caused by the proposed action, that are reasonably certain to occur (see definition of "effects of the action" at 50 CFR §402.02). Additional regulations at 50 CFR §402.17(a) identify factors to consider when determining whether activities caused by the proposed action (but not part of the proposed action) are reasonably certain to occur. These factors include, but are not limited to:

(1) past experiences with activities that have resulted from actions that are similar in scope, nature, and magnitude to the proposed action;
(2) existing plans for the activity; and
(3) any remaining economic, administrative, and legal requirements necessary for the activity to go forward.

In its request for consultation, the Corps did not describe any other activities caused by the proposed action that are reasonably certain to occur.

2.3. Action Area

The action area is defined as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action" (50 CFR §402.02). Delineating the action area is necessary for the Federal action agency to obtain a list of species and critical habitats that may occur in that area, which necessarily precedes any subsequent analyses of the effects of the action to particular species or critical habitats.

It is practical to treat the action area for a proposed Federal action as the spatial extent of its direct and indirect "modifications to the land, water, or air" (a key phrase from the definition of "action" at 50 CFR §402.02). Indirect modifications include those caused by other activities that would not occur but for the action under consultation. The action area determines any overlap with critical habitat and the physical and biological features therein that we defined as essential to the species' conservation in the designation final rule. For species, the action area establishes the bounds for an analysis of individuals' exposure to action-caused changes, but the subsequent consequences of such exposure to those individuals are not necessarily limited to the action area.

The project is located on the oceanfront shorelines of Wrightsville Beach, New Hanover County, North Carolina, and in State and Federal waters in the Atlantic Ocean.

Figure 2-2 shows the locations of all activities that the proposed Action would cause and the spatial extent of reasonably certain changes to land, water, or air caused by these activities, based on the descriptions and analyses of these activities in **section 2.1**. The Action Area for this BO includes the portion of Atlantic Ocean shoreline along Wrightsville Beach, North Carolina and the offshore borrow areas in the Atlantic Ocean.

2.4. Figures

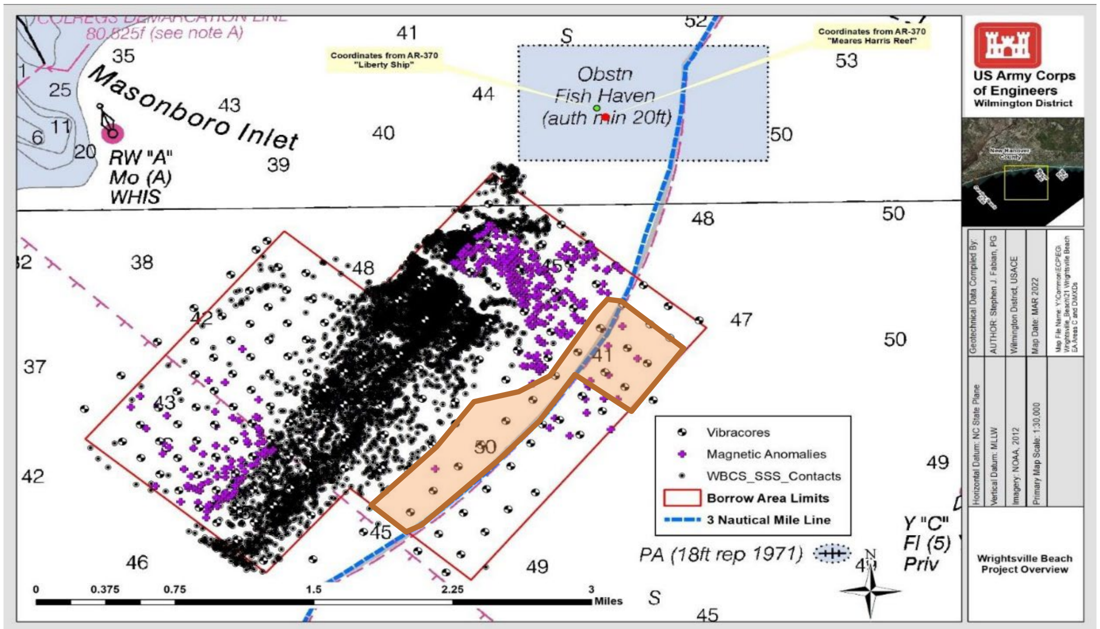

Figure 2-1. Borrow Areas C and D, showing Side Scan and Magnetometer Data and the area to be dredged for the emergency repair project. From the August 2022 Draft BA.

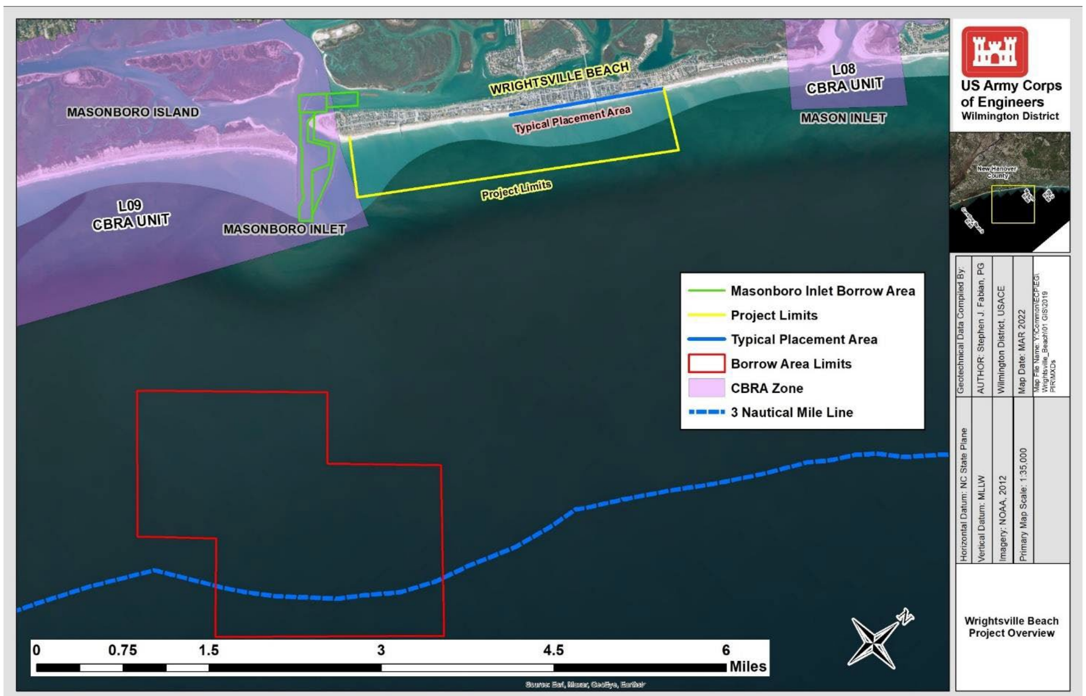

Figure 2-2. Action Area for the Emergency Repair (Post-Dorian) associated with the Wrightsville Beach CSRM Project. From the August 2022 Draft BA.

3. SOURCES OF CUMULATIVE EFFECTS

A BO must predict the consequences to species caused by future non-Federal activities within the action area, *i.e.,* cumulative effects. "Cumulative effects are those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation" (50 CFR §402.02). Additional regulations at 50 CFR §402.17(a) identify factors to consider when determining whether activities are reasonably certain to occur. These factors include but are not limited to existing plans for the activity; and any remaining economic, administrative, and legal requirements necessary for the activity to go forward.

In its request for consultation, the Corps did not describe, and the Service is not aware of, any future non-Federal activities that are reasonably certain to occur within the Action Area. Therefore, we anticipate no cumulative effects that we must consider in formulating our opinion for the Action.

4. LOGGERHEAD, GREEN, LEATHERBACK, HAWKSBILL, AND KEMP'S RIDLEY SEA TURTLES

This section provides the Service's biological opinion of the Action for the leatherback sea turtle (*Dermochelys coriacea*), Kemp's ridley sea turtle (*Lepidochelys kempii*), hawksbill sea turtle (*Eretmochelys imbricata*) the North Atlantic Ocean Distinct Population Segment (DPS) of the green sea turtle (*Chelonia mydas*), and the Northwest Atlantic (NWA) Ocean DPS of the loggerhead sea turtle (*Caretta caretta*). This section summarizes best available data about the biology and current condition of these four species throughout the ranges that are relevant to formulating an opinion about the Action.

4.1. Status of Sea Turtle Species

The Service and National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) share Federal jurisdiction for sea turtles under the ESA. The Service has responsibility for sea turtles on the nesting beach. NMFS has jurisdiction for sea turtles in the marine environment. In accordance with the ESA, the Service completes consultations with all Federal agencies for actions that may adversely affect sea turtles on the nesting beach. The Service's analysis only addresses activities that may impact nesting sea turtles, their nests and eggs, and hatchlings as they emerge from the nest and crawl to the sea. NMFS assesses and consults with Federal agencies concerning potential impacts to sea turtles in the marine environment, including updrift and downdrift nearshore areas affected by sand placement projects on the beach. This BO addresses nesting sea turtles, their nests and eggs, and hatchlings as they emerge from the nest and crawl to the sea.

4.1.1. Description of Sea Turtle Species

4.1.1.1. **Description - Loggerhead Sea Turtle**

The loggerhead sea turtle, which occurs throughout the temperate and tropical regions of the Atlantic, Pacific, and Indian Oceans, was federally listed worldwide as a threatened species on July 28, 1978 (43 Federal Register (FR) 32800). On September 22, 2011, the loggerhead sea turtle's listing under the ESA was revised from a single threatened species to nine DPSs listed as either threatened or endangered (79 FR 39755).

Loggerheads were named for their relatively large heads, which support powerful jaws and enable them to feed on hard-shelled prey, such as whelks and conch. The carapace (top shell) is slightly heart-shaped and reddish-brown in adults and sub-adults, while the plastron (bottom shell) is generally a pale yellowish color. The neck and flippers are usually dull brown to reddish brown on top and medium to pale yellow on the sides and bottom. Hatchlings are a dull brown color. Mean straight carapace length of adults in the southeastern U.S. is approximately 36 inches (in), and mean weight is about 250 pounds (lb).

No critical habitat for the NWA Ocean DPS of the loggerhead sea turtle exists with the Action Area.

4.1.1.2. **Description - Green Sea Turtle**

The green sea turtle was federally listed on July 28, 1978 (43 FR 32800). On April 6, 2016, the NMFS and Service issued a final rule to list 11 DPSs of the green sea turtle. Three of the DPSs are endangered species (Central South Pacific, Central West Pacific, and Mediterranean Sea), and eight are threatened species (81 FR 20058). In North Carolina, the green sea turtle is part of the North Atlantic Ocean DPS and is listed as threatened. The green sea turtle has a worldwide distribution in tropical and subtropical waters.

The green sea turtle grows to a maximum size of about 4 feet (ft) and a weight of 440 lb. It has a heart-shaped shell, small head, and single-clawed flippers. The carapace is smooth and colored gray, green, brown, and black. Hatchlings are black on top and white on the bottom (NMFS 2009). Hatchling green turtles eat a variety of plants and animals, but adults feed almost exclusively on seagrasses and marine algae.

Critical habitat for the green sea turtle has been designated for the waters surrounding Culebra Island, Puerto Rico, and its outlying keys. There is no designated critical habitat in North Carolina.

4.1.1.3. **Description - Kemp's Ridley Sea Turtle**

The Kemp's ridley sea turtle was federally listed as endangered on December 2, 1970 (35 FR 18320).

The Kemp's ridley has one of the most geographically restricted distributions of any sea turtle species. The range of the Kemp's ridley includes the Gulf coasts of Mexico and the U.S., and the Atlantic coast of North America as far north as Nova Scotia and Newfoundland.

Adult Kemp's ridleys and olive ridleys are the smallest sea turtles in the world. The weight of an adult Kemp's ridley is generally between 70 to 108 lb with a carapace measuring approximately 24 to 26 in in length (Heppell et al. 2005). The carapace is almost as wide as it is long. The species' coloration changes significantly during development from the grey-black dorsum and plastron of hatchlings, a grey-black dorsum with a yellowish-white plastron as post-pelagic juveniles and then to the lighter grey-olive carapace and cream-white or yellowish plastron of adults. Their diet consists mainly of crabs, but may also include fish, jellyfish, and an array of mollusks.

No critical habitat has been designated for the Kemp's ridley sea turtle.

4.1.1.4. **Description - Leatherback Sea Turtle**

The Service published its decision to list the leatherback sea turtle as endangered on June 2, 1970 (35 FR 8491).

Leatherbacks have the widest distribution of the sea turtles with nonbreeding animals recorded as far north as the British Isles and the Maritime Provinces of Canada and as far south as Argentina and the Cape of Good Hope (Pritchard 1992). They have evolved physiological and anatomical adaptations (Frair et al. 1972; Greer et al. 1973) that allow them to exploit waters far colder than any other sea turtle species would be capable of surviving. The adult leatherback can reach 4 to 8 feet in length and weigh 500 to 2,000 pounds. The carapace is distinguished by a rubber-like texture, about 1.6 inches thick, made primarily of tough, oil-saturated connective tissue. Hatchlings are dorsally mostly black and are covered with tiny scales; the flippers are edged in white, and rows of white scales appear as stripes along the length of the back (NMFS 2009c). Jellyfish are the main staple of its diet, but it is also known to feed on sea urchins, squid, crustaceans, tunicates, fish, blue-green algae, and floating seaweed.

Marine and terrestrial critical habitat for the leatherback sea turtle has been designated at Sandy Point on the western end of the island of St. Croix, U.S. Virgin Islands (44 FR 17710). There is no designated critical habitat in North Carolina.

4.1.1.5. **Description - Hawksbill Sea Turtle**

The hawksbill sea turtle was Federally listed as endangered on June 2, 1970 (35 FR 8491). The hawksbill is found in tropical and subtropical seas of the Atlantic, Pacific, and Indian Oceans. Hawksbills typically weigh around 176 pounds or less. The carapace is heart shaped in young turtles and becomes more elongated or egg-shaped with maturity. The top scutes are often richly patterned with irregularly radiating streaks of brown or black on an amber background. The head is elongated and tapers sharply to a point. The lower jaw is V-shaped (NMFS 2009d).

Within the continental U.S., hawksbill sea turtle nesting is rare, and nests are only known from Florida and North Carolina. Nesting in Florida is restricted to the southeastern coast of Florida (Volusia through Miami-Dade Counties) and the Florida Keys (Monroe County) (Meylan 1992; Meylan et al. 1995). Two nests have been recorded in North Carolina, both in 2015. Both nests, located on the Seashore, were originally thought to be loggerhead nests, but discovered to be hawksbill nests after DNA testing of eggshells. Hawksbill tracks are difficult to differentiate from those of loggerheads and may not be recognized by surveyors. Therefore, surveys in Florida and elsewhere in the southeastern U.S. may underestimate actual hawksbill nesting numbers (Meylan et al. 1995). In the U.S. Caribbean, hawksbill nesting occurs on beaches throughout Puerto Rico and the U.S. Virgin Islands (NMFS and USFWS 1993).

Critical Habitat for the hawksbill sea turtle was designated on June 24, 1982 (47 FR 27295) and September 2, 1998 (63 FR 46693). Critical habitat for the hawksbill sea turtle has been designated for selected beaches and/or waters of Mona, Monito, Culebrita, and Culebra Islands, Puerto Rico. There is no designated critical habitat in North Carolina.

4.1.2. Life History of Sea Turtle Species

Sea turtles are long-lived, slow-growing animals that use multiple habitats across entire ocean basins throughout their life history. This complex life history encompasses terrestrial, nearshore, and open ocean habitats. The three basic ecosystems in which sea turtles live are the:

1. Terrestrial zone (supralittoral) - the nesting beach where both oviposition (egg laying) and embryonic development and hatching occur.

2. Neritic zone - the inshore marine environment (from the surface to the sea floor) where water depths do not exceed 656 ft. The neritic zone generally includes the continental shelf, but in areas where the continental shelf is very narrow or nonexistent, the neritic zone conventionally extends to areas where water depths are less than 656 ft.

3. Oceanic zone - the vast open ocean environment (from the surface to the sea floor) where water depths are greater than 656 ft.

Maximum intrinsic growth rates of sea turtles are limited by the extremely long duration of the juvenile stage and fecundity. Sea turtles require high survival rates in the juvenile and adult stages, common constraints critical to maintaining long-lived, slow-growing species, to achieve positive or stable long-term population growth (Congdon et al. 1993; Heppell 1998; Crouse 1999; Heppell et al. 1999, 2003; Musick 1999).

4.1.2.1. **Life history – Loggerhead Sea Turtle**

Table 4-1 summarizes key life history characteristics for loggerheads nesting in the U.S. Loggerheads are long-lived, slow-growing animals that use multiple habitats across entire ocean basins throughout their life history. This complex life history encompasses terrestrial (nesting beaches), nearshore, and open ocean habitats. The loggerhead feeds on mollusks, crustaceans, fish, and other marine animals. The species is found hundreds of miles offshore, and in nearshore areas such as bays, lagoons, salt marshes, creeks, ship channels, and the mouths of large rivers. Coral reefs, rocky places, and shipwrecks are often used as feeding areas.

Nesting

For the NWA Ocean DPS, most nesting activity occurs from April through September, with a peak in June and July (Williams-Walls *et al*. 1983, Dodd 1988, Weishampel *et al*. 2006). Nesting occurs along the coasts of North America, Central America, northern South America, the Antilles, Bahamas, and Bermuda, but is concentrated in the southeastern United States and the Yucatán Peninsula of Mexico (Sternberg 1981; Ehrhart 1989; Ehrhart *et al*. 2003; NMFS and USFWS 2008).

Loggerheads nest on ocean beaches and occasionally on estuarine shorelines with suitable sand. Females dig nests typically between the high-tide line and the dune front (Routa 1968, Hailman and Elowson 1992). Wood and Bjorndal (2000) evaluated four environmental factors (slope, temperature, moisture, and salinity) and found that slope had the greatest influence on loggerhead nest-site selection on a beach in Florida. Loggerheads appear to prefer relatively narrow, steeply sloped, coarse-grained beaches, although nearshore contours may also play a role in nesting beach site selection (Provancha and Ehrhart 1987).

Numbers of nests and nesting females are often highly variable from year to year due to a number of factors including environmental stochasticity, periodicity in ocean conditions, anthropogenic effects, and density-dependent and density-independent factors affecting survival, somatic growth, and reproduction (Meylan 1982; Hays 2000; Chaloupka 2001; Solow *et al.* 2002). Despite these sources of variation, and because female turtles exhibit strong nest-site fidelity, a nesting beach survey of sufficient duration and standardized methods provides a valuable indicator of changes in the adult female population (Meylan 1982; Gerrodette and Brandon 2000; Reina *et al*. 2002).

Early Development

The warmer the sand surrounding the egg chamber, the faster the embryos develop (Mrosovsky and Yntema 1980). Sand temperatures prevailing during the middle third of the incubation period determine the sex of hatchling sea turtles (Mrosovsky and Yntema 1980). Incubation temperatures near the upper end of the tolerable range produce only female hatchlings, while incubation temperatures near the lower end of the tolerable range produce only male hatchlings.

Loggerhead hatchlings pip and escape from their eggs over a 1- to 3-day interval and move upward and out of the nest over a 2- to 4-day interval (Christens 1990). The time from pipping to emergence ranges from 4 to 7 days with an average of 4.1 days (Godfrey and Mrosovsky 1997). Hatchlings emerge from their nests en masse almost exclusively at night, and presumably using decreasing sand temperature as a cue (Hendrickson 1958; Mrosovsky 1968; Witherington *et al.* 1990). Moran *et al*. (1999) concluded that a lowering of sand temperatures below a critical threshold, which most typically occurs after nightfall, is the most probable trigger for hatchling emergence from a nest. After an initial emergence, there may be secondary emergences on subsequent nights (Carr and Ogren 1960, Ernest and Martin 1993, Houghton and Hays 2001).

Hatchlings use a progression of orientation cues to guide their movement from the nest to the marine environments where they spend their early years (Lohmann and Lohmann 2003). Hatchlings first use light cues to find the ocean. On naturally lighted beaches without artificial lighting, ambient light from the open sky creates a relatively bright horizon compared to the dark silhouette of the dune and vegetation landward of the nest. This contrast guides the hatchlings to the ocean (Limpus 1971; Salmon *et al.* 1992; Witherington and Martin 1996; Witherington 1997; Stewart and Wyneken 2004).

4.1.2.2. **Life history - Green Sea Turtle**

Green sea turtles deposit from one to nine clutches within a nesting season, but the overall average is about 3.3 nests. The interval between nesting events within a season varies around a mean of about 13 days (Hirth 1997). Mean clutch size varies widely among populations. Clutch size varies from 75 to 200 eggs with incubation requiring 48 to 70 days, depending on incubation temperatures. Only occasionally do females produce clutches in successive years. Usually, two or more years intervene between breeding seasons (NMFS and Service 1991). Age at sexual maturity is believed to be 20 to 50 years (Hirth 1997).

4.1.2.3. **Life history – Kemp's Ridley Sea Turtle**

Nesting occurs primarily from April into July. Nesting often occurs in synchronized emergences, known as "arribadas" or "arribazones," which may be triggered by high wind speeds, especially north winds, and changes in barometric pressure (Jimenez et al. 2005). Nesting occurs primarily during daylight hours. Clutch size averages 100 eggs and eggs typically take 45 to 58 days to hatch depending on incubation conditions, especially temperatures (Marquez-Millan 1994; Rostal 2007).

Females lay an average of 2.5 clutches within a season (TEWG 1998) and inter-nesting interval generally ranges from 14 to 28 days (Miller 1997; Donna Shaver, Padre Island National Seashore, pers. comm., 2007 as cited in NMFS et al. 2011). Juvenile Kemp's ridleys spend on average 2 years in the oceanic zone (NMFS SEFSC unpublished preliminary analysis, July 2004, as cited in NMFS et al. 2011) where they likely live and feed among floating algal communities. They remain here until they reach about 7.9 in in length (approximately 2 years of age), at which size they enter coastal shallow water habitats (Ogren 1989); however, the time spent in the oceanic zone may vary from 1 to 4 years or perhaps more (Turtle Expert Working Group (TEWG) 2000; Baker and Higgins 2003; Dodge et al. 2003). The mean remigration interval for adult females is 2 years, although intervals of 1 and 3 years are not uncommon (Marquez et al. 1982; TEWG 1998; 2000). Males may not be reproductively active on an annual basis (Wibbels et al. 1991). Age at sexual maturity is believed to be between 10 to 17 years (Snover et al. 2007).

4.1.2.4. **Life history – Leatherback Sea Turtle**

Leatherbacks nest an average of five to seven times within a nesting season, with an observed maximum of 11 nests (NMFS and USFWS 1992). The interval between nesting events within a season is about 9 to 10 days. Clutch size averages 80 to 85 yolked eggs, with the addition of usually a few dozen smaller, yolkless eggs, mostly laid toward the end of the clutch (Pritchard 1992). Nesting migration intervals of 2 to 3 years were observed in leatherbacks nesting on the Sandy Point National Wildlife Refuge, St. Croix, U.S. Virgin Islands (McDonald and Dutton 1996). Leatherbacks are believed to reach sexual maturity in 13 to 16 years (Dutton et al. 2005; Jones et al. 2011).

Leatherback turtle nesting grounds are distributed worldwide in the Atlantic, Pacific, and Indian Oceans on beaches in the tropics and subtropics. The Pacific Coast of Mexico historically supported the world's largest known concentration of nesting leatherbacks. The leatherback turtle regularly nests in the U.S. Caribbean in Puerto Rico and the U.S. Virgin Islands. Along the U.S. Atlantic coast, most nesting occurs in Florida (NMFS and USFWS 1992). Nesting has also been reported in Georgia, South Carolina, and North Carolina (Rabon et al. 2003) and in Texas (Shaver 2008). Adult females require sandy nesting beaches backed with vegetation and sloped sufficiently so the distance to dry sand is limited. Their preferred beaches have proximity to deep water and generally rough seas.

4.1.2.5. **Life history – Hawksbill Sea Turtle**

Hawksbills nest on average about 4.5 times per season at intervals of approximately 14 days (Corliss et al. 1989). In Florida and the U.S. Caribbean, clutch size is approximately 140 eggs, although several records exist of over 200 eggs per nest (NMFS and USFWS 1993). Based on limited information, nesting migration intervals of two to three years appear to predominate.

Hawksbills are recruited into the reef environment at about 14 inches in length and are believed to begin breeding about 30 years later. However, the time required to reach 14 inches in length is unknown and growth rates vary geographically. As a result, actual age at sexual maturity is unknown.

4.1.3. Numbers, Reproduction, and Distribution

4.1.3.1. **Numbers, Reproduction, and Distribution – Loggerhead Sea Turtle**

The loggerhead occurs throughout the temperate and tropical regions of the Atlantic, Pacific, and Indian Oceans (Dodd 1988). However, the majority of loggerhead nesting is at the western rims of the Atlantic and Indian Oceans. The most recent reviews show that only two loggerhead nesting beaches have greater than 10,000 females nesting per year (Baldwin et al. 2003; Ehrhart et al. 2003; Kamezaki et al. 2003; Limpus and Limpus 2003; Margaritoulis et al. 2003): South Florida (U.S.) and Masirah (Oman). Those beaches with 1,000 to 9,999 females nesting each year are Georgia through North Carolina (U.S.), Quintana Roo and Yucatán (Mexico), Cape Verde Islands (Cape Verde, eastern Atlantic off Africa), and Western Australia.

The major nesting concentrations in the U.S. are found in South Florida. However, loggerheads nest from Texas to Virginia. Since 2000, the annual number of loggerhead nests in NC has fluctuated between 333 in 2004 to 1,622 in 2016 (Godfrey, unpublished data; www.seaturtle.org (accessed August 30, 2018). Total estimated nesting in Florida, where 90 percent of nesting occurs, has fluctuated between 52,374 and 122,707 nests per year from 2009-2016 (FWC 2018;

http://myfwc.com/media/4326434/loggerheadnestingdata12-16.pdf). Adult loggerheads are known to make considerable migrations between foraging areas and nesting beaches (Schroeder et al. 2003; Foley et al. 2008). During non-nesting years, adult females from U.S. beaches are distributed in waters off the eastern U.S. and throughout the Gulf of Mexico, Bahamas, Greater Antilles, and Yucatán.

Range-wide Trend: Five recovery units have been identified in the Northwest Atlantic based on genetic differences and a combination of geographic distribution of nesting densities, geographic separation, and geopolitical boundaries (NMFS and Service 2008). Recovery units are subunits of a listed species that are geographically or otherwise identifiable and essential to the recovery of the species. Recovery units are individually necessary to conserve genetic robustness, demographic robustness, important life history stages, or some other feature necessary for long-term sustainability of the species. Within the U.S., four terrestrial recovery units have been designated for the NWA Ocean DPS of the loggerhead sea turtle: the Northern Recovery Unit (NRU), Peninsular Florida Recovery Unit (PFRU), Dry Tortugas Recovery Unit (DTRU), and Northern Gulf of Mexico Recovery Unit (NGMRU). North Carolina is located within the NRU, which is defined as loggerheads originating from nesting beaches from the Florida-Georgia border through southern Virginia (the northern extent of the nesting range). The mtDNA analyses show that there is limited exchange of females among recovery units (Ehrhart 1989; Foote et al. 2000; NMFS 2001; Hawkes et al. 2005). Male-mediated gene flow appears to be keeping the subpopulations genetically similar on a nuclear DNA level (Francisco-Pearce 2001).

Historically, the literature has suggested that the northern U.S. nesting beaches produce a relatively high percentage of males and the more southern nesting beaches produce a relatively high percentage of females (e.g., Hanson et al. 1998; NMFS 2001; Mrosovsky and Provancha 1989). The NRU and the NGMRU were believed to play an important role in providing males to mate with females from the more female-dominated subpopulations to the south. However, in 2002 and 2003, researchers studied loggerhead sex ratios for two of the U.S. nesting subpopulations, the northern and southern subpopulations (Blair 2005; Wyneken et al. 2005). The study produced interesting results. In 2002, the northern beaches produced more females, and the southern beaches produced more males than previously believed. However, the opposite was true in 2003 with the northern beaches producing more males and the southern beaches producing more females in keeping with prior literature. Wyneken et al. (2005) speculated that the 2002 result may have been anomalous; however, the study did point out the potential for males to be produced on the southern beaches. Although this study revealed that more males may be produced on southern recovery unit beaches than previously believed, the Service maintains that the NRU and the NGMRU play an important role in the production of males to mate with females from the more southern recovery units.

The NRU is the second largest loggerhead recovery unit within the NWA Ocean DPS. Annual nest totals from northern beaches averaged 5446 nests from 2006 to 2011, representing approximately 1,328 nesting females per year (4.1 nests per female, Murphy and Hopkins 1984) (NMFS and Service 2008). Overall, there is strong statistical data to suggest the NRU has experienced a long-term decline (NMFS and Service 2008). Currently, however, nesting for the NRU is showing possible signs of stabilizing (76 FR 58868, September 22, 2011).

Recovery Criteria for the NRU (only the Demographic Recovery Criteria are presented below; for the Listing Factor Recovery Criteria, see NMFS and Service 2008)

1. Number of Nests and Number of Nesting Females
    a. There is statistical confidence (95 percent) that the annual rate of increase over a generation time of 50 years is 2 percent or greater resulting in a total annual number of nests of 14,000 or greater for this recovery unit (approximate distribution of nests is North Carolina =14 percent [2,000 nests], South Carolina = 66 percent [9,200 nests], and Georgia = 20 percent [2,800 nests]); and
    b. This increase in number of nests must be a result of corresponding increases in number of nesting females (estimated from nests, clutch frequency, and remigration interval).

2. Trends in Abundance on Foraging Grounds
   A network of in-water sites, both oceanic and neritic across the foraging range is established and monitoring is implemented to measure abundance. There is statistical confidence (95 percent) that a composite estimate of relative abundance from these sites is increasing for at least one generation.

3. Trends in Neritic Strandings Relative to In-water Abundance
   Stranding trends are not increasing at a rate greater than the trends in in-water relative abundance for similar age classes for at least one generation.

4.1.3.2. **Numbers, Reproduction, and Distribution - Green Sea Turtle**

There are an estimated 150,000 green sea turtle females that nest each year in 46 sites throughout the world (NMFS and Service 2007). Within the U.S., green turtles nest in small numbers in the U.S. Virgin Islands and Puerto Rico, and in larger numbers along the east coast of Florida, particularly in Brevard, Indian River, St. Lucie, Martin, Palm Beach, and Broward Counties (NMFS and Service 1991). Nests have been documented, in smaller numbers, north of these counties in Florida, as well as in Georgia, South Carolina, North Carolina, and as far north as Delaware in 2011. Years of coordinated conservation efforts, including protection of nesting beaches, reduction of bycatch in fisheries, and prohibitions on the direct harvest of sea turtles, have led to increasing numbers of turtles nesting in Florida and along the Pacific coast of Mexico. On April 6, 2016, NMFS and the Service reclassified the status of the two segments that include those breeding populations (North Atlantic Ocean DPS and East Pacific Ocean DPS) from endangered to threatened (81 FR 20058). In North Carolina, between 4 and 44 green sea turtle nests are laid annually (Godfrey, unpublished data). In the U.S. Pacific, over 90 percent of nesting throughout the Hawaiian archipelago occurs at the French Frigate Shoals, where about 200 to 700 females nest each year (NMFS and Service 1998). Elsewhere in the U.S. Pacific, nesting takes place at scattered locations in the Commonwealth of the Northern Marianas, Guam, and American Samoa. In the western Pacific, the largest green turtle nesting aggregation in the world occurs on Raine Island, Australia, where thousands of females nest nightly in an average nesting season (Limpus et al. 1993). In the Indian Ocean, major nesting beaches occur in Oman where 30,000 females are reported to nest annually (Ross and Barwani 1995).

Range-wide Trend: Eleven DPSs have been listed for the green sea turtle (81FR20058). Three of the DPSs are listed as endangered, while eight are listed as threatened, including the North Atlantic Ocean DPS, which is included in the Action Area. The range of the DPS extends from the boundary of South and Central America, north along the coast to include Panama, Costa Rica, Nicaragua, Honduras, Belize, Mexico, and the United States, then due east across the Atlantic Ocean to the Islamic Republic of Mauritania on the African continent. It then extends west to the Caribbean basin, then due south and west to the boundary of South and Central America. It includes Puerto Rico, the Bahamas, Cuba, Turks and Caicos Islands, Republic of Haiti, Dominican Republic, Cayman Islands, and Jamaica. The North Atlantic DPS includes the Florida breeding population, which was originally listed as endangered under the ESA (43 FR 32800, July 28, 1978).

The North Atlantic Ocean DPS currently exhibits high nesting abundance, with an estimated total nester abundance of 167,424 females at 73 nesting sites. More than 100,000 females nest at Tortuguero, Costa Rica, and more than 10,000 females nest at Quintana Roo, Mexico. Nesting data indicate long-term increases at all major nesting sites. There is little genetic substructure within the DPS, and turtles from multiple nesting beaches share common foraging areas. Nesting is geographically widespread and occurs at a diversity of mainland and insular sites (81 FR 20058). Annual nest totals documented as part of the Florida SNBS program from 1989-2010 have ranged from 435 nests laid in 1993 to 13,225 in 2010. Nesting occurs in 26 counties with a peak along the east coast, from Volusia through Broward Counties. Green sea turtle nesting in Florida is increasing based on 22 years (1989-2010) of INBS data from throughout the state (FWC/FWRI 2010b). The increase in nesting in Florida is likely a result of several factors, including: (1) a Florida statute enacted in the early 1970s that prohibited the killing of green turtles in Florida; (2) the species listing under the ESA afforded complete protection to eggs, juveniles, and adults in all U.S. waters; (3) the passage of Florida's constitutional net ban amendment in 1994 and its subsequent enactment, making it illegal to use any gillnets or other entangling nets in State waters; (4) the likelihood that the majority of Florida green turtles reside within Florida waters where they are fully protected; (5) the protections afforded Florida green turtles while they inhabit the waters of other nations that have enacted strong sea turtle conservation measures (e.g., Bermuda); and (6) the listing of the species on Appendix I of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which stopped international trade and reduced incentives for illegal trade from the U.S (NMFS and Service 2007a).

Recovery Criteria

The U.S. Atlantic population of green sea turtles can be considered for delisting if, over a period of 25 years, the following conditions are met:

1. The level of nesting in Florida has increased to an average of 5,000 nests per year for at least six years. Nesting data must be based on standardized surveys;
2. At least 25 percent (65 mi) of all available nesting beaches (260 mi) is in public ownership and encompasses at least 50 percent of the nesting activity;
3. A reduction in stage class mortality is reflected in higher counts of individuals on foraging grounds; and

4. All priority one tasks identified in the recovery plan have been successfully implemented.

The Recovery Plan for U.S. Population of Atlantic Green Turtle was signed in 1991 (NMFS and Service 1991), and the Recovery Plan for U.S. Pacific Populations of the East Pacific Green Turtle was signed in 1998 (NMFS and Service 1998).

4.1.3.3. **Numbers, Reproduction, and Distribution – Kemp's Ridley Sea Turtle**

The Kemp's ridley has a restricted distribution. Most Kemp's ridleys nest on the beaches of the western Gulf of Mexico, primarily in Tamaulipas, Mexico. Nesting also occurs in Veracruz and Campeche, Mexico, although a small number of Kemp's ridleys nest consistently along the Texas coast (NMFS et al. 2011). In addition, rare nesting events have been reported in Alabama, Florida, Georgia, South Carolina, and North Carolina. Historical information indicates that tens of thousands of ridleys nested near Rancho Nuevo, Mexico, during the late 1940s (Hildebrand 1963). The Kemp's ridley population experienced a devastating decline between the late 1940s and the mid-1980s. The total number of nests per nesting season at Rancho Nuevo remained below 1,000 throughout the 1980s, but gradually began to increase in the 1990s. In 2009, 16,273 nests were documented along the 18.6 mi of coastline patrolled at Rancho Nuevo, and the total number of nests documented for all the monitored beaches in Mexico was 21,144 (USFWS 2010). In 2011, a total of 20,570 nests were documented in Mexico, 81 percent of these nests were documented in the Rancho Nuevo beach (Burchfield and Peña 2011). In addition, 153 and 199 nests were recorded during 2010 and 2011, respectively, in the U.S., primarily in Texas. Between 2009 and 2017 in North Carolina, there were typically one or two Kemp's ridley nests each year, and there were four in 2016.

Today, under strict protection, the population appears to be in the early stages of recovery. The recent nesting increase can be attributed to full protection of nesting females and their nests in Mexico resulting from a bi-national effort between Mexico and the U.S. to prevent the extinction of the Kemp's ridley, and the requirement to use Turtle Excluder Devices (TEDs) in shrimp trawls both in the U.S. and Mexico.

The Mexico government also prohibits harvesting and is working to increase the population through more intensive law enforcement, by fencing nest areas to diminish natural predation, and by relocating most nests into corrals to prevent poaching and predation. While relocation of nests into corrals is currently a necessary management measure, this relocation and concentration of eggs into a "safe" area is of concern since it can reduce egg viability.

Recovery Criteria (only the Demographic Recovery Criteria are presented below; for the Listing Factor Recovery Criteria, see NMFS et al. 2011)

The current recovery goal is for the species to be reduced from endangered to threatened status. The Recovery Team members feel that the criteria for a complete removal of this species from the endangered species list need not be considered now, but rather left for future revisions of the plan. Complete removal from the federal list would certainly necessitate that some other instrument of protection, similar to the MMPA, be in place and be international in scope.

Kemp's ridley can be considered for reclassification to threatened status when the following four criteria are met:

1. Continuation of complete and active protection of the known nesting habitat and the waters adjacent to the nesting beach (concentrating on the Rancho Nuevo area) and continuation of the bi-national protection project;
2. Elimination of mortality from incidental catch in commercial shrimping in the U.S. and Mexico through the use of TEDs and achievement of full compliance with the regulations requiring TED use;
3. Attainment of a population of at least 10,000 females nesting in a season; and
4. Successful implementation of all priority one recovery tasks in the recovery plan.

The Recovery Plan for the Kemp's Ridley Sea Turtle was signed in 1992 (USFWS and NMFS 1992). Significant new information on the biology and population status of Kemp's ridley has become available since 1992. Consequently, a full revision of the recovery plan has been completed by the Service and NMFS. The Bi-National Recovery Plan for the Kemp's Ridley Sea turtle (2011) provides updated species biology and population status information, objective and measurable recovery criteria, and updated and prioritized recovery actions.

4.1.3.4. **Numbers, Reproduction, and Distribution – Leatherback Sea Turtle**

A dramatic drop in nesting numbers has been recorded on major nesting beaches in the Pacific. Spotila et al. (2000) have highlighted the dramatic decline and possible future extirpation of leatherbacks in the Pacific.

The East Pacific and Malaysia leatherback populations have collapsed. Spotila et al. (1996) estimated that only 34,500 females nested annually worldwide in 1995, which is a dramatic decline from the 115,000 estimated in 1980 (Pritchard 1982). In the eastern Pacific, the major nesting beaches occur in Costa Rica and Mexico. At Playa Grande, Costa Rica, considered the most important nesting beach in the eastern Pacific, numbers have dropped from 1,367 leatherbacks in 1988-1989 to an average of 188 females nesting between 2000-2001 and 2003-2004. In Pacific Mexico, 1982 aerial surveys of adult female leatherbacks indicated this area had become the most important leatherback nesting beach in the world. Tens of thousands of nests were laid on the beaches in 1980s, but during the 2003-2004 seasons a total of 120 nests were recorded. In the western Pacific, the major nesting beaches lie in Papua New Guinea, Papua, Indonesia, and the Solomon Islands. These are some of the last remaining significant nesting assemblages in the Pacific. Compiled nesting data estimated approximately 5,000 to 9,200 nests annually with 75 percent of the nests being laid in Papua, Indonesia.

However, the most recent population size estimate for the North Atlantic alone is a range of 34,000 to 94,000 adult leatherbacks (TEWG 2007). During recent years in Florida, the total number of leatherback nests counted as part of the SNBS program ranged from 540 to 1,797 from 2006-2010 (FWC/FWRI 2010a). Assuming a clutch frequency (number of nests/female/season) of 4.2 in Florida (Stewart 2007), these nests were produced by a range of 128 to 428 females in a given year. Nesting in North Carolina is sporadic. In 2010, two nests were reported in North Carolina, five were reported in 2012, and none were reported in 2013-

2015. In North Carolina between the year 2000 and 2013, as many as 9 nests were laid per year (Godfrey, unpublished data).

Range-wide Trend: Pritchard (1982) estimated 115,000 nesting females worldwide, of which 60 percent nested along the Pacific coast of Mexico. Declines in leatherback nesting have occurred over the last two decades along the Pacific coasts of Mexico and Costa Rica. The Mexican leatherback nesting population, once considered to be the world's largest leatherback nesting population (historically estimated to be 65 percent of the worldwide population), is now less than 1 percent of its estimated size in 1980. Spotila et al. (1996) estimated the number of leatherback sea turtles nesting on 28 beaches throughout the world from the literature and from communications with investigators studying those beaches. The estimated worldwide population of leatherbacks in 1995 was about 34,500 females on these beaches with a lower limit of about 26,200, and an upper limit of about 42,900. This is less than one-third the 1980 estimate of 115,000. Leatherbacks are rare in the Indian Ocean and in very low numbers in the western Pacific Ocean. The most recent population size estimate for the North Atlantic is a range of 34,000 to 94,000 adult leatherbacks (TEWG 2007). The largest population is in the western Atlantic. Using an age-based demographic model, Spotila et al. (1996) determined that leatherback populations in the Indian Ocean and western Pacific Ocean cannot withstand even moderate levels of adult mortality and that the Atlantic populations are being exploited at a rate that cannot be sustained. They concluded that leatherbacks are on the road to extinction and further population declines can be expected unless action is taken to reduce adult mortality and increase survival of eggs and hatchlings.

Recovery Criteria

The U.S. Atlantic population of leatherbacks can be considered for delisting if the following conditions are met:

1. The adult female population increases over the next 25 years, as evidenced by a statistically significant trend in the number of nests at Culebra, Puerto Rico, St. Croix, U.S. Virgin Islands, and along the east coast of Florida;
2. Nesting habitat encompassing at least 75 percent of nesting activity in U.S. Virgin Islands, Puerto Rico, and Florida is in public ownership; and
3. All priority one tasks identified in the recovery plan have been successfully implemented.

4.1.3.5. **Numbers, Reproduction, and Distribution – Hawksbill Sea Turtle**

About 15,000 females are estimated to nest each year throughout the world with the Caribbean accounting for 20 to 30 percent of the world's hawksbill population. Only five regional populations remain with more than 1,000 females nesting annually (Seychelles, Mexico, Indonesia, and two in Australia) (Meylan and Donnelly 1999). Mexico is now the most important region for hawksbills in the Caribbean with about 3,000 nests per year (Meylan 1999). The hawksbill sea turtle has experienced global population declines of 80 percent or more during the past century and continued declines are projected (Meylan and Donnelly 1999). Most populations are declining, depleted, or remnants of larger aggregations. Hawksbills were previously abundant, as evidenced by high-density nesting at a few remaining sites and by trade statistics.

Recovery Criteria

The U.S. Atlantic population of hawksbills can be considered for delisting if, over a period of 25 years, the following conditions are met:

1. The adult female population is increasing, as evidenced by a statistically significant trend in the annual number of nests on at least five index beaches, including Mona Island and Buck Island Reef National Monument;

2. Habitat for at least 50 percent of the nesting activity that occurs in the U.S. Virgin Islands and Puerto Rico is protected in perpetuity;

3. Numbers of adults, subadults, and juveniles are increasing, as evidenced by a statistically significant trend on at least five key foraging areas within Puerto Rico, U.S. Virgin Islands, and Florida; and

4. All priority one tasks identified in the recovery plan have been successfully implemented.

The Recovery Plan for the Hawksbill Turtle in the U.S. Caribbean, Atlantic, and Gulf of Mexico was signed in 1993 (NMFS and USFWS 1993), and the Recovery Plan for U.S. Pacific Populations of the Hawksbill Turtle was signed in 1998 (NMFS and USFWS 1998b).

4.1.4. Conservation Needs and Threats for Sea Turtle Species

Reason for Listing: All sea turtle species are listed for similar reasons. There are many threats to sea turtles, including nest destruction from natural events, such as tidal surges and hurricanes, or eggs lost to predation by raccoons, foxes, ghost-crabs, and other animals. However, human activity has significantly contributed to the decline of sea turtle populations along the Atlantic Coast and in the Gulf of Mexico (NRC 1990). These factors include the modification, degradation, or loss of nesting habitat by coastal development, artificial lighting, beach driving, and marine pollution and debris. Furthermore, the overharvest of eggs for food, intentional killing of adults and immature turtles for their shells and skin, and accidental drowning in commercial fishing gear are primarily responsible for the worldwide decline in sea turtle populations.

Barrier islands and inlets are complex and dynamic coastal systems that are continually responding to sediment supply, waves, and fluctuations in sea level. The location and shape of the beaches of barrier islands perpetually adjusts to these physical forces. Waves that strike a barrier island at an angle, for instance, generate a longshore current that carries sediment along the shoreline. Cross-shore currents carry sediment perpendicular to the shoreline. Wind moves sediment across the dry beach, dunes, and island interior. During storm events, overwash may breach the island at dune gaps or other weak spots, depositing sediments on the interior and back sides of islands, increasing island elevation and accreting the soundside shoreline.

Tidal inlets play a vital role in the dynamics and processes of barrier islands. Sediment is transferred across inlets from island to island via the tidal shoals or deltas. The longshore sediment transport often causes barrier spits to accrete, shifting inlets towards the neighboring island. Flood tidal shoals that are left behind by the migrating inlet are typically incorporated into the soundside shoreline and marshes of the island, widening it considerably. Many inlets have a cycle of inlet migration, breaching of the barrier spit during a storm, and closure of the old inlet with the new breach becoming the new inlet. Barrier spits tend to be low in elevation, sparse in vegetation, and repeatedly submerged by high and storm tides.

Threats to Sea Turtle Species

Coastal Development

Loss of sea turtle nesting habitat related to coastal development has had the greatest impact on nesting sea turtles. Beachfront development not only causes the loss of suitable nesting habitat but can result in the disruption of powerful coastal processes accelerating erosion and interrupting the natural shoreline migration (NRC 1990b). This may in turn cause the need to protect upland structures and infrastructure by armoring, groin placement, beach emergency berm construction and repair, and beach nourishment, all of which cause changes in, additional loss of, or impact to the remaining sea turtle habitat.

Hurricanes and Storms

Hurricanes and other large storms were probably responsible for maintaining coastal beach habitat upon which sea turtles depend through repeated cycles of destruction, alteration, and recovery of beach and dune habitat. Hurricanes and large storms generally produce damaging winds, storm tides and surges, and rain, which can result in severe erosion of the beach and dune systems. Overwash and blowouts are common on barrier islands.

Hurricanes and other storms can result in the direct loss of sea turtle nests, either by erosion or washing away of the nests by wave action and inundation or "drowning" of the eggs or pre-emergent hatchlings within the nest, or indirectly by causing the loss of nesting habitat. Depending on their frequency, storms can affect sea turtles on either a short-term basis (nests lost for one season and/or temporary loss of nesting habitat) or long term, if frequent (habitat unable to recover). The manner in which hurricanes affect sea turtle nesting also depends on their characteristics (winds, storm surge, rainfall), the time of year (within or outside of the nesting season), and where the northeast edge of the hurricane crosses land.

Because of the limited remaining nesting habitat in a natural state with no immediate development landward of the sandy beach, frequent or successive severe weather events could threaten the ability of certain sea turtle populations to survive and recover. Sea turtles evolved under natural coastal environmental events such as hurricanes. The extensive amount of predevelopment coastal beach and dune habitat allowed sea turtles to survive even the most severe hurricane events. It is only within the last 20 to 30 years that the combination of habitat loss to beachfront development and destruction of remaining habitat by hurricanes has increased the threat to sea turtle survival and recovery. On developed beaches, typically little space remains for sandy beaches to become reestablished after periodic storms. While the beach itself moves landward during such storms, reconstruction or persistence of structures at their pre-storm locations can result in a loss of nesting habitat.

Erosion

A critically eroded area is a segment of shoreline where natural processes or human activity have caused or contributed to erosion and recession of the beach or dune system to such a degree that upland development, recreational interests, wildlife habitat, or important cultural resources are threatened or lost. It is important to note that for an erosion problem area to be critical there must be an existing threat to or loss of one of four specific interests – upland development, recreation, wildlife habitat, or important cultural resources.

Beachfront Lighting

Artificial lights along a beach can deter females from coming ashore to nest or misdirect females trying to return to the surf after a nesting event. A significant reduction in sea turtle nesting activity has been documented on beaches illuminated with artificial lights (Witherington 1992). Artificial beachfront lighting may also cause disorientation (loss of bearings) and misorientation (incorrect orientation) of sea turtle hatchlings (Philibosian 1976; Mann 1977; Witherington and Martin 1996). Visual signs are the primary sea-finding mechanism for hatchlings (Mrosovsky and Carr 1967; Mrosovsky and Shettleworth 1968; Dickerson and Nelson 1989; Witherington and Bjorndal 1991). The emergence from the nest and crawl to the sea is one of the most critical periods of a sea turtle's life. Hatchlings that do not make it to the sea quickly become food for ghost crabs, birds, and other predators, or become dehydrated and may never reach the sea. In addition, research has documented significant reduction in sea turtle nesting activity on beaches illuminated with artificial lights (Witherington 1992). During the 2010 sea turtle nesting season in Florida, over 47,000 turtle hatchlings were documented as being disoriented (FWC/FWRI 2011).

Predation

Predation of sea turtle eggs and hatchlings by native and introduced species occurs on almost all nesting beaches. Predation by a variety of predators can considerably decrease sea turtle nest hatching success. The most common predators in the southeastern U.S. are ghost crabs (*Ocypode quadrata*), raccoons (*Procyon lotor*), feral hogs (*Sus scrofa*), foxes (*Urocyon cinereoargenteus* and *Vulpes vulpes*), coyotes (*Canis latrans*), armadillos (*Dasypus novemcinctus*), and fire ants (*Solenopsis invicta*) (Dodd 1988; Stancyk 1995). In the absence of nest protection programs in a number of locations throughout the southeast U.S., raccoons may depredate up to 96 percent of all nests deposited on a beach (Davis and Whiting 1977; Hopkins and Murphy 1980; Stancyk et al. 1980; Talbert et al. 1980; Schroeder 1981; Labisky et al. 1986).

Beach Driving

The operation of motor vehicles on the beach affects sea turtle nesting by interrupting or striking a female turtle on the beach, headlights disorienting or misorienting emergent hatchlings, vehicles running over hatchlings attempting to reach the ocean, and vehicle tracks traversing the beach that interfere with hatchlings crawling to the ocean. Hatchlings appear to become diverted not because they cannot physically climb out of the rut (Hughes and Caine 1994), but because the sides of the track cast a shadow and the hatchlings lose their line of sight to the ocean horizon (Mann 1977). The extended period of travel required to negotiate tire tracks and ruts may increase the susceptibility of hatchlings to dehydration and depredation during migration to the ocean (Hosier et al. 1981). Driving on the beach can cause sand compaction which may result in adverse impacts on nest site selection, digging behavior, clutch viability, and emergence by hatchlings, decreasing nest success and directly killing pre-emergent hatchlings (Mann 1977; Nelson and Dickerson 1987; Nelson 1988).

The physical changes and loss of plant cover caused by vehicles on dunes can lead to various degrees of instability, and therefore encourage dune migration. As vehicles move either up or down a slope, sand is displaced downward, lowering the trail. Since the vehicles also inhibit plant growth, and open the area to wind erosion, dunes may become unstable, and begin to migrate. Unvegetated sand dunes may continue to migrate across stable areas as long as vehicle traffic continues. Vehicular traffic through dune breaches or low dunes on an eroding beach may cause an accelerated rate of overwash and beach erosion (Godfrey et al. 1978). If driving is required, the area where the least amount of impact occurs is the beach between the low and high tide water lines. Vegetation on the dunes can quickly reestablish provided the mechanical impact is removed.

Climate Change

The varying and dynamic elements of climate science are inherently long term, complex, and interrelated. Regardless of the underlying causes of climate change, glacial melting and expansion of warming oceans are causing sea level rise, although its extent or rate cannot as yet be predicted with certainty. At present, the science is not exact enough to precisely predict when and where climate impacts will occur. Although we may know the direction of change, it may not be possible to predict its precise timing or magnitude. These impacts may take place gradually or episodically in major leaps.

Climate change is evident from observations of increases in average global air and ocean temperatures, widespread melting of snow and ice, and rising sea level, according to the Intergovernmental Panel on Climate Change Report (IPCC 2007a). The IPCC Report (2007a) describes changes in natural ecosystems with potential widespread effects on many organisms, including marine mammals and migratory birds. The potential for rapid climate change poses a significant challenge for fish and wildlife conservation. Species' abundance and distribution are dynamic, relative to a variety of factors, including climate. As climate changes, the abundance and distribution of fish and wildlife will also change. Highly specialized or endemic species are likely to be most susceptible to the stresses of changing climate. Based on these findings and other similar studies, the U.S. Department of the Interior (DOI) requires agencies under its direction to consider potential climate change effects as part of their long-range planning activities (USFWS 2007).

In the southeastern U.S., climatic change could amplify current land management challenges involving habitat fragmentation, urbanization, invasive species, disease, parasites, and water management. Global warming will be a particular challenge for endangered, threatened, and other "at risk" species. It is difficult to estimate, with any degree of precision, which species will be affected by climate change or exactly how they will be affected. The Service will use Strategic Habitat Conservation planning, an adaptive science-driven process that begins with explicit trust resource population objectives, as the framework for adjusting our management strategies in response to climate change (USFWS 2006). As the level of information increases relative to the effects of global climate change on sea turtles and their designated critical habitat, the Service will have a better basis to address the nature and magnitude of this potential threat and will more effectively evaluate these effects to the range-wide status of sea turtles.

Temperatures are predicted to rise from 1.6°F to 9°F for North America by the end of this century (IPCC 2007a, b). Alterations of thermal sand characteristics could result in highly female-biased sex ratios because sea turtles exhibit temperature dependent sex determination (e.g., Glen and Mrosovsky 2004; Hawkes et al. 2008).

Along developed coastlines, and especially in areas where shoreline protection structures have been constructed to limit shoreline movement, rising sea levels will cause severe effects on nesting females and their eggs. Erosion control structures can result in the permanent loss of dry nesting beach or deter nesting females from reaching suitable nesting sites (NRC 1990a). Nesting females may deposit eggs seaward of the erosion control structures potentially subjecting them to repeated tidal inundation or washout by waves and tidal action.

Based on the present level of available information concerning the effects of global climate change on the status of sea turtles and their designated critical habitat, the Service acknowledges the potential for changes to occur in the Action Area, but presently has no basis to evaluate if or how these changes are affecting sea turtles or their designated critical habitat. Nor does our present knowledge allow the Service to project what the future effects from global climate change may be or the magnitude of these potential effects.

Recreational Beach Use

Human presence on or adjacent to the beach at night during the nesting season, particularly recreational activities, can reduce the quality of nesting habitat by deterring or disturbing and causing nesting turtles to avoid otherwise suitable habitat. In addition, human foot traffic can make a beach less suitable for nesting and hatchling emergence by increasing sand compaction and creating obstacles to hatchlings attempting to reach the ocean (Hosier et al. 1981). The use and storage of lounge chairs, cabanas, umbrellas, catamarans, and other types of recreational equipment on the beach at night can also make otherwise suitable nesting habitat unsuitable by hampering or deterring nesting by adult females and trapping or impeding hatchlings during their nest to sea migration. The documentation of non-nesting emergences (also referred to as false crawls) at these obstacles is becoming increasingly common as more recreational beach equipment is left on the beach at night. Sobel (2002) describes nesting turtles being deterred by wooden lounge chairs that prevented access to the upper beach. In 2018, a dead female Kemp's ridley sea turtle washed up Near Fort Morgan Alabama, entangled in a beach chair (USA Today 2018).

Sand Placement

Sand placement projects may result in changes in sand density (compaction), beach shear resistance (hardness), beach moisture content, beach slope, sand color, sand grain size, sand grain shape, and sand grain mineral content if the placed sand is dissimilar from the original beach sand (Nelson and Dickerson 1988a). These changes could result in adverse impacts on sea turtle nest site selection, digging behavior, clutch viability, and hatchling emergence (Nelson and Dickerson 1987; Nelson 1988).

Beach nourishment projects create an elevated, wider, and unnatural flat slope berm. Sea turtles nest closer to the water the first few years after nourishment because of the altered profile (and perhaps unnatural sediment grain size distribution) (Ernest and Martin 1999; Trindell 2005). Beach compaction and unnatural beach profiles resulting from beach nourishment activities could negatively impact sea turtles regardless of the timing of projects. Sand compaction may increase the length of time required for female sea turtles to excavate nests and cause increased physiological stress to the animals (Nelson and Dickerson 1988b). The placement of debris or rocky material may have similar effects. These impacts can be minimized by using suitable sand.

A change in sediment color on a beach could change the natural incubation temperatures of sea turtle nests in an area, which, in turn, could alter natural sex ratios. To provide the most suitable sediment for nesting sea turtles, the color of the nourished sediments should resemble the natural beach sand in the area. Natural reworking of sediments and bleaching from exposure to the sun would help to lighten dark nourishment sediments; however, the timeframe for sediment mixing and bleaching to occur could be critical to a successful sea turtle nesting season.

During project construction, predators of eggs and nestlings may be attracted to the Action Area due to food waste from the construction crew.

Sand fencing

Sand fencing captures windblown sand, bolstering dunes and altering the beach profile (Rice 2017). When fences are installed seaward of houses, the sand fencing displaces the dune crest farther seaward than would naturally occur (Nordstrom and McCluskey 1985). The installation of sand fencing in overwash areas hastens the conversion of these flat, bare areas to elevated, vegetated dune habitat. Sand fencing may impede the movement of sea turtles. Between 2012 and early 2016, 62.69 mi (19%) of sandy beach habitat in North Carolina was modified by sand fencing.

In-water and Shoreline Alterations

Many navigable mainland or barrier island tidal inlets along the Atlantic and Gulf of Mexico coasts are stabilized with jetties or groins. Jetties are built perpendicular to the shoreline and extend through the entire nearshore zone and past the breaker zone to prevent or decrease sand deposition in the channel (Kaufman and Pilkey 1979). Groins are also shore-perpendicular structures designed to trap sand that would otherwise be transported by longshore currents. These in-water structures can cause downdrift erosion and cause profound effects on adjacent beaches (Kaufman and Pilkey 1979). Jetties and groins placed to stabilize a beach or inlet prevent normal sand transport, resulting in accretion of sand on updrift beaches and acceleration of beach erosion downdrift of the structures (Komar 1983; Pilkey et al. 1984). Witherington et al. (2005) found a significant relationship between loggerhead nesting density and distance from the nearest of 17 ocean inlets on the Atlantic coast of Florida. The effect of inlets in lowering nesting density was observed both updrift and downdrift of the inlets, leading researchers to propose that beach instability from both erosion and accretion may discourage sea turtle nesting. Following construction, the presence of groins and jetties may interfere with nesting turtle access to the beach, result in a change in beach profile and width (downdrift erosion, loss of sandy berms, and escarpment formation), trap hatchlings, and concentrate predatory fishes, resulting in higher probabilities of hatchling predation. In addition to decreasing nesting habitat suitability, construction or repair of groins and jetties during the nesting season may result in the destruction of nests, disturbance of females attempting to nest, and disorientation of emerging hatchlings from project lighting.

4.1.5. Tables

Table 4-1. Typical values of life history parameters for loggerheads nesting in the U.S. (NMFS and Service 2008).

Life History Trait	**Data**
Clutch size (mean)	100-126 eggs[1]
Incubation duration (varies depending on time of year and latitude)	Range = 42-75 days[2,3]
Pivotal temperature (incubation temperature that produces an equal number of males and females)	84˚F[5]
Nest productivity (emerged hatchlings/total eggs) x 100 (varies depending on site specific factors)	45-70 percent[2,6]
Clutch frequency (number of nests/female/season)	3-4 nests[7]
Internesting interval (number of days between successive nests within a season)	12-15 days[8]
Juvenile (<34 in Curved Carapace Length) sex ratio	65-70 percent female[4]
Remigration interval (number of years between successive nesting migrations)	2.5-3.7 years[9]
Nesting season	late April-early September
Hatching season	late June-early November
Age at sexual maturity	32-35 years[10]
Life span	>57 years[11]

1 Dodd (1988).
2 Dodd and Mackinnon (1999, 2000, 2001, 2002, 2003, 2004).
3 Witherington (2006) (information based on nests monitored throughout Florida beaches in 2005, n = 865).
4 NMFS (2001); Foley (2005).
5 Mrosovsky (1988).
6 Witherington (2006) (information based on nests monitored throughout Florida beaches in 2005, n = 1,680).
7 Murphy and Hopkins (1984); Frazer and Richardson (1985); Hawkes et al. 2005; Scott 2006.
8 Caldwell (1962), Dodd (1988).
9 Richardson et al. (1978); Bjorndal et al. (1983).
10 Snover (2005).
11 Dahlen et al. (2000).

4.2. Environmental Baseline for Sea Turtle Species

This section describes the best available data about the condition of all sea turtle species in the Action Area without the consequences caused by the proposed Action.

4.2.1. Action Area Numbers, Reproduction, and Distribution

See **Table 4-2** for data on observed sea turtle nests in the Action Area. Data was provided from the BA and www.seaturtle.org (accessed September 16, 2022). Leatherback, Kemp's ridley, green, hawksbill, and loggerhead sea turtles have been documented nesting along North Carolina's ocean shoreline, but only loggerhead has been documented within the Action Area since 2009. No green sea turtle nests have been reported on Wrightsville Beach since 2009, but green sea turtle nests are reported most years on adjacent Masonboro Island, including three in 2020 and eight (preliminary data) in 2022. Between 2009 and 2015 in New Hanover County, no Kemp's ridley sea turtle nests were reported in Wrightsville Beach or on Masonboro Island. However, Kemp's ridley sea turtles are known to occasionally nest throughout the state, including beaches both north and south of the project area. Between 2009 and 2015 in New Hanover County, one leatherback sea turtle nest was reported in Carolina Beach in 2009. Leatherback sea turtles are known to occasionally nest throughout the state, including beaches both north and south of the project area. Two hawksbill nests were reported in 2015 at Cape Hatteras National Seashore south of Hatteras; the first records of hawksbill sea turtle nests in the state of North Carolina. Both nests were north of the Action Area. One nest successfully hatched (hatching success of 64.5%), the other was destroyed by high surf from storms. The nest that successfully hatched had an incubation period of 59 days. It is currently unclear whether or not the hawksbill sea turtle may nest in the Action Area.

The loggerhead sea turtle nesting and hatching season for North Carolina beaches extends from May 1 through November 15. Incubation ranges from about 45 to 95 days. The green sea turtle nesting and hatching season on North Carolina beaches extends from May 15 through November 15, and incubation ranges from about 45 to 75 days. The Kemp's ridley sea turtle nesting and hatchling season on North Carolina beaches appears to be similar to other species and incubation ranges from 45 to 58 days. The leatherback sea turtle nesting and hatching season on North Carolina Beaches extends from April 15 through November 15 and incubation ranges from about 55 to 75 days. The hawksbill sea turtle nesting and hatching season on North Carolina beaches is unclear but is expected to be similar to other sea turtle species.

4.2.2. Action Area Conservation Needs and Threats

Early in American history, Wrightsville Beach was owned by the State of North Carolina. The island was transferred into private hands through three grants between 1791 and 1881. However, there were no residents and very few visitors until the late 1800's, after the development of the Carolina Yacht Club. Wrightsville Beach was incorporated in 1899 and began developing in earnest in the early to mid-1900s (https://www.intracoastalrealty.com/blog/history-wrightsville-beach/). Today, most of the beach shoreline in the Action Area is highly developed with businesses, hotels, and/or residences. Recreational use in the Action Area is quite high from residents and tourists.

A number of recent and on-going beach disturbance activities have altered the proposed Action Area and, to a greater extent, the North Carolina coastline, and many more are proposed along the coastline for the near future. See section 4.1.4 for discussion of the impacts of these activities. Table 4-3 lists BOs issued for projects in New Hanover County since 2010 for adverse impacts to sea turtle species. Almost all of the projects listed in Table 4-3 were conducted during the work window (outside of the sea turtle nesting season).

*Nourishment activities*: The Corps' CSRM project has a life of 50 years, to 2036. In the past, the project has typically been conducted every 3-4 years. This schedule is expected to be continued into the future. Routinely scheduled dredging activities for the CSRM project and/or navigation have historically been implemented during the winter environmental window (November 16 to April 30) to limit the effect on federally managed species.

Some individuals in a population are more "valuable" than others in terms of the number of offspring they are expected to produce. An individual's potential for contributing offspring to future generations is its reproductive value. Because of delayed sexual maturity, reproductive longevity, and low survivorship in early life stages, nesting females are of high value to a population. The loss of a nesting female in a small recovery unit would represent a significant loss to the recovery unit. The reproductive value for a nesting female has been estimated to be approximately 253 times greater than an egg or a hatchling (NMFS and USFWS 2008).
With regard to indirect loss of eggs and hatchlings, on most beaches, nesting success typically declines for the first year or two following sand placement, even though more nesting habitat is available for turtles (Trindell et al. 1998; Ernest and Martin 1999; Herren 1999). Reduced nesting success on constructed beaches has been attributed to increased sand compaction, escarpment formation, and changes in beach profile (Nelson et al. 1987; Crain et al. 1995; Lutcavage et al. 1997; Steinitz et al. 1998; Ernest and Martin 1999; Rumbold et al. 2001). In addition, even though constructed beaches are wider, nests deposited there may experience higher rates of wash out than those on relatively narrow, steeply sloped beaches (Ernest and Martin 1999). This occurs because nests on constructed beaches are more broadly distributed than those on natural beaches, where they tend to be clustered near the base of the dune. Nests laid closest to the waterline on constructed beaches may be lost during the first year or two following construction as the beach undergoes an equilibration process during which seaward portions of the beach are lost to erosion. As a result, the project may be anticipated to result in decreased nesting and loss of nests that are laid within the Action Area for two subsequent nesting seasons following the completion of the proposed sand placement. However, it is unknown whether nests that would have been laid in an Action Area during the two subsequent nesting seasons had the project not occurred are actually lost from the population, or if nesting is simply displaced to adjacent beaches. Regardless, eggs and hatchlings have a low reproductive value; each egg or hatchling has been estimated to have only 0.004 percent of the value of a nesting female (NMFS and USFWS 2008). Thus, even if the majority of the eggs and hatchlings that would have been produced on the project beach are not realized for up to 2 years following project completion, the Service would not expect this loss to have a significant effect on the recovery and survival of the species, for the following reasons: 1) some nesting is likely just displaced to adjacent non-project beaches, 2) not all eggs will produce hatchlings, and 3) destruction and/or failure of nests will not always result from a sand placement project. A variety of natural and unknown factors negatively affect incubating egg clutches, including tidal

inundation, storm events, and predation, accretion of sand, and erosional processes. The loss of all life stages of sea turtles including eggs are considered "take" and minimization measures are required to avoid and minimize all life stages.

Dredging activities: Adult and juvenile marine sea turtles may be injured or killed by dredging activities via entrainment, vessel strike or the effects of noise and vibration. The Corps has dredged the Federal navigation channels in the AIWW and in Masonboro Inlet for decades. In general, the risk of impacts to marine sea turtles from dredging is greater offshore than in inlets and the AIWW.

Beach scraping or bulldozing: Beach scraping or bulldozing has been frequent on North Carolina beaches in recent years, in response to storms and the continuing retreat of the shoreline with rising sea level. The Town of Wrightsville Beach has recently requested a renewal of its permit for beach bulldozing. Work is proposed to be conducted outside of the sea turtle nesting season.

Pedestrian Use of the Beach: There are a number of potential sources of pedestrians and pets, including those individuals originating from beachfront and nearby residences.

Beach Driving: No public driving is allowed on Wrightsville Beach, but local government vehicles generally traverse the entire length of beach in response to emergencies, for trash removal, and other purposes.

Shoreline stabilization: There are two existing rock revetments along the coast of North Carolina: one at Fort Fisher (approximately 3,040 lf), and another along Carolina Beach (approximately 2,050 lf).

4.2.3. Tables

Table 4-2. Number of loggerhead nests observed between 2009 and 2021 on Wrightsville Beach. From www.seaturtle.org, accessed September 16, 2022.

Year	**Wrightsville Beach**
2009	1
2010	1
2011	2
2012	3
2013	8
2014	2
2015	4
2016	15
2017	10
2018	2
2019	11
2020	15
2021	14

Table 4-3. Sand placement projects conducted within New Hanover County since 2009 analyzed for adverse impacts to sea turtle species from sand placement. All projects were covered either by the 2017 Statewide Programmatic Biological Opinion for Beach Sand Placement (SPBO) or an individual project BO.

Project/Opinion	Year	Species	Issued Take
Wrightsville Beach CSRM (Corps)	2018	Loggerhead, green, Kemp's ridley, hawksbill, and leatherback sea turtle, piping plover, red knot, seabeach amaranth	Approximately 16,200 lf of shoreline.
Dredging of Mason Inlet and placement of sand on Figure Eight Island (MIRP)	2016	Loggerhead, green, Kemp's ridley, hawksbill, and leatherback sea turtle, piping plover, red knot, seabeach amaranth	Approximately 10,000 lf of shoreline
Wrightsville Beach CSRM (Corps)	2014	Loggerhead, green, Kemp's ridley, hawksbill, and leatherback sea turtle, piping plover, red knot, seabeach amaranth	Approximately 16,200 lf of shoreline.
Dredging of Mason Inlet and placement of sand on Figure Eight Island (MIRP)	2013	Loggerhead, green, Kemp's ridley, hawksbill, and leatherback sea turtle, piping plover, red knot, seabeach amaranth	Approximately 10,000 lf of shoreline.
Masonboro Inlet dredging and nourishment on Wrightsville Beach (Corps)	2009/2010	Loggerhead, green, Kemp's ridley, hawksbill, and leatherback sea turtle, piping plover, red knot, seabeach amaranth	Approximately 16,200 lf of shoreline.

4.3. Effects of the Action on Sea Turtle Species

In a BO for a listed species, the effects of the proposed action are all reasonably certain consequences to the species caused by the action, including the consequences of other activities caused by the action. Activities caused by the action would not occur but for the action. Consequences to species may occur later in time and may occur outside the action area.

We identified and described the activities in the proposed Action in **section 2.1**, to include sand placement. Our analyses of the consequences caused by sand placement activities follows.

4.3.1. Effects of Sand Placement on Sea Turtle Species

Applicable Science and Pathways of Response

Direct Effects: Potential adverse effects during the project construction phase include disturbance of existing nests, which may have been missed by surveyors and thus not marked for avoidance, disturbance of females attempting to nest, and disorientation of emerging hatchlings. In addition, heavy equipment will be required to re-distribute the sand to the original natural beach template. This equipment will have to traverse the beach portion of the Action Area, which could result in harm to nesting sea turtles, their nests, and emerging hatchlings. In addition, heavy equipment may be required to remove derelict tire material from the sand and re-distribute the sand to the original natural beach template. This equipment will have to traverse the beach portion of the Action Area several times, which could result in harm to nesting sea turtles, their nests, and emerging hatchlings

Placement of sand on a beach in and of itself may not provide suitable nesting habitat for sea turtles. Although sand placement activities may increase the potential nesting area, significant negative impacts to sea turtles may result if protective measures are not incorporated during project construction. Sand placement activities during the nesting season can cause increased loss of eggs and hatchlings and, along with other mortality sources, may significantly impact the long-term survival of the species. For instance, projects conducted during the nesting and hatching season could result in the loss of sea turtles through disruption of adult nesting activity and by burial or crushing of nests or hatchlings. While a nest monitoring and egg relocation program would reduce these impacts, nests may be inadvertently missed (when crawls are obscured by rainfall, wind, or tides) or misidentified as false crawls during daily patrols. In addition, nests may be destroyed by operations at night prior to beach patrols being performed. Even under the best of conditions, about 7 percent of the nests can be misidentified as false crawls by experienced sea turtle nest surveyors (Schroeder 1994).

a. Equipment during construction

The use of heavy machinery on beaches during a construction project may have adverse effects on sea turtles. Equipment left on the nesting beach overnight can create barriers to nesting females emerging from the surf and crawling up the beach, causing a higher incidence of false crawls and unnecessary energy expenditure. The Corps may need to employ beach rakes or screens to remove derelict tire material from the shoreline after the material is placed, and perhaps in future years if derelict materials are uncovered due to erosion.

The operation of motor vehicles or equipment on the beach to complete the project work at night affects sea turtle nesting by: interrupting or colliding with a nesting turtle on the beach, headlights disorienting or misorienting emergent hatchlings, vehicles running over hatchlings attempting to reach the ocean, and vehicle ruts on the beach interfering with hatchlings crawling to the ocean. Apparently, hatchlings become diverted not because they cannot physically climb out of a rut (Hughes and Caine 1994), but because the sides of the track cast a shadow and the hatchlings lose their line of sight to the ocean horizon (Mann 1977). The extended period of travel required to negotiate tire ruts may increase the susceptibility of hatchlings to dehydration and depredation during migration to the ocean (Hosier et al. 1981). Driving directly above or over incubating egg clutches or on the beach can cause sand compaction, which may result in adverse impacts on nest site selection, digging behavior, clutch viability, and emergence by hatchlings, as well as directly kill pre-emergent hatchlings (Mann 1977; Nelson and Dickerson 1987; Nelson 1988).

The physical changes and loss of plant cover caused by vehicles on vegetated areas or dunes can lead to various degrees of instability and cause dune migration. As vehicles move over the sand, sand is displaced downward, lowering the substrate. Since the vehicles also inhibit plant growth, and open the area to wind erosion, the beach and dunes may become unstable. Vehicular traffic on the beach or through dune breaches or low dunes may cause acceleration of overwash and erosion (Godfrey et al. 1978). Driving along the beachfront should be between the low and high tide water lines. To minimize the impacts to the beach, dunes, and dune vegetation, transport and access to the construction sites should be from the road to the maximum extent possible. However, if vehicular access to the beach is necessary, the areas for vehicle and equipment usage should be designated and marked.

b. Artificial lighting as a result of an unnatural beach slope on the adjacent beach

Visual cues are the primary sea-finding mechanism for hatchling sea turtles (Mrosovsky and Carr 1967; Mrosovsky and Shettleworth 1968; Dickerson and Nelson 1989; Witherington and Bjorndal 1991). When artificial lighting is present on or near the beach, it can misdirect hatchlings once they emerge from their nests and prevent them from reaching the ocean (Philibosian 1976; Mann 1977; FWC 2007). For example, in July 2018 in Atlantic Beach, NC, more than 80 hatchlings from an unmarked loggerhead sea turtle nest were rescued from the road, parking lots, and dunes after they were disoriented by artificial lights (Godfrey 2018, pers. comm.). At least one hatchling was crushed by a car on the road.

A significant reduction in sea turtle nesting activity has also been documented on beaches illuminated with artificial lights (Witherington 1992). Construction lights along a project beach and on the dredging vessel may deter females from coming ashore to nest, misdirect females trying to return to the surf after a nesting event, and misdirect emergent hatchlings from adjacent non-project beaches.

The unnatural sloped beach adjacent to the structure exposes sea turtles and their nests to lights that were less visible, or not visible, from nesting areas before the sand placement activity, leading to a higher mortality of hatchlings. Review of over 10 years of empirical information from beach nourishment projects indicates that the number of sea turtles impacted by lights increases on the post-construction berm. A review of selected nourished beaches in Florida (South Brevard, North Brevard, Captiva Island, Ocean Ridge, Boca Raton, Town of Palm Beach, Longboat Key, and Bonita Beach) indicated disorientation reporting increased by approximately 300 percent the first nesting season after project construction and up to 542 percent the second year compared to pre-nourishment reports (Trindell et al. 2005).

Specific examples of increased lighting disorientations after a sand placement project include a sand placement project in Brevard County, Florida, completed in 2002. After the project, there was an increase of 130 percent in disorientations in the nourished area. Disorientations on beaches in the County that were not nourished remained constant (Trindell 2007). This same result was also documented in 2003 when another beach in Brevard County was nourished and the disorientations increased by 480 percent (Trindell 2007). Installing appropriate beachfront lighting is the most effective method to decrease the number of disorientations on any developed beach including nourished beaches.

c. Nest relocation

Besides the potential for missing nests during surveys and a nest relocation program, there is a potential for eggs to be damaged by nest movement or relocation, particularly if eggs are not relocated within 12 hours of deposition (Limpus et al. 1979). Nest relocation can have adverse impacts on incubation temperature (and hence sex ratios), gas exchange parameters, hydric environment of nests, hatching success, and hatchling emergence (Limpus et al. 1979; Ackerman 1980; Parmenter 1980; Spotila et al. 1983; McGehee 1990). Relocating nests into sands deficient in oxygen or moisture can result in mortality, morbidity, and reduced behavioral competence of hatchlings. Water availability is known to influence the incubation environment of the embryos and hatchlings of turtles with flexible-shelled eggs, which has been shown to affect nitrogen excretion (Packard et al. 1984), mobilization of calcium (Packard and Packard 1986), mobilization of yolk nutrients (Packard et al. 1985), hatchling size (Packard et al. 1981; McGehee 1990), energy reserves in the yolk at hatching (Packard et al. 1988), and locomotory ability of hatchlings (Miller et al. 1987).

In a 1994 Florida study comparing loggerhead hatching and emerging success of relocated nests with nests left in their original location, Moody (1998) found that hatching success was lower in relocated nests at nine of 12 beaches evaluated. In addition, emerging success was lower in relocated nests at 10 of 12 beaches surveyed in 1993 and 1994.

Indirect Effects: Many of the direct effects of beach nourishment may persist over time and become indirect impacts. These indirect effects include increased susceptibility of relocated nests to catastrophic events, the consequences of potential increased beachfront development, changes in the physical characteristics of the beach, the formation of escarpments, and future sand migration.

a. Changes in the physical environment

Beach nourishment projects create an elevated, wider, and unnatural flat slope berm. Sea turtles nest closer to the water the first few years after nourishment because of the altered profile (and perhaps unnatural sediment grain size distribution) (Ernest and Martin 1999; Trindell 2005).

Beach compaction, placement of debris or incompatible sediment, and unnatural beach profiles resulting from beach nourishment activities could negatively impact sea turtles regardless of the timing of project. Very fine sand or the use of heavy machinery can cause sand compaction on nourished beaches (Nelson et al. 1987; Nelson and Dickerson 1988a). Significant reductions in nesting success (i.e., false crawls occurred more frequently) have been documented on severely compacted nourished beaches (Fletemeyer 1980; Raymond 1984; Nelson and Dickerson 1987; Nelson et al. 1987), and increased false crawls may result in increased physiological stress to nesting females. Sand compaction may increase the length of time required for female sea turtles to excavate nests and cause increased physiological stress to the animals (Nelson and Dickerson 1988b). These impacts can be minimized by using suitable sand.

The presence of any derelict tires or shredded bits of tires in the dredged sediment could negatively impact sea turtles regardless of timing of the project. The Corps' contractor should be able to remove larger tire pieces relatively easily, with heavy equipment or by hand. Smaller pieces may require beach raking or other screening activities. If pieces are too small to be captured by a beach rake or screen, they will likely remain on the beach until the placed sediment erodes and is no longer present.

A change in sediment color on a beach could change the natural incubation temperatures of nests in an area, which, in turn, could alter natural sex ratios. To provide the most suitable sediment for nesting sea turtles, the color of the nourished sediments should resemble the natural beach sand in the area. Natural reworking of sediments and bleaching from exposure to the sun would help to lighten dark nourishment sediments; however, the timeframe for sediment mixing and bleaching to occur could be critical to a successful sea turtle nesting season.

b. Escarpment formation

On nourished beaches, steep escarpments may develop along their water line interface as they adjust from an unnatural construction profile to a more natural beach profile (Coastal Engineering Research Center 1984; Nelson et al. 1987). Escarpments can hamper or prevent access to nesting sites (Nelson and Blihovde 1998). Researchers have shown that female sea turtles coming ashore to nest can be discouraged by the formation of an escarpment, leading to situations where they choose marginal or unsuitable nesting areas to deposit eggs (e.g., in front of the escarpments, which often results in failure of nests due to prolonged tidal inundation). This impact can be minimized by leveling any escarpments prior to the nesting season.

c. Increased susceptibility to catastrophic events

Nest relocation within a nesting season may concentrate eggs in an area making them more susceptible to catastrophic events. Hatchlings released from concentrated areas also may be subject to greater predation rates from both land and marine predators because the predators learn where to concentrate their efforts (Glenn 1998; Wyneken et al. 1998).

d. Increased beachfront development

Pilkey and Dixon (1996) stated that beach replenishment frequently leads to more development in greater density within shorefront communities that are then left with a future of further replenishment or more drastic stabilization measures. Dean (1999) also noted that the very existence of a beach nourishment project can encourage more development in coastal areas. Following completion of a beach nourishment project in Miami during 1982, investment in new and updated facilities substantially increased tourism there (NRC 1995). Increased building density immediately adjacent to the beach often resulted as much larger buildings that accommodated more beach users replaced older buildings. Overall, shoreline management creates an upward spiral of initial protective measures resulting in more expensive development that leads to the need for more and larger protective measures. Increased shoreline development may adversely affect sea turtle nesting success. Greater development may support larger populations of mammalian predators, such as foxes and raccoons, than undeveloped areas (NRC 1990a), and can also result in greater adverse effects due to artificial lighting, as discussed above.

Beneficial Effects: The placement of sand on a beach with reduced dry foredune habitat may increase sea turtle nesting habitat if the placed sand is highly compatible (i.e., grain size, shape, color, etc.) with naturally occurring beach sediments in the area, and compaction and escarpment remediation measures are incorporated into the project. In addition, a nourished beach that is designed and constructed to mimic a natural beach system may benefit sea turtles more than an eroding beach it replaces.

Responses and Interpretation of Effects

Sand placement activities may impact nesting and hatchling sea turtles and sea turtle nests occurring along up to 15,560 lf of shoreline in Wrightsville Beach. Sand placement activities would occur within and adjacent to nesting habitat for sea turtles and dune habitats that ensure the stability and integrity of the nesting beach. Specifically, the project would potentially impact leatherback, loggerhead, green, Kemp's ridley, and hawksbill nesting females, their nests, and hatchling sea turtles. The Service expects the proposed construction activities could directly and indirectly affect the availability of habitat for nesting and hatchling sea turtles. The timing of the sand placement activities could directly and indirectly impact nesting females, their nests, and hatchling sea turtles when conducted between May 1 and November 15.

The effects of sand placement activities may change the nesting behavior of adult female sea turtles, diminish nesting success, and cause reduced hatching and emerging success. Sand placement can also change the incubation conditions within the nest. Any decrease in productivity and/or survival rates would contribute to the vulnerability of the sea turtles nesting in the southeastern U.S.

During the first post-construction year, nests on nourished beaches are deposited significantly seaward of the toe of the dune and significantly landward of the tide line than nests on natural beaches. More nests are washed out on the wide, flat beaches of the nourished treatments than on the narrower steeply sloped natural beaches. This phenomenon may persist through the second post-construction year monitoring and result from the placement of nests near the seaward edge of the beach berm where dramatic profile changes, caused by erosion and scarping, occur as the beach equilibrates to a more natural contour.

The principal effect of beach nourishment on sea turtle reproduction is a reduction in nesting success during the first year following project construction. Although most studies have attributed this phenomenon to an increase in beach compaction and escarpment formation, Ernest and Martin (1999) indicated that changes in beach profile may be more important. Regardless, as a nourished beach is reworked by natural processes in subsequent years and adjusts from an unnatural construction profile to a natural beach profile, beach compaction and the frequency of escarpment formation decline, and nesting and nesting success return to levels found on natural beaches.

The sand placement activity is a one-time activity. Thus, the direct effects would be expected to be short-term in duration. Indirect effects from the activity may continue to impact nesting and hatchling sea turtles and sea turtle nests in subsequent nesting seasons. Disturbance from any necessary tire debris removal efforts may have long-term impacts, particularly if required in future years.

For this and other sand placement BOs, the Service typically uses a surrogate to estimate the extent of take. The amount of take is directly proportional to the spatial/temporal extent of occupied habitat that the Action affects, and exceeding this extent would represent a taking that is not anticipated in this BO. The Service anticipates incidental take of sea turtles will be difficult to detect for the following reasons: (1) the turtles nest primarily at night and all nests are not found because [a] natural factors, such as rainfall, wind, and tides may obscure crawls and [b] human-caused factors, such as pedestrian and vehicular traffic, may obscure crawls, and result in nests being destroyed because they were missed during a nesting survey, nest mark and avoidance, or egg relocation program (2) the total number of hatchlings per undiscovered nest is unknown; (3) the reduction in percent hatching and emerging success per relocated nest over the natural nest site is unknown; (4) an unknown number of females may avoid the project beach and be forced to nest in a less than optimal area; (5) lights may misdirect an unknown number of hatchlings and cause death; and (6) escarpments may form and prevent an unknown number of females from accessing a suitable nesting site.

However, the level of take of these species can be anticipated by the sand placement activities on suitable turtle nesting beach habitat because: (1) turtles nest within the Action Area; (2) the nourishment project will modify the incubation substrate, beach slope, and sand compaction; and (3) artificial lighting will deter and/or misdirect nesting hatchling turtles.

4.4. Cumulative Effects on Sea Turtle Species

In section 3, we did not identify any activities that satisfy the regulatory criteria for sources of cumulative effects. Therefore, cumulative effects to sea turtle species are not relevant to formulating our opinion for the Action.

4.5. Conclusion for Sea Turtle Species

In this section, we summarize and interpret the findings of the previous sections (status, baseline, effects, and cumulative effects) relative to the purpose of the BO for the loggerhead, green, leatherback, Kemp's ridley, and hawksbill sea turtle, which is to determine whether the Action is likely to jeopardize the continued existence of each species.

Status

Leatherback, Kemp's ridley, green, hawksbill, and loggerhead sea turtles have been documented nesting in North Carolina. Between 2009 and 2021, only loggerhead sea turtle nests were documented nesting within the project area. However, the leatherback, Kemp's ridley, and green sea turtles have all be documented nesting on adjacent beaches.

There are many threats to sea turtles, including nest destruction from natural events, such as tidal surges and hurricanes, or eggs lost to predation by raccoons, foxes, ghost-crabs, and other animals. However, human activity has significantly contributed to the decline of sea turtle populations along the Atlantic Coast and in the Gulf of Mexico (NRC 1990). These factors include the modification, degradation, or loss of nesting habitat by coastal development, artificial lighting, beach driving, and marine pollution and debris. Furthermore, the overharvest of eggs for food, intentional killing of adults and immature turtles for their shells and skin, and accidental drowning in commercial fishing gear are primarily responsible for the worldwide decline in sea turtle populations.

Baseline

The Action Area is quite developed. Residential/commercial development has steadily increased since the early to mid- 1900s. The entire Action Area is presently lined with structures, including homes, motels, restaurants, and gift shops. Recreational use in the Action Area is quite high from residents and tourists. A wide range of recent and on-going activities have altered the proposed Action Area and, to a greater extent, the North Carolina coastline, and many more are proposed along the coastline for the near future.

Effects

Sand placement activities may impact nesting and hatchling sea turtles and sea turtle nests occurring along up to 15,560 lf of shoreline in Wrightsville Beach. Sand placement activities would occur within and adjacent to nesting habitat for sea turtles and dune habitats that ensure the stability and integrity of the nesting beach. The project would potentially impact loggerhead, leatherback, green, Kemp's ridley, and hawksbill nesting females, their nests, and hatchling sea turtles. The Service expects the proposed construction activities could directly and indirectly affect the availability of habitat for nesting and hatchling sea turtles. The timing of the sand placement activities could directly and indirectly impact nesting females, their nests, and hatchling sea turtles when conducted between May 1 and November 15. Any necessary removal of derelict tires or other incompatible materials may directly and indirectly affect the availability or quality of habitat for nesting and hatching sea turtles in future years.

The Service determined there is a potential for long-term adverse effects on sea turtles as a result of sand placement. However, the Service acknowledges the potential benefits of the sand placement project, since it provides additional sea turtle nesting habitat. Nonetheless, an increase in sandy beach may not necessarily equate to an increase in suitable sea turtle nesting habitat.

Opinion

After reviewing the current status of the nesting sea turtle species, the environmental baseline for the Action Area, the effects of the proposed activities, the proposed Conservation Measures, and the cumulative effects, it is the Service's biological opinion that the placement of sand is not likely to jeopardize the continued existence of the loggerhead sea turtle, leatherback sea turtle, green sea turtle, Kemp's ridley sea turtle, and hawksbill sea turtle.

5. PIPING PLOVER

5.1. Piping Plover Status

This section summarizes best available data about the biology and current condition of piping plover (*Charadrius melodus*) throughout its range that are relevant to formulating an opinion about the Action. 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 (USFWS 1985).

Multiple recovery plans and 5-year reviews have been developed for the three piping plover populations since listing, including a 1988 recovery plan and 1994 revised draft recovery plan for the Great Lakes and Northern Great Plains populations (USFWS 1998; USFWS 1994), a 1996 revised recovery plan for the Atlantic Coast breeding population (USFWS 1996a), a 2003 recovery plan for the Great Lakes population (USFWS 2003a), a document outlining the comprehensive conservation strategy (CCS) for the piping plover in its coastal migration and wintering range (USFWS 2012), and a 2016 recovery plan for the Northern Great Plains piping plover (USFWS 2015), which incorporates an updated CCS.

Our most recent 5-year status review of the species recommended retaining the current ESA classification (USFWS 2009c). The status review also summarized data that would support classifying the piping plover for ESA purposes as two subspecies, *C. m. melodus* (Atlantic Coast breeding population), and *C. m. circumcinctus.* Additional data would support classifying the latter as two discrete breeding populations: (a) the Northern Great Plains of the U.S. and Canada, and (b) the Great Lakes watershed of the U.S. and Canada. However, the review concludes that revising the classification accordingly would have little regulatory or conservation effect, because the current classification appropriately represents the status of the three breeding populations.

5.1.1. Description of Piping Plover

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). Piping plovers that breed on the Atlantic Coast of the U.S. and Canada belong to the subspecies *C. m. melodus*. The second subspecies, *C. m. circumcinctus*, is comprised of two Distinct Population Segments (DPSs). One DPS breeds on the Northern Great Plains of the U.S. and Canada, while the other breeds on the Great Lakes. Each of these three entities is demographically independent. The piping plover winters in coastal areas of the 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).

North Carolina is one of the only states where piping plovers' breeding and wintering ranges overlap, and the birds are present year-round. Piping plovers in the Action Area may include individuals from all three breeding populations. Piping plover subspecies are phenotypically indistinguishable, and most studies in the nonbreeding range report results without regard to breeding origin. Although a 2012 analysis shows strong patterns in the wintering distribution of piping plovers from different breeding populations (Gratto-Trevor et al. 2012), partitioning is not complete and major information gaps persist.

5.1.2. Life History of Piping Plover

Named for its melodic mating call, the piping plover is a pale-colored shorebird about the size of a robin. Length is 17–18 cm; weight is 43–63 g. Plumage, bill, and leg coloration are slightly different between the breeding season and winter, between juveniles and adults, and between males and females. Cryptic coloration is a primary defense mechanism for piping plovers where nests, adults, and chicks all blend in with their typical beach surroundings.

Piping plovers live an average of 5 years, although studies have documented birds as old as 11 (Wilcox 1959) and 15 years (Audubon Society 2017). Plovers are known to begin breeding as early as one year of age (MacIvor 1990; Haig 1992). In studies with large numbers of marked interior breeding piping plovers, Saunders et al. (2014) found that 56 percent of female Great Lakes piping plovers mated in their first season post-hatch, while 68 percent of female yearlings mated in Saskatchewan in 2001-2006 (Gratto-Trevor et al. 2010). Both studies found that probability of breeding in the first year was lower for males than females, but Great Lakes males that had not bred earlier were more likely than females to recruit into the breeding population in years two and three. Virtually all surviving Great Lakes piping plovers began breeding by year three (Saunders et al. 2014). Piping plover 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). Piping plovers generally fledge only a single brood per season but may re-nest several times if previous nests are lost. The reduction in suitable nesting habitat due to a number of factors is a major threat to the species, likely limiting reproductive success and future recruitment into the population (USFWS 2009a).

Plovers depart their breeding grounds for their wintering grounds between July and late August, but southward migration extends through November. More information about the three breeding populations of piping plovers can be found in the following documents:

a. Piping Plover, Atlantic Coast Population: 1996 Revised Recovery Plan (USFWS 1996a);
b. 2009 Piping Plover (*Charadrius melodus*) 5-Year Review: Summary and Evaluation (USFWS 2009a);
c. 2003 Recovery Plan for the Great Lakes Piping Plover (*Charadrius melodus*) (USFWS 2003a);
d. Questions and Answers about the Northern Great Plains population of Piping Plover (USFWS 2002).
e. 2016 Draft Revised Recovery Plan for the Northern Great Plains population of Piping Plover (USFWS 2015).

Atlantic Coast plovers nest on coastal beaches, sand flats at the ends of sand spits and barrier islands, gently-sloped foredunes, sparsely-vegetated dunes, and washover areas cut into or between dunes. The species requires broad, open, sand flats for feeding, and undisturbed flats with low dunes and sparse dune grasses for nesting. Plovers arrive on the breeding grounds from mid-March through mid-May and remain for three to four months per year; the Atlantic Coast plover breeding activities begin in March in North Carolina with courtship and territorial establishment (Coutu et al. 1990; McConnaughey et al. 1990). Following establishment of nesting territories and courtship rituals, the pair forms a depression in the sand, where the female lays her eggs. Egg-laying begins around mid-April with nesting and brood rearing activities continuing through July. They lay three to four eggs in shallow, scraped depressions lined with light colored pebbles and shell fragments. The eggs are well camouflaged and blend extremely well with their surroundings. Chicks are precocial, often leaving the nest within hours of hatching, but are tended by adults who lead the chicks to and from feeding areas, shelter them from harsh weather, and protect the young from perceived predators. Chicks remain together with one or both parents until they fledge (are able to fly) at 25 to 35 days of age. By early September both adults and young depart for their wintering areas.

Breeding and wintering plovers feed on exposed wet sand in swash zones; intertidal ocean beach; wrack lines; washover passes; mud, sand, and algal flats; and shorelines of streams, ephemeral ponds, lagoons, and salt marshes by probing for invertebrates at or just below the surface (Coutu et al. 1990; USFWS 1996a). Behavioral observations of piping plovers on the wintering grounds suggest that they spend the majority of their time foraging and roosting (Nicholls and Baldassarre 1990; Drake 1999a; 1999b; Maddock et al. 2009). 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 found on top of the soil or just beneath the surface (Bent 1929; Cairns 1977; Nicholls 1989; Zonick and Ryan 1996). They use beaches adjacent to foraging areas for roosting and preening. Small sand dunes, debris, and sparse vegetation within adjacent beaches provide shelter from wind and extreme temperatures.

Piping plovers from the federally endangered Great Lakes population as well birds from the threatened populations of the Atlantic Coast and Northern Great Plains overwinter on North Carolina beaches. 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. Data based on four rangewide mid-winter (late January to early February) population surveys, conducted at 5-year intervals starting in 1991, show that total numbers have fluctuated over time, with some areas experiencing increases and others decreases. Regional and local fluctuations may reflect the quantity and quality of suitable foraging and roosting habitat, which vary over time in response to natural coastal formation processes as well as anthropogenic habitat changes (e.g., inlet relocation, dredging of shoals and spits). Fluctuations may also represent localized weather conditions (especially wind) during surveys, or unequal survey coverage. 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.

Piping plovers exhibit a high degree of intra- and interannual wintering site fidelity (Nicholls and Baldassarre 1990b; Drake et al. 2001; Noel and Chandler 2008; Stucker and Cuthbert 2006; Gibson et al. 2017). However, local movements during winter 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 11.2 mi by approximately 10 percent of the banded population. Larger movements within South Carolina were seen during fall and spring migration.

5.1.3. Numbers, Reproduction, and Distribution of Piping Plover

The International Piping Plover Breeding Census is conducted throughout the breeding grounds every 5 years by the Great Lakes/Northern Great Plains Recovery Team of the U.S. Geological Survey (USGS). Although there are shortcomings in the census method, it is the largest known, complete avian species census. The 2011 survey documented 2,391 breeding pairs, with a total of 5,723 birds throughout Canada and the U.S. (Elliot-Smith et al. 2015).

The most consistent finding in the various population viability analyses conducted for piping plovers (Ryan et al. 1993; Melvin and Gibbs 1996; Plissner and Haig 2000; Amirault et al. 2005; Calvert et al. 2006; Brault 2007; Gibson et al. 2018) indicates even small declines in adult and juvenile survival rates will cause increases in extinction risk. A banding study conducted between 1998 and 2004 in Atlantic Canada concluded lower return rates of juvenile (first year) birds to the breeding grounds than was documented for Massachusetts (Melvin and Gibbs 1996), Maryland (Loegering 1992), and Virginia (Cross 1996) breeding populations in the mid-1980s and very early 1990s. This is consistent with failure of the Atlantic Canada population to increase in abundance despite high productivity (relative to other breeding populations) and extremely low rates of dispersal to the U.S. over the last 15 plus years (Amirault et al. 2005).

Northern Great Plains Population

The Northern Great Plains plover breeds from Alberta to Manitoba, Canada and south to Nebraska; although some nesting has occurred in Oklahoma (Boyd 1991). Currently the most westerly breeding piping plovers in the U.S. occur in Montana and Colorado.

The Northern Great Plains breeding population is geographically widespread, with many birds in very remote places, especially in the U.S. and Canadian alkali lakes. The decline of piping plovers on rivers in the Northern Great Plains has been largely attributed to the loss of sandbar island habitat and forage base due to dam construction and operation. Nesting occurs on sand flats or bare shorelines of rivers and lakes, including sandbar islands in the upper Missouri River system, and patches of sand, gravel, or pebbly mud on the alkali lakes of the northern Great Plains. Plovers do nest on shorelines of reservoirs created by the dams, but reproductive success is often low and reservoir habitat is not available in many years due to high water levels or vegetation. Dams operated with steady constant flows allow vegetation to grow on potential nesting islands, making these sites unsuitable for nesting. Population declines in alkali wetlands are attributed to wetland drainage, contaminants, and predation.

Every fifth year since 1991, the USGS has coordinated a range wide International Piping Plover Census (IPPC) on both the species' wintering and breeding grounds. Results from the most recent census in 2016 are not yet published. The IPPC numbers indicate that the Northern Great Plains breeding population (including Canada) declined from 1991 through 2001, and then increased dramatically in 2006. This increase corresponded with a multi-year drought in the Missouri River basin that exposed a great deal of nesting habitat, suggesting that the population can respond fairly rapidly to changes in habitat quantity and quality. Despite this improvement, we do not consider the elements of the population recovery criteria achieved.

As the Missouri River basin emerged from drought and breeding habitat was inundated in subsequent years after 2006, the population declined (**Figure 5-1**). Combined with the numbers from Canada, the IPPC numbers suggest that the population declined from 1991 through 2001, then increased almost 58% between 2001 and 2006 (Elliott-Smith et al. 2009). The 2011 breeding census count was substantially lower than the count in 2006 (over 4,500 birds in 2006 and 2,249 in 2011) (Elliott-Smith et al. 2015). It is unknown if the decrease in counts is an accurate accounting of the piping plover population numbers, or if birds were not counted due to displacement from flooding in the region that made traditional habitat unsuitable. The management activities carried out in many areas during drought conditions undoubtedly helped to maintain and increase the piping plover population, especially to mitigate for otherwise poor reproductive success during wet years when habitat is limited.

In the 2009 status review, the Service concluded that the Northern Great Plains breeding population remains vulnerable, especially due to management of river systems throughout the breeding range (USFWS 2009a). Many of the threats identified in the 1988 recovery plan, including those affecting Northern Great Plains breeding population during the two-thirds of its annual cycle spent in the wintering range, remain today or have intensified.

Great Lakes Breeding Population

The Great Lakes plovers once nested on Great Lakes beaches in Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, Wisconsin, and Ontario. Great Lakes piping plovers nest on wide, flat, open, sandy or cobble shoreline with very little grass or other vegetation. Reproduction is adversely affected by human disturbance of nesting areas and predation by foxes, gulls, crows, and other avian species. Shoreline development, such as the construction of marinas, breakwaters, and other navigation structures, has adversely affected nesting and brood rearing.

The Recovery Plan (USFWS 2003a) 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 breeding population, which has been traditionally represented as the number of breeding pairs, has slowly increased after the completion of the recovery plan between 2003 and 2016 (**Figure 5-2**) (Cuthbert and Roche 2007; Cuthbert and Roche 2006; Westbrock et al. 2005; Stucker and Cuthbert 2004; Stucker et al. 2003; Cuthbert and Saunders 2013). The Great Lakes piping plover recovery plan documents the 2002 population at 51 breeding pairs (USFWS 2003a), and in 2016, 75 breeding pairs were estimated (Cavalieri pers. comm. 2016a). The total of 75 breeding pairs represents 50% of the current recovery goal of 150 breeding pairs for the Great Lakes breeding population. Productivity goals, as specified in the 2003 recovery plan, have been met over the past 5 years. During this time period the average annual fledging rate has varied, but averages about 1.7, well above the 1.5 fledglings per breeding pair recovery goal (Cavalieri pers. comm. 2016d). It is the productivity rate, or recruitment rate, that has continued to increase the overall population, despite considerable decreases in adult survival rates. Continued population growth will require the long-term maintenance of productivity goals concurrent with measures to sustain or improve important vital rates.

The Great Lakes annual monitoring program is an intensive survey effort with nearly daily monitoring of active breeding locations. Virtually all of the Great Lakes individuals are banded, unlike individuals from the Atlantic Coast or Northern Great Plains breeding populations. Chicks also receive bands identifying the brood to which they belong and receive an individual band when returning to the breeding grounds after surviving their first year. Banding of Great Lakes birds began in 1993 (University of Minnesota 2017). The probability of detection of adults during the breeding season is near perfect (95-97%). Several years of population growth is evidence of the effectiveness of the ongoing Great Lakes piping plover recovery program. However, the average annual growth of just less than 2.3% in this small population typically results in only 3 or 4 additional surviving individuals each year (Catlin pers. comm. 2016a).

In the 2009 status review, the Service concluded that the Great Lakes breeding population remains at considerable risk of extinction due to its small size, limited distribution, and vulnerability to stochastic events, such as disease outbreak (USFWS 2009a). In addition, the factors that led to the piping plover's 1986 listing remain present.

Atlantic Coast Population

The Atlantic Coast piping plover breeds on coastal beaches from Newfoundland and southeastern Quebec to North Carolina. Historical population trends for the Atlantic Coast piping plover have been reconstructed from scattered, largely qualitative records. Nineteenth-century naturalists, such as Audubon and Wilson, described the piping plover as a common summer resident on Atlantic Coast beaches (Haig and Oring 1987). However, by the beginning of the 20th century, egg collecting and uncontrolled hunting, primarily for the millinery trade, had greatly reduced the population, and in some areas along the Atlantic Coast, the piping plover was close to extirpation. Following passage of the Migratory Bird Treaty Act (MBTA) (40 Stat. 775; 16 U.S.C. 703-712) in 1918, and changes in the fashion industry that no longer exploited wild birds for feathers, piping plover numbers recovered to some extent (Haig and Oring 1985).

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). While Wilcox (1939) estimated more than 500 pairs of piping plovers on Long Island, New York, the 1989 population estimate was 191 pairs (see Table 4, USFWS 1996a). 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.

Substantial population growth, from approximately 790 pairs in 1986 to an estimated 1,870 pairs in 2015, has decreased the Atlantic Coast piping plover's vulnerability to extinction since ESA listing (**Figure 5-3**). Thus, considerable progress has been made towards the overall goal of 2,000 breeding pairs. As discussed in the 1996 revised recovery plan, however, the overall security of the Atlantic Coast piping plover is fundamentally dependent on even distribution of population growth, as specified in subpopulation targets, to protect a sparsely distributed species with strict biological requirements from environmental variation (including catastrophes) and increase the likelihood of interchange among subpopulations. Population growth has been tempered by geographic and temporal variability. By far, the largest net population increase between 1989 and 2015 occurred in New England (445 percent). Net growth in the southern recovery unit population was over 182 percent between 1989 and 2015, but the subpopulation recovery target has not yet been attained. Preliminary estimates indicate abundance in the New York-New Jersey recovery unit experienced a net increase of 129 percent between 1989 and 2015. However, the population declined sharply from a peak of 586 pairs in 2007 and has still not recovered, with only 411 pairs in 2015. In Eastern Canada, where increases have often been quickly eroded in subsequent years, the population posted a 25-percent decline between 1989 and 2015.

Twenty years of relatively steady population growth, driven by productivity gains, evidences the efficacy of the ongoing Atlantic Coast piping plover recovery program. However, all of the major threats identified in the 1986 ESA listing and 1996 revised recovery plan remain persistent and pervasive along the Atlantic Coast. Because threats to Atlantic Coast piping plovers remain or have increased since listing, reversal of gains in abundance and productivity would quickly follow diminishment of current protection efforts. In the 2009 status review, the Service concluded that the Atlantic Coast piping plover remains vulnerable to low numbers in the Southern and Eastern Canada (and, to a lesser extent, the New York-New Jersey) Recovery Units (USFWS 2009a).

Non-breeding Range

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 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. Coastal migration stopovers by banded piping plovers from the Great Lakes region have been documented in New Jersey, Maryland, Virginia, North Carolina, South Carolina, and Georgia (Stucker et al. 2010). Migrating birds from eastern Canada have been observed in Massachusetts, New Jersey, New York, and North Carolina (Amirault et al. 2005). Piping plovers banded in the Bahamas have been sighted during migration in nine Atlantic Coast states and provinces between Florida and Nova Scotia (Gratto-Trevor pers. comm. 2012a). In general, the distance between stopover locations and the duration of stopovers throughout the coastal migration range remain poorly understood (USFWS 2015).

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.

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. 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. This species exhibits a high degree of intra- and inter-annual wintering site fidelity (Noel and Chandler 2008; Cohen and Gratto-Trevor 2011; Gratto-Trevor et al. 2016; Drake et al. 2001; Noel et al. 2005; Stucker and Cuthbert 2006), even when encountering a high level of environmental disturbance (Gibson et al. 2017; 2018). 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). In the years following the 2010 Deepwater Horizon oil spill, Gibson et al. (2017) found that, in spite of significant environmental disturbance, most individuals returned to and persisted at the same wintering site.

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 18 km by approximately 10% 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). In Cape Lookout National Seashore, wintering banded birds were surveyed along Shackleford Banks. Individual birds were always observed in the same general area over multiple seasons, indicating that the wintering birds are very site-specific and return to the same area in consecutive years (NPS 2003).

The majority of birds from the Canadian Prairie were observed in Texas (particularly southern Texas), while individuals from the U.S. Great Plains were more widely distributed on the Gulf Coast from Texas to Florida. Seventy-nine percent of 57 piping plovers banded in the Bahamas in 2010 were reported breeding on the Atlantic Coast; one was resighted in the Northern Great Plains (Catlin pers. comm. 2012a). Furthermore, consistent with patterns observed in other parts of the wintering range, a few individuals banded in the Great Lakes and Northern Great Plains breeding populations have been observed in the Bahamas (Gratto-Trevor pers. comm. 2012; Catlin pers. comm. 2012a). Collectively, these studies demonstrate an intermediate level of connectivity between breeding and wintering areas. Specific breeding populations will be disproportionately affected by habitat and threats occurring where they are most concentrated in the winter (USFWS 2015).

Five rangewide mid-winter IPPCs are summarized in **Table 5-1.** Total numbers have fluctuated over time, with some areas experiencing increases and others decreases. Regional and local fluctuations may reflect the quantity and quality of suitable foraging and roosting habitat, which vary over time in response to natural coastal formation processes as well as anthropogenic habitat changes (e.g., inlet relocation, dredging of shoals and spits). Fluctuations may also represent localized weather conditions (especially wind) during surveys, or unequal survey coverage. 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.

IPPC surveys may substantially underestimate the abundance of nonbreeding piping plovers using a site or region during other months. In late September 2007, 104 piping plovers were counted at the south end of Ocracoke Island, North Carolina (NPS 2007), where none were seen during the 2006 International Piping Plover January Winter Census (Elliott-Smith et al. 2009). Further, Weithman et al. (2018) estimated that 569 piping plovers (mostly Atlantic population) utilize the south end of Ocracoke Island as a migration stopping point. This represents approximately 15% of the Atlantic population, and 10% of all piping plover populations combined. Noel et al. (2007) observed up to 100 piping plovers during peak migration at Little St. Simons Island, Georgia, where approximately 40 piping plovers wintered in 2003–2005. Differences among fall, winter, and spring counts in South Carolina were less pronounced, but inter-year fluctuations (e.g., 108 piping plovers in spring 2007 versus 174 piping plovers in spring 2008) at 28 sites were striking (Maddock et al. 2009). Even as far south as the Florida Panhandle, monthly counts at Phipps Preserve in Franklin County ranged from a mid-winter low of four piping plovers in December 2006 to peak counts of 47 in October 2006 and March 2007 (Smith 2007).

5.1.4. Conservation Needs of and Threats to Piping Plover

Reason for Listing

Piping plovers were listed principally because of habitat destruction and degradation, predation, and human disturbance. Hunting during the 19th and early 20th centuries likely led to initial declines in the species; however, shooting piping plovers has been prohibited since 1918 pursuant to the provisions of the MBTA. Other human activities, such as habitat loss and degradation, disturbance from recreational pressure, contaminants, and predation are likely responsible for continued declines. The final rule also stated, in addition to extensive breeding area problems, the loss and modification of wintering habitat was a significant threat to the piping plover.

Recovery Criteria

Delisting of the three piping plover populations may be considered when the following criteria are met:

Northern Great Plains Breeding Population (USFWS 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).

In 2016, the Service drafted new recovery criteria for the Northern Great Plains breeding population. The new criteria are expected to be finalized in the near future.

Great Lakes Breeding Population (USFWS 2003a)

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 Breeding Population (USFWS 1996a)

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

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

2. Verify the adequacy of a 2,000 pair population of piping plovers to maintain heterozygosity and allelic diversity over the long term.
3. Achieve a 5-year average productivity of 1.5 fledged chicks per pair in each of the 4 recovery units described in criterion 1, based on data from sites that collectively support at least 90% of the recovery 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.

Conservation Recommendations

Nonbreeding Plovers from All Three Breeding Populations (USFWS 2012)

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

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

At inlets, foraging plovers are associated with moist substrate features such as intertidal flats, algal flats, and ephemeral pools (Nicholls and Baldassarre 1990a; Wilkinson and Spinks 1994; Dinsmore et al. 1998).

Threats to Piping Plovers

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, groins, and revetments, could eliminate wintering areas and alter sedimentation patterns leading to the loss of nearby habitat. Unregulated motorized and pedestrian recreational use, inlet and shoreline stabilization projects, beach maintenance and nourishment, and pollution affect most winter and migration areas. Data from studies at Hilton Head, Kiawah Island, and other locations in South Carolina and Georgia demonstrate that impacts from poor winter habitat conditions can be seen the following year on the breeding grounds (Saunders et al. 2014; Gibson et al. 2016). Piping plovers wintering at areas with fewer anthropogenic disturbances had higher survival, recruitment, and population growth rates than areas with greater disturbance.

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. As discussed in more detail below, all these efforts result in loss of piping plover habitat. These threats are exacerbated by accelerating sea level rise, which increases erosion and habitat loss where existing development and hardened stabilization structures prevent the natural migration of the beach and/or barrier island. Construction 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. In addition, up to 24 shorebird species migrate or winter along the Atlantic Coast and almost 40 species of shorebirds are present during migration and wintering periods in the Gulf of Mexico region (Helmers 1992). Continual degradation and loss of habitats used by wintering and migrating shorebirds may cause an increase in intra-specific and inter-specific competition for remaining food supplies and roosting habitats. The shrinking extent of shoreline that supports natural coastal formation processes concentrates foraging and roosting opportunities for all shorebird species and forces some individuals into suboptimal habitats. Thus, intra- and inter-specific competition most likely exacerbates threats from habitat loss and degradation. The 2016 draft CCS includes a table to help the reader determine the relative importance of each threat, ranked as low, medium, or high based on how much of a threat they are to the wintering population (**Table 5-2)**.

Loss, modification, and degradation of habitat

The wide, flat, sparsely vegetated barrier beaches, spits, sandbars, and bayside flats preferred by piping plovers in the U.S. are formed and maintained by natural forces and are thus susceptible to degradation caused by development and shoreline stabilization efforts.

Development and Construction

Development and associated construction threaten the piping plover in its migration and wintering range by degrading, fragmenting, and eliminating habitat. Constructing buildings and infrastructure adjacent to the beach can eliminate roosting and loafing habitat within the development's footprint and degrade adjacent habitat by replacing sparsely vegetated dunes or back-barrier beach areas with landscaping, pools, fences, etc. In addition, bayside development can replace foraging habitat with finger canals, bulkheads, docks, and lawns. High-value plover habitat becomes fragmented as lots are developed or coastal roads are built between oceanside and bayside habitats.

There are approximately 2,119 mi of sandy beaches within the U.S. continental wintering range of the piping plover (Rice 2012b). Approximately 40% (856 mi) of these sandy beaches are developed, with mainland Mississippi (80%), Florida (57%), Alabama (55%), South Carolina (51%), and North Carolina (49%) comprising the most developed coasts (Rice 2012b). Developed beaches are highly vulnerable to further habitat loss because they cannot migrate in response to sea level rise.

Rice (2012b) has identified over 900 mi (43%) of sandy beaches in the wintering range that are currently "preserved" through public ownership, ownership by non-governmental conservation organizations, or conservation easements. This means that the remaining 17% of shoreline habitat (that which is currently undeveloped but not preserved) is susceptible to future loss to development and the attendant threats from shoreline stabilization activities and sea level rise. These preserved beaches may be subject to some erosion as they migrate in response to sea level rise or if sediment is removed from the coastal system, and they are vulnerable to recreational disturbance. However, they are the areas most likely to maintain the geomorphic characteristics of suitable piping plover habitat.

Inlet Dredging and Sand Mining

The dredging and mining of sediment from inlet complexes threatens the piping plover on its wintering grounds through habitat loss and degradation. The maintenance of navigation channels by dredging, especially deep shipping channels such as those in Alabama and Mississippi can significantly alter the natural coastal processes on inlet shorelines of nearby barrier islands, as described by Otvos (2006), Morton (2008), Otvos and Carter (2008), and Stockdon et al. (2010). Inlet shoals consist of ebb shoals, formed by wave action interacting with the ebb tidal flow, and flood shoals, formed through supply and deposition from the littoral system into the bay during flood tide. Sediment initially is deposited in the near-field flood zone, closest to the inlet entrance. A far-field zone forms through the spreading of sediment from the near-field zone farther into the bay (Carr de Betts, 1999). Cialone and Stauble (1998) describe the impacts of mining ebb shoals within inlets as a source of beach fill material at eight locations and provide a recommended monitoring protocol for future mining events; Dabees and Kraus (2008) also describe the impacts of ebb shoal mining in southwest Florida. There are very few studies on the impacts of flood shoal mining.

Forty-four percent of the tidal inlets within the U.S. wintering range of the piping plover have been or continue to be dredged, primarily for navigational purposes. States where more than two-thirds of inlets have been dredged include Alabama (three of four), Mississippi (four of six), North Carolina (16 of 20), and Texas (13 of 18), and 16 of 21 along the Florida Atlantic coast. The dredging of navigation channels or relocation of inlet channels for erosion-control purposes contributes to the cumulative effects of inlet habitat modification by removing or redistributing the local and regional sediment supply; the maintenance dredging of deep shipping channels can convert a natural inlet that normally bypasses sediment from one shoreline to the other into a sediment sink, where sediment no longer bypasses the inlet.

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

Inlets associated with ports and other high-traffic areas typically have maintenance dredging conducted annually, if not more often. At five shallow-draft inlets (Bogue, Topsail, Carolina Beach, and Lockwoods Folly) the Corps has typically dredged the inlet on a quarterly basis and maintained inlet crossings and connecting channels every 1-2 years (NCDENR, 2015). Local governments have received authorization to also conduct maintenance dredging of these inlets on the same general schedule, with beach disposal during the winter work window. Inlets that are mined for Coastal Storm Damage Reduction (CSDR) projects (conducted by the Corps or local governments) are typically dredged on three-year intervals, with placement of the sand on the adjacent shoreline. Dredging may remove intertidal shoals and unvegetated sandy habitat on inlet shoulders. These types of activities are typically conducted during the winter work window to avoid impacts to nesting sea turtles but may have significant impacts to migrating and overwintering piping plovers.

As sand sources for beach nourishment projects have become more limited, the mining of ebb tidal shoals for sediment has increased (Cialone and Stauble 1998). This is a problem because exposed ebb and flood tidal shoals and sandbars are prime roosting and foraging habitats for piping plovers. In general, such areas are only accessible by boat; and as a result, they tend to receive less human recreational use than nearby mainland beaches. Rice (2012a) found that the ebb shoal complexes of at least 20 inlets within the wintering range of the piping plover have been mined for beach fill. Ebb shoals are especially important because they act as “sand bridges” that connect beaches and islands by transporting sediment via longshore transport from one side (updrift) to the other (downdrift) side of an inlet. The mining of sediment from these shoals upsets the inlet system equilibrium and can lead to increased erosion of the adjacent inlet shorelines (Cialone and Stauble 1998). Rice (2012a) noted that this mining of material from inlet shoals for use as beach fill is not equivalent to the natural sediment bypassing that occurs at unmodified inlets for several reasons, most notably for the massive volumes involved that are "transported" virtually instantaneously instead of gradually and continuously and for the placement of the material outside of the immediate inlet vicinity, where it would naturally bypass. The mining of inlet shoals can remove massive amounts of sediment, with 1.98 mcy mined for beach fill from Longboat Pass (Florida) in 1998, 1.7 mcy from Shallotte Inlet (North Carolina) in 2001 and 1.6 mcy from Redfish Pass (Florida) in 1988 (Cialone and Stauble 1998, USACE 2004). Cialone and Stauble (1998) found that monitoring of the impacts of ebb shoal mining has been insufficient, and in one case the mining pit was only 66% recovered after five years; they conclude that the larger the volume of sediment mined from the shoals, the larger the perturbation to the system and the longer the recovery period.

Compared to ebb shoals, flood shoals have received much less attention and study, perhaps because flood shoals are often more complex (particularly where the source of sediment may be oceanic as well as riverine) and are modified by dredging of navigation channels (Carr de Betts 1999; Militello and Kraus 2001). The mined or channelized portions of these flood channels would experience greater sediment deposition as compared to the existing condition because the deeper water would reduce the speed of the current within. When examining a proposal to mine the sand from the flood shoal in Shinnecock Bay, Militello and Kraus (2001) determined that the flood shoal could take a decade or longer to regenerate.

Inlet Stabilization and Relocation

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

Rice (2012a) found that, as of 2011, an estimated 54% of 221 mainland or barrier island tidal inlets in the U.S continental wintering range of the piping plover had been modified by some form of hardened structure, dredging, relocation, mining, or artificial opening or closure. On the Atlantic Coast, 43% of the inlets have been stabilized with hard structures, whereas 37% were stabilized on the Gulf Coast. The Atlantic coast of Florida has 17 stabilized inlets adjacent to each other, extending between the St. John's River in Duval County and Norris Cut in Miami-Dade County, a distance of 341 mi. A shorebird would have to fly nearly 344 mi between unstabilized inlets along this stretch of coast.

The state with the highest proportion of natural, unmodified inlets is Georgia (74%). The highest number of adjacent unmodified, natural inlets is the 15 inlets found in Georgia between Little Tybee Slough at Little Tybee Island Nature Preserve and the entrance to Altamaha Sound at the south end of Wolf Island National Wildlife Refuge, a distance of approximately 54 mi. Another relatively long stretch of adjacent unstabilized inlets is in Louisiana, where 17 inlets between a complex of breaches on the West Belle Pass barrier headland (in Lafourche Parish) and Beach Prong (near the western boundary of the state Rockefeller Wildlife Refuge) have no stabilization structures; one of these inlets (the Freshwater Bayou Canal), however, is dredged (Rice 2012a).

Unstabilized inlets naturally migrate, reforming important habitat components over time, particularly during a period of rising sea level. Inlet stabilization with rock jetties and revetments alters the dynamics of longshore sediment transport and the natural movement and formation of inlet habitats such as shoals, unvegetated spits and flats. Once a barrier island becomes "stabilized" with hard structures at inlets, natural overwash and beach dynamics are restricted, allowing encroachment of new vegetation on the bayside that replaces the unvegetated (open) foraging and roosting habitats that plovers prefer. Rice (2012a) found that 40% (89 out of 221) of the inlets open in 2011 have been stabilized in some way, contributing to habitat loss and degradation throughout the wintering range. Accelerated erosion may compound future habitat loss, depending on the degree of sea level rise (Titus et al. 2009). Due to the complexity of impacts associated with projects such as jetties and groins, Harrington (2008) noted the need for a better understanding of potential effects of inlet-related projects, such as jetties, on bird habitats.

Relocation of tidal inlets also can cause loss and/or degradation of piping plover habitat. Although less permanent than construction of hard structures, the effects of inlet relocation can persist for years.

The construction of jetties, groins, seawalls, and revetments at inlets leads to habitat loss and both direct and indirect impacts to adjacent shorelines. Rice (2012a) found that these structures result in long-term effects, with at least 13 inlets across six of the eight states having hard structures initially constructed in the 19th century. The cumulative effects are ongoing and increasing in intensity, with hard structures built as recently as 2015 and others proposed for the near future. With sea level rising and global climate change altering storm dynamics, pressure to modify the remaining half of sandy tidal inlets in the range is likely to increase, notwithstanding that this would be counterproductive to the climate change adaptation strategies recommended by the USFWS (2010d), CCSP (2009), Williams (2013), Pilkey and Young (2009), and others.

Over the past decade or two, development of the North Carolina coast has accelerated. Of the 20 currently open inlets, 16 are modified by man in some manner (Rice 2016). All 16 are dredged, and 7 have hardened structures.

Groins

In 2017, there are 34 groins along the North Carolina coast (Rice 2016). Groins pose an ongoing threat to piping plover beach habitat within the continental wintering range. Groins are hard structures built perpendicular to the shoreline, designed to trap sediment traveling in the littoral drift and to slow erosion on a particular stretch of beach or near an inlet. "Leaky" groins, also known as permeable or porous groins, are low-crested structures built like typical groins but which allow some fraction of the littoral drift or longshore sediment transport to pass through the groin. They have been used as terminal groins near inlets or to hold beach fill in place for longer durations. Although groins can be individual structures, they are often clustered along the shoreline in "groin fields." Because they intentionally act as barriers to longshore sand transport, groins cause downdrift erosion, which degrades and fragments sandy beach habitat for the piping plover and other wildlife. The resulting beach typically becomes scalloped in shape, thereby fragmenting plover habitat over time.

Groins and groin fields are found throughout the southeastern Atlantic and Gulf Coasts and are present at 28 of 221 sandy tidal inlets (Rice 2012a). In North Carolina, there are three currently existing terminal groins: along Oregon Inlet, at Fort Macon along Beaufort Inlet in Carteret County, and on Bald Head Island in New Hanover County. The terminal groin on Bald Head Island was installed in 2015, but the other two (Oregon Inlet and Fort Macon) were installed decades ago, and downdrift erosion has been severe at both, requiring frequent nourishment (Pietrafesa 2012; Riggs et al 2009). The Fort Macon groin is fronted by a larger structure that Rice (2016) refers to as jetty. There are two degraded groin/jetty structures in Dare County, adjacent to the old location of the Cape Hatteras lighthouse.

Although most groins were in place before the piping plover's 1986 ESA listing, new groins continue to be installed, perpetuating the threat to migrating and wintering piping plovers. As sea level rises at an accelerating rate, the threat of habitat loss, fragmentation and degradation from groins and groin fields may increase as communities and beachfront property owners seek additional ways to protect infrastructure and property.

Seawalls and Revetments

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

Rice (2012b) found that at least 230 mi of beach habitat has been armored with hard erosion-control structures. Data were not available for all areas, so this number is a minimum estimate of the length of habitat that has been directly modified by armoring. Out of 221 inlets surveyed, 89 were stabilized with some form of hard structure, of which 24 had revetments or seawalls along their shorelines.

Although North Carolina has prohibited the use of hard erosion-control structures or armoring since 1985 (with the exception of the six terminal groins recently legislated), the "temporary" installation of sandbag revetments is allowed. As a result, the precise length of armored sandy beaches in North Carolina is unknown, but at least 350 sandbag revetments have been constructed (Rice 2012b). South Carolina also limits the installation of some types of new armoring but already has 24 mi (27% of the developed shoreline or 13% of the entire shoreline) armored with some form of shore-parallel erosion-control structure (SC DHEC 2010).

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

Sand Placement Projects

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

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

Sand placement projects threaten migration and wintering habitat of the piping plover in every state throughout the range (Rice 2012b). At least 684.8 mi (32%) of sandy beach habitat in the continental wintering range of the piping plover have received artificial sand placement via dredge disposal activities, beach nourishment or restoration, dune restoration, emergency berms, inlet bypassing, inlet closure and relocation, and road reconstruction projects, including over 91 mi in North Carolina. In most areas, sand placement projects are in developed areas or adjacent to shoreline or inlet hard stabilization structures in order to address erosion, reduce storm damages, or ameliorate sediment deficits caused by inlet dredging and stabilization activities.

Wintering and migrating piping plovers depend on the availability and abundance of macroinvertebrates as an important food item. Polychaete worms comprise the majority of the shorebird diet (Kalejta 1992; Mercier and McNeil 1994; Tsipoura and Burger 1999; Verkuil et al. 2006) and of the piping plover diet in particular (Hoopes 1993; Nicholls 1989; Zonick and Ryan 1996). The quality and quantity of the macroinvertebrate prey base is threatened by shoreline stabilization activities, including the approximately 685 mi of beaches that have received sand placement of various types. The addition of dredged sediment can temporarily affect the benthic fauna of intertidal systems. Invertebrates may be crushed or buried during project construction. Although some benthic species can burrow through a thin layer of additional sediment (38-89 cm for different species), thicker layers (i.e., >1 meter (m)) are likely to smother these sensitive benthic organisms (Greene 2002). Numerous studies of such effects indicate that the recovery of benthic fauna after beach nourishment or sediment placement projects can take anywhere from six months to two years, and possibly longer in extreme cases (Thrush et al. 1996; Peterson et al. 2000; Zajac and Whitlatch 2003; Bishop et al. 2006; Peterson et al. 2006).

Delayed recovery of the benthic prey base or changes in their communities due to physical habitat changes may affect the quality of piping plover foraging habitat. The duration of the impact can adversely affect piping plovers because of their high site fidelity. Uncertainty persists about the impacts of various projects to invertebrate communities and how these impacts affect shorebirds, particularly the piping plover.

Both the number and the size of sand projects along the Atlantic and Gulf coasts are increasing (Trembanis et al. 1999), and these projects are increasingly being chosen as a means to combat sea level rise and related beach erosion problems (Klein et al. 2001). Throughout the plover migration and wintering range, the number of sand placement events has increased every decade for which records are available, with at least 710 occurring between 1939 and 2007, and more than 75% occurring since 1980 (Trembanis et al. 1999). The cumulative volume of sand placed on East Coast beaches has risen exponentially since the 1920s (Trembanis et al. 1999). As a result, sand placement projects increasingly pose threats to plover habitat.

Invasive Vegetation

The spread of invasive plants into suitable wintering piping plover habitat is a relatively recently identified threat (USFWS 2009a). Such plants tend to reproduce and spread quickly and to exhibit dense growth habits, often outcompeting native plants. Uncontrolled invasive plants can shift habitat from open or sparsely vegetated sand to dense vegetation, resulting in the loss or degradation of piping plover roosting habitat, which is especially important during high tides and migration periods. The propensity of invasive species to spread, and their tenacity once established, make them a persistent threat that is only partially countered by increasing landowner awareness and willingness to undertake eradication activities. Many invasive species are either currently affecting or have the potential to affect coastal beaches and thus plover habitat, including beach vitex (*Vitex rotundifolia*), crowfootgrass (*Dactyloctenium aegyptium*), Australian pine (*Casuarina equisetifolia*), and Japanese sedge *(Carex kobomugi)*. Defeo et al. (2009) cite biological invasions of both plants and animals as global threats to sandy beaches, with the potential to alter the food web, nutrient cycling and invertebrate assemblages. Although the extent of the threat is uncertain, this may be due to poor survey coverage more than an absence of invasions.

Wrack Removal and Beach Cleaning

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

Although beach cleaning and raking machines effectively remove human-made debris, they also remove accumulated wrack, topographic depressions, emergent foredunes and hummocks, and sparse vegetation nodes used by roosting and foraging piping plovers (Nordstrom 2000; Dugan and Hubbard 2010). Removal of wrack also reduces or eliminates natural sand-trapping, further destabilizing the beach. Furthermore, the sand adhering to seaweed and trapped in the cracks and crevices of wrack also is lost to the beach when the wrack is removed. Although the amount of sand lost during a single sweeping activity may be small, over a period of years this loss could be significant (Neal et al. 2007).

Accelerating sea level rise and other climate change impacts

Accelerating sea level rise poses a threat to piping plovers during the migration and wintering portions of their life cycle. As noted in the previous section, threats from sea level rise are tightly intertwined with artificial coastal stabilization activities that modify and degrade habitat. If climate change increases the frequency or magnitude of extreme temperatures, piping plover survival rates may be affected.

Numerous studies have documented accelerating rise in sea levels worldwide (Rahmstorf et al. 2007; Douglas et al. 2001 as cited in Hopkinson et al. 2008; CCSP 2009; Pilkey and Young 2009; Vermeer and Rahmstorf 2009). Potential effects of sea level rise on piping plover roosting and foraging habitats may vary regionally due to subsidence or uplift, the geological character of the coast and nearshore, and the influence of management measures such as beach nourishment, jetties, groins, and seawalls (CCSP 2009; Galbraith et al. 2002; Gutierrez et al. 2011). Gutierrez et al. (2011) found that along the Atlantic coast, the central and southern Florida coast is the most likely Atlantic portion of the wintering and migration range to experience moderate to severe erosion with sea level rise.

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

Modeling by Galbraith et al. (2002) for three sea level rise scenarios at five important U.S. shorebird staging and wintering sites predicted aggregate loss of 20-70% of current intertidal foraging habitat. The most severe losses were projected at sites where the coastline is unable to move inland due to steep topography or seawalls. Although habitat losses in some areas are likely to be offset by gains in other locations, Galbraith et al. (2002) noted that time lags between these losses and the creation of replacement habitat elsewhere may have serious adverse effects on shorebird populations. Furthermore, even if piping plovers are able to move their wintering locations in response to accelerated habitat changes, there could be adverse effects on the birds' survival rates or subsequent productivity.

Storm Events

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

Adverse effects attributed to storms alone are sometimes actually due to a combination of storms and other environmental changes or human use patterns. Storm-induced adverse effects include post-storm acceleration of human activities such as beach nourishment, sand scraping, closure of new inlets, and berm and seawall construction. Such stabilization activities can result in the loss and degradation of feeding and resting habitats. Land managers sometimes face public pressure after big storm events to plant vegetation, install sandfences, and bulldoze artificial "dunes." Storms also can cause widespread deposition of debris along beaches. Subsequent removal of this debris often requires large machinery that in turn can cause extensive disturbance and adversely affect habitat elements such as wrack. Challenges associated with management of public use can grow when storms increase access (Gibson et. al. 2009; LeBlanc pers. comm. 2009).

Some available information indicates that birds may be resilient, even during major storms, and move to unaffected areas without harm. Other reports suggest that birds may perish in or following storm events. Noel and Chandler (2005) suspected that changes in habitat caused by multiple hurricanes along the Georgia coastline altered the spatial distribution of piping plovers and may have contributed to the winter mortality of three individuals. Wilkinson and Spinks (1994) suggested that low plover numbers in South Carolina in January 1990 could have been partially influenced by effects on habitat from Hurricane Hugo the previous fall, while Johnson and Baldassarre (1988) found a redistribution of piping plovers in Alabama following Hurricane Elena in 1985.

Severe Cold Weather

Several sources suggest the potential for adverse effects of severe winter cold on survival of piping plovers. The Atlantic Coast piping plover recovery plan mentioned high mortality of coastal birds and a drop from approximately 30-40 to 15 piping plovers following an intense 1989 snowstorm along the North Carolina coast (Fussell 1990). A preliminary analysis of survival rates for Great Lakes piping plovers found that the highest variability in survival occurred in spring and correlated positively with minimum daily temperature (weighted mean based on proportion of the population wintering near five weather stations) during the preceding winter (Roche pers. comm. 2010; 2012). Catlin (pers. comm. 2012b) reported that the average mass of ten piping plovers captured in Georgia during unusually cold weather in December 2010 was 5.7 grams (g) less than the average for nine birds captured in October of the same year (46.6 g and 52.4 g, respectively; $p = 0.003$).

Disturbance from recreation activities

Increasing human disturbance is a major threat to piping plovers in their coastal migration and wintering range (USFWS 2009a). Intense human disturbance in shorebird winter habitat can be functionally equivalent to habitat loss if the disturbance prevents birds from using an area (Goss-Custard et al. 1996). Nicholls and Baldassarre (1990a) found less people and off-road vehicles at sites where nonbreeding piping plovers were present than at sites without piping plovers. Pfister et al. (1992) and Gibson et al. (2018) implicate anthropogenic disturbance as a factor in the long-term decline of migrating shorebirds at staging areas and overwintering areas. Disturbance can cause shorebirds to spend less time roosting or foraging and more time in alert postures or fleeing from the disturbances (Burger 1991; 1994; Elliott and Teas 1996; Lafferty 2001a, 2001b; Thomas et al. 2003). Shorebirds that are repeatedly flushed in response to disturbance expend energy on costly short flights (Nudds and Bryant 2000).

Shorebirds are more likely to flush from the presence of dogs than people, and breeding and nonbreeding shorebirds react to dogs from farther distances than people (Lafferty 2001a, 2001b; Lord et al. 2001; Thomas et al. 2003). Off-road vehicles can disrupt piping plover's normal behavior patterns. The density of off-road vehicles negatively correlated with abundance of piping plovers on the ocean beach in Texas (Zonick 2000). Cohen et al. (2008) found that radio-tagged wintering piping plovers using ocean beach habitat at Oregon Inlet in North Carolina were far less likely to use the north side of the inlet where off-road vehicle use was allowed. Ninety-six percent of piping plover detections occurred on the south side of the inlet even though it was more than four times farther away from foraging sites, prompting a recommendation that controlled management experiments be conducted to determine if recreational disturbance drives roost site selection (Cohen et al. 2008).

Recreational activities, especially off-road vehicles, may degrade piping plover habitat. Tires that crush wrack into the sand render it unavailable as a roosting habitat or foraging substrate (Goldin 1993; Hoopes 1993). Off-road vehicles significantly lessened densities of invertebrates on intertidal flats on the Cape Cod National Seashore in Massachusetts (Wheeler 1979).

Various local and regional examples also illustrate threats from recreation. On a 12-km stretch of Mustang Island in Texas, Foster et al. (2009) observed a 25% decline in piping plover abundance and a simultaneous five-fold increase in human use over a 29-year study period, 1979 – 2007. This trend was marginally significant, but declines in two other plover species were significant; declining shorebird abundance was attributed to a combination of human disturbance and overall declines in shorebird populations (Foster et al. 2009). In South Carolina, almost half of sites with five or more piping plovers had ten or more people present during surveys conducted in 2007-2008 and more than 60% allow dogs (Maddock and Bimbi unpubl. data). Zdravkovic and Durkin (2011) noted disturbance to piping plovers in Texas from kiteboarding, windsurfing, and horseback riding.

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

Oil spills

Piping plovers may accumulate contaminants from point and non-point sources at migratory and wintering sites. Depending on the type and degree of contact, contaminants can have lethal and sub-lethal effects on birds, including behavioral impairment, deformities, and impaired reproduction (Rand and Petrocelli 1985; Gilbertson et al. 1991; Hoffman et al. 1996). Contaminants have both the potential to cause direct toxicity to individual birds and to negatively impact their invertebrate prey base (Chapman 1984; Rattner and Ackerson 2008). Piping plovers' extensive use of the intertidal zone puts them in constant contact with coastal habitats likely to be contaminated by water-borne spills. Negative impacts can also occur during rehabilitation of oiled birds. Frink et al. (1996) describe how standard treatment protocols were modified to reflect the extreme susceptibility of piping plovers to handling and other stressors.

Following the Ixtoc spill, which began on June 3, 1979 off the coast of Mexico, approximately 350 metric tons of oil accumulated on South Texas barrier beaches, resulting in a 79% decrease in the total number of infaunal organisms on contaminated portions of the beach (Kindinger 1981; Tunnell et al. 1982). Shorebirds avoided the intertidal area of the beach, occupying the backshore or moving to estuarine habitats when most of the beach was coated (Chapman 1984).

Chapman (1984) surmised that the decline in infauna probably contributed to the observed shifts in habitats used. His observations indicated that all the shorebirds, including piping plovers, avoided the contaminated sediments and concentrated in oil-free areas.

According to government estimates, the 2010 Deepwater Horizon Mississippi Canyon Well #252 oil spill discharged more than 200 million gallons of oil into the Gulf of Mexico (U.S. Government 2010). Containment activities, recovery of oil-water mix, and controlled burning removed some oil, but additional impacts to natural resources may have been caused by the 1.84 million gallons of dispersant that were applied to the spill (U.S. Government 2010). At the end of July 2010, approximately 625 mi of Gulf of Mexico shoreline was oiled.

Efforts to prevent shoreline oiling and cleanup response activities can disturb piping plovers and their habitat. Although most piping plovers were on their breeding grounds in May, June, and early July when the Deepwater well was discharging oil, oil was still washing onto Gulf beaches when the plovers began arriving back on the Gulf in mid-July. Surface oil collection methods in these areas involved rakes, shovels, boats, all-terrain-vehicles, mechanical raking, chain raking, and surface sifters. Sub-surface collection methods from some beaches and vegetated coastlines involved auguring and digging pits/trenches using various beach-cleaning machines, excavators, track hoes, and wheeled/tracked vehicles. Potential long-term adverse effects stem from the construction of sand berms and closing of at least 32 inlets (Rice 2012a). Subtler but cumulatively damaging sources of oil and other contaminants are leaking vessels, offshore oil rigs and undersea pipelines in the Gulf of Mexico, pipelines buried under the bay bottoms, and onshore facilities such as petroleum refineries and petrochemical plants. In Louisiana, about 2,500-3,000 oil spills are reported in the Gulf region each year, ranging in size from very small to thousands of barrels (Carver pers. comm. 2011). The oil from these smaller leaks and seeps, if they occur far enough from land, will tend to wash ashore as tar balls.

Pesticides and Other Contaminants

A piping plover was found among dead shorebirds discovered on a sandbar near Marco Island, Florida following the county's aerial application of the organophosphate pesticide Fenthion for mosquito control in 1997 (Pittman 2001; Williams 2001). Subsequent to further investigations of bird mortalities associated with pesticide applications and to a lawsuit being filed against the Environmental Protection Agency in 2002, the manufacturer withdrew Fenthion from the market, and Environmental Protection Agency banned all use after November 30, 2004 (American Bird Conservancy 2007). Absent identification of contaminated substrates or observation of direct mortality of shorebirds on a site used by migrating and wintering piping plovers, detection of contaminants threats is most likely to occur through analysis of unhatched eggs. Contaminants in eggs can originate from any point in the bird's annual cycle, and considerable effort may be required to ascertain where in the annual cycle exposure occurred (see, for example, Dickerson et al. 2011 characterizing contaminant exposure of mountain plovers).

There has been limited opportunistic testing of piping plover eggs. Polychlorinated biphenol (PCB) concentrations in several composites of Great Lakes piping plover eggs tested in the 1990s had potential to cause reproductive harm. Analysis of prey available to piping plovers at representative Michigan breeding sites indicated that breeding areas along the upper Great Lakes region were not likely the major source of contaminants to this population (Best pers. comm. 1999 in USFWS 2003a). Relatively high levels of PCB, dichloro diphenyl dichloroethylene (DDE), and polybrominated diphenyl ether (PBDE) were detected in one of two clutches of Ontario piping plover eggs analyzed in 2009 (Cavalieri pers. comm. 2011). Results of opportunistic egg analyses to date from Atlantic Coast piping plovers did not warrant follow-up investigation (Mierzykowski 2009; 2010; 2012; Mierzykowski pers. comm. 2012). No recent testing has been conducted for contaminants in the Northern Great Plains piping plover population.

Predation

The extent of predation on migrating or wintering piping plovers remains largely unknown and is difficult to document. Avian and mammalian predators are common throughout the species' wintering range. Human activities affect the types, numbers, and activity patterns of some predators, thereby exacerbating natural predation on breeding piping plovers (USFWS 1996a). One incident involving a cat observed stalking piping plovers was reported in Texas (NY Times 2007). It has been estimated that free-roaming cats kill over one billion birds every year in the U.S., representing one of the largest single sources of human-influenced mortality for small native wildlife (Sax and Gaines 2008, Loss et al. 2012).

Predatory birds, including peregrine falcons (*F. peregrinus)*, merlin, and harriers, are present in the nonbreeding range. Newstead (pers. comm. 2012) reported two cases of suspected avian depredation of piping plovers in a Texas telemetry study, but he also noted that red tide may have compromised the health of these plovers. It has been noted, however, that the behavioral response of crouching when in the presence of avian predators may minimize avian predation on piping plovers (Morrier and McNeil 1991; Drake 1999a; Drake et al. 2001). Drake (1999a) theorized that this piping plover behavior enhances concealment associated with roosting in depressions and debris in Texas.

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

Military operations

Five of the eleven coastal military bases located in the U.S. continental range of nonbreeding piping plovers have consulted with the USFWS about potential effects of military activities on plovers and their habitat (USFWS 2009a; USFWS 2010). Formal consultation under section 7 of the ESA with Camp Lejeune, North Carolina in 2002 provided for year-round piping plover surveys, but restrictions on activities on Onslow Beach only pertain to the plover breeding season (Hammond pers. comm. 2012). Informal consultations with three Florida bases (Naval Station Mayport, Eglin Air Force Base, and Tyndall Air Force Base) addressed training activities that included beach exercises and occasional use of motorized equipment on beaches and bayside habitats. Eglin Air Force Base conducts twice-monthly surveys for piping plovers, and habitats consistently used by piping plovers are posted with avoidance requirements to minimize direct disturbance from troop activities. Operations at Tyndall Air Force Base and Naval Station Mayport were determined to occur outside optimal piping plover habitats. A 2001 consultation with the Navy for one-time training operations on Peveto Beach in Louisiana concluded informally (USFWS 2010). Current threats to wintering and migrating piping plovers posed by military activities appear minimal.

Disease

No instances of disease have been documented in piping plovers outside the breeding range. The 2009 5-Year Review concluded that West Nile virus and avian influenza remain minor threats to piping plovers on their wintering and migration grounds.

Conservation Efforts

The 2012 CCS (USFWS 2012; 2015) synthesizes conservation needs across the shared coastal migration and wintering ranges of the three piping plover populations, and presents recommended conservation actions for protection of nonbreeding piping plovers that are contained in the approved recovery plans (USFWS 1988b, 1996, 2003) and recommendations for future action in the 2009 5-Year Review (USFWS 2009a). Implementation of actions described in the CCS will support attainment of relevant reclassification and delisting criteria (USFWS 1996; 2003).

Conservation efforts on behalf of piping plovers in their non-breeding range have increased since the species listing and further accelerated since the early 2000s. Diverse conservation tools are selectively used to address protection needs across federal, state, municipal, and private land ownership.

5.1.5. Summary of Piping Plover Status

North Carolina is the only state where the piping plover's breeding and wintering ranges overlap, and the birds are present year-round. Piping plovers in the Action Area may include individuals from all three breeding populations. 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.

Since its 1986 listing under the ESA, the Atlantic Coast population estimate has increased 234%, from approximately 790 pairs to an estimated 1,849 pairs in 2008, and the U.S. portion of the population has almost tripled, from approximately 550 pairs to an estimated 1,596 pairs.

It appears that the Northern Great Plains breeding population (including Canada) declined from 1991 through 2001, increased dramatically in 2006, and then declined again in 2011 (Elliott-Smith et al. 2015).

The Great Lakes population has shown significant growth, from approximately 17 pairs at the time of listing in 1986, to 75 pairs in 2016 (Cavalieri pers. comm. 2016a). The total of 75 breeding pairs represents 50% of the current recovery goal of 150 breeding pairs for the Great Lakes population.

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. 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. Therefore, while there is a great deal of effort extended to improve breeding success, to 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.

A review of threats to piping plovers and their habitat in their migration and wintering range shows a continuing loss and degradation of habitat due to sand placement projects, inlet stabilization, sand mining, groins, seawalls, and revetments, dredging of canal subdivisions, invasive vegetation, and wrack removal. Shoreline stabilization projects can have lasting impacts on coastal migration and winter habitat. 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. This cumulative habitat loss is, by itself, of major threat to piping plovers, as well as the many other shorebird species competing with them for foraging resources and roosting habitats in their nonbreeding range. However, artificial shoreline stabilization also impedes the processes by which coastal habitats adapt to storms and accelerating sea level rise, thus setting the stage for compounding future losses. Furthermore, inadequate management of increasing numbers of beach recreationists reduces the functional suitability of coastal migration and wintering habitat and increases pressure on piping plovers and other shorebirds depending upon a shrinking habitat base. Experience during the Deepwater Horizon oil spill illustrates how, in addition to the direct threat of contamination, spill response activities can result in short- and long-term effects on habitat and disturb piping plovers and other shorebirds. If climate change increases the frequency and magnitude of severe weather events, this may pose an additional threat.

5.1.6. Tables and Figures for Status of Piping Plover

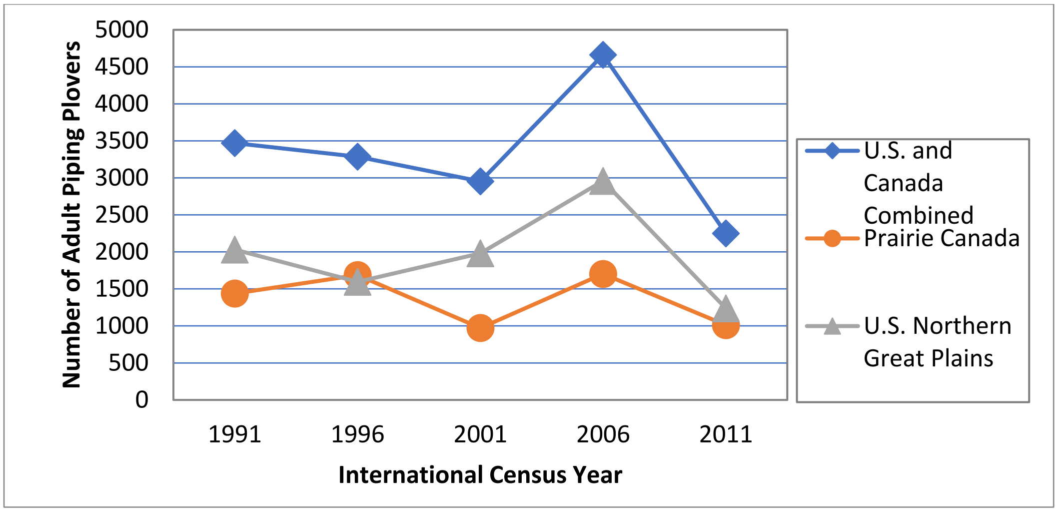

Figure 5-1. The number of adults reported for the U.S. and Canada Northern Great Plains breeding population during the International Censuses from 1991 to 2011. Data from Elliott-Smith et al. 2009, Elliott-Smith et al. 2015, Ferland and Haig 2002, Haig and Plissner 1993, Plissner and Haig 2000.

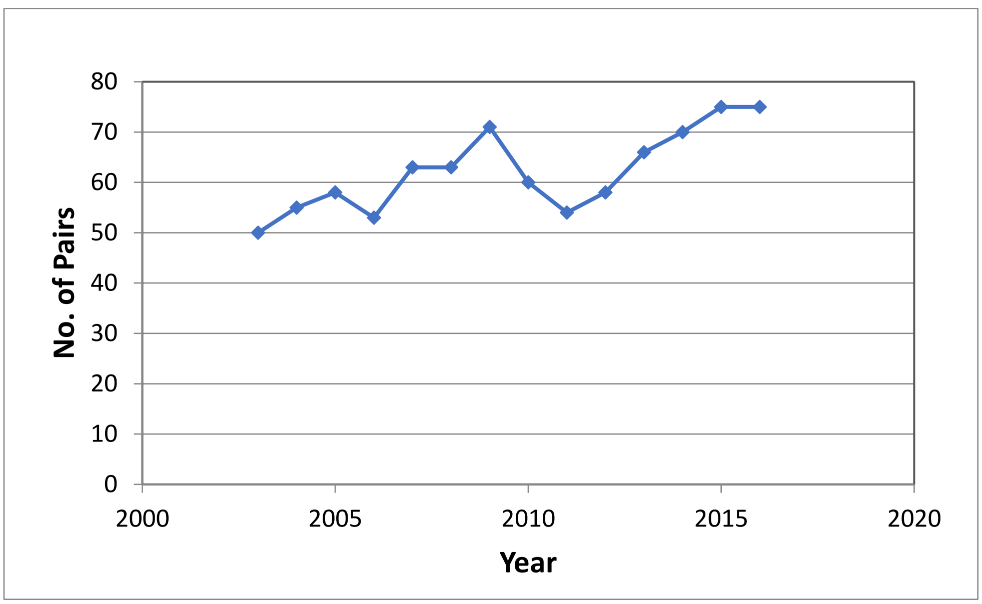

Figure 5-2. Annual Breeding Pair Estimates for Great Lakes Piping Plovers (2003-2016). Data from Cuthbert and Saunders 2013, Cavalieri pers. comm. 2016a; 2016c.

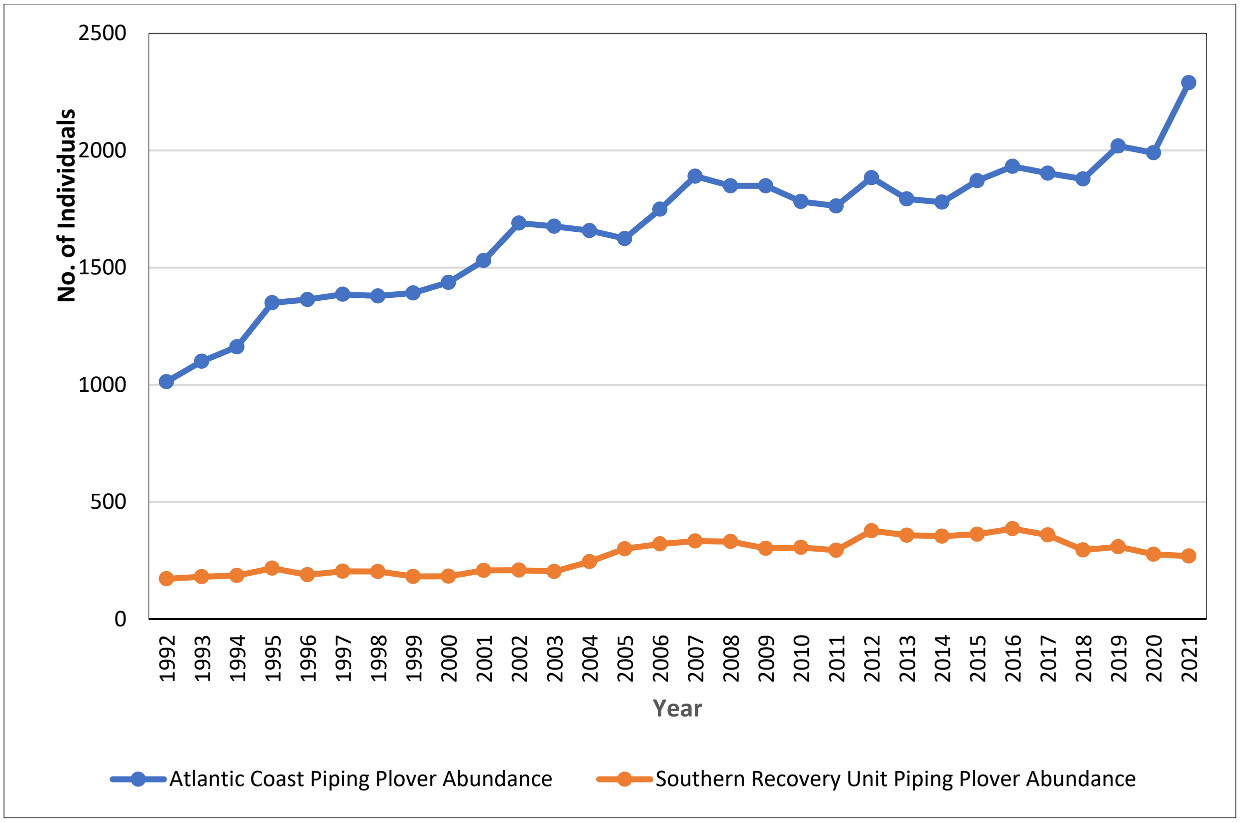

Figure 5-3. Annual abundance estimates for Atlantic Coast Piping Plovers and the Southern Recovery Unit (1992 – 2021) .

Table 5-1. Results of the 1991, 1996, 2001, 2006, and 2011 International Piping Plover Winter Censuses (Haig and Plissner 1993; Plissner and Haig 2000; Ferland and Haig 2002; Haig et al. 2005; Elliott-Smith et al. 2009; Elliott-Smith et al. 2015).

Location	**1991**	**1996**	**2001**	**2006**	**2011**
Virginia	not surveyed (ns)	ns	ns	1	1
North Carolina	**20**	**50**	**87**	**84**	**43**
South Carolina	51	78	78	100	86
Georgia	37	124	111	212	63
Florida	551	375	416	454	306
-Atlantic	*70*	*31*	*111*	*133*	*83*
-Gulf	*481*	*344*	*305*	*321*	*223*
Alabama	12	31	30	29	38
Mississippi	59	27	18	78	88
Louisiana	750	398	511	226	86
Texas	1,904	1,333	1,042	2,090	2,145
Puerto Rico	0	0	6	2	2
U.S. Total	**3,384**	**2,416**	**2,299**	**3,357**	**2,858**
Mexico	27	16	ns	76	30
Bahamas	29	17	35	417	1,066
Cuba	11	66	55	89	19
Other Caribbean Islands	0	0	0	28	ns
GRAND TOTAL	**3,451**	**2,515**	**2,389**	**3,884**	**3,973**
Percent of Total International Piping Plover Breeding Census	62.9%	42.4%	40.2%	48.2%	69.4%

Table 5-2. Piping plover wintering grounds threats matrix. The threats are ranked according to their overall potential impact on the population. The Service acknowledges there are differences in relative importance of each threat at a regional scale; the chart represents an overall ranking on the wintering population based on the amount of information currently known, the amount of habitat affected, and the difficulty in ameliorating the threat.

	Threat Level			
	Low	**Medium**	**High**	**Unknown**
Loss, modification, and degradation of habitat				
Development and construction			X	
Dredging and sand mining			X	
Inlet stabilization and relocation			X	
Groins			X	
Seawalls and revetments			X	
Sand placement projects		X[1]		
Loss of macroinvertebrate prey base due to shoreline stabilization		X		
Invasive vegetation			X[2]	
Wrack removal and beach cleaning		X		
Accelerating sea level rise and other climate change impacts			X	
Weather events				
Storm events	X			
Severe cold weather	X			
Disturbance from recreational activities		X[3]		
Oil spills and other contaminants				
Oil Spills		X		
Pesticides and Other Contaminants	X			
Energy development				
Land-based oil and gas exploration and development	X			
Wind turbines				X
Predation	X			
Military operations	X			
Disease	X			

[1] The threat level of sand placement projects varies among sites and projects. In areas where the loss of critical habitat is imminent due to sea level rise and subsidence, well-designed, infrequent sand placement projects can provide overall benefits to critical habitat once the benthic fauna recovers and natural processes are allowed to reshape the beach and dune system.
[2] The impact and extent of invasive vegetation varies across the range. Regionally, invasive plant growth can have a large impact on habitat availability, while in other parts of the wintering range, invasive species are not an issue.
[3] At some sites recreational disturbance would be considered a higher level of threat if the disturbance in essence makes the site unavailable or marginally useful to the plovers.

5.2. Environmental Baseline for Piping Plover

This section is an analysis of the effects of past and ongoing human and natural factors leading to the current status of the piping plover, its habitat, and ecosystem within the Action Area. The environmental baseline is a "snapshot" of the species' health in the Action Area at the time of the consultation and does not include the effects of the Action under review.

5.2.1. Action Area Numbers, Reproduction, and Distribution of Piping Plover

Although there are efforts to post breeding areas on the north and south ends of Wrightsville Beach, there do not appear to be any organized management actions to protect wintering and migrating piping plovers in the Action Area. Survey efforts conducted by NCWRC, third parties (including Audubon North Carolina), or by permittees provide information on the piping plover populations that are present on the ocean shoreline and inlet shoulders on Wrightsville Beach.

Breeding Piping Plovers

On Wrightsville Beach, no piping plover nests have been documented for many years, though individuals have been documented during the breeding season in most years on Wrightsville Beach or Masonboro Island. South Carolina has historically been the most southern Atlantic state where piping plover nesting occurs. Nesting habitat for piping plovers is being lost incrementally in the Carolinas. In recent years, no piping plover nests have been observed in South Carolina. Recently, the southernmost reported nests have been found on Figure Eight Island at Rich Inlet, north of the Action Area.

Nonbreeding Piping Plovers

Surveys by multiple groups have documented piping plovers during migration and winter within the Action Area. The migrant population is larger than the winter population. Surveys performed by Audubon North Carolina on Wrightsville Beach or in Masonboro Inlet from 2010 to 2014 recorded piping plover observations in every month of the year, except for May (Addison and McIver 2014), although other surveys have recorded a plover on Masonboro Island during May. Surveys were completed on foot or by boat. No piping plover nests were recorded on Wrightsville Beach or Masonboro Island during that period. Data collected by Audubon North Carolina and other observers (ncpaws.org, accessed September 19, 2022) is provided in **Table 5-3**

Reports from the National Seashores, and unpublished data from NCWRC's PAWS database (www.ncpaws.org) and Audubon North Carolina provide banded piping plover data for most coastal areas of North Carolina. The majority of banded piping plovers are recorded on Cape Hatteras and Cape Lookout National Seashores, and the islands and inlet complexes from Cape Lookout south to Masonboro Island. Only a few banded birds have been recorded in North Carolina south of Carolina Beach Inlet, in part because there are fewer records due to development of these areas, and also focus by the bird community on areas north. Banded piping plovers from all three breeding populations have been recorded on the National Seashores and south to Masonboro Inlet. This region of North Carolina, from Cape Lookout to Masonboro

Inlet, is extremely important to the survival and recovery of the piping plover, particularly the Great Lakes piping plover. Piping plovers that have previously wintered in the project area on Mason Inlet or Masonboro Inlet are known to migrate through Rich Inlet and Topsail Inlet. Conversely, some of the banded piping plovers that have been documented at Mason Inlet or Masonboro Inlet during the migration season have overwintered at Rich Inlet or Topsail Island.

Piping plovers that winter at sites (meaning they spend the majority of their nonbreeding season at one location) can arrive at their winter site as early as August and depart as late as April (Maddock et al. 2009). However, because plovers are also migrating through North Carolina from late summer through early winter and again from late winter through early spring the best winter population estimate is determined in December and/or January. Results of a band re-sighting analysis for birds documented at sites in South Carolina showed zero immigration or emigration during the months of December and January (Cohen, pers. comm. 2009). Therefore, the Service determines the local winter population by using the single highest count of birds observed during surveys conducted between December 1 and January 31.

The number or percentage of banded birds in each of the three populations depends on active banding projects. Virtually all of the Great Lakes individuals are banded, unlike individuals from the Atlantic Coast or Northern Great Plains breeding populations; the larger Atlantic Coast and Northern Great Plain populations only have banding projects at a few sites across their broad breeding ranges (Gratto-Trevor et al. 2012). Banding of the Great Lakes population began in 1993. Adults are banded with aluminum Service bands and three-color bands to uniquely identify the individual. Chicks are banded with aluminum Service bands and a single-color band to identify the hatch site (University of Minnesota 2017). Most of the unbanded birds are expected to be from the Atlantic Coast population.

Between 2006 and 2016, Audubon North Carolina identified approximately 122 individually banded piping plovers along the North Carolina coast from Topsail Island south to Masonboro Island (Addison pers. comm. 2016). This area encompasses four inlets and five islands: Topsail Island, (New) Topsail Inlet, Lea-Hutaff Island, Rich Inlet, Figure Eight Island, Mason Inlet, Wrightsville Beach, Masonboro Inlet, and Masonboro Island.

See **Table 5-4** for total number of banded individuals in the Action Area by population, per year. Unpublished data from NCWRC's PAWS database (www.ncpaws.org) and Audubon North Carolina (Addison, pers. comm. 2016) indicate that at least 21 individually banded piping plovers were documented on either side of Mason Inlet between 2007 and 2016 (including 15 from the Great Lakes population). Between 2012 and 2016, 11 individually banded piping plovers were documented at Masonboro Inlet, including five from the Great Lakes population. Only one of the individually banded piping plovers has been reported at both inlets during this time period (one from the Great Lakes population that wintered on Mason Inlet in 2013/2014 and was documented also at Masonboro Inlet). Individual piping plovers often returned to the Action Area in multiple years, which is reflected in the table.

5.2.2. Action Area Conservation Needs of and Threats to Piping Plover

The Action Area is developed with residences, hotels, and other businesses. Residential and commercial development began in earnest in the mid-1900s. The entire Action Area is lined with structures. Recreational use in the Action Area is quite high from residents and tourists. A wide range of recent and on-going activities have altered the proposed Action Area and, to a greater extent, the North Carolina coastline, and many more are proposed along the coastline for the near future. **Table 4-3** lists sand placement projects since 2009 within the Action Area covered under BOs for adverse impacts to piping plovers and red knots. The BOs include those for dredging and beach renourishment, included in the Environmental Baseline for this BO. In each of these BOs, a surrogate (linear footage of shoreline or acreage of inlet habitat) was used to express the amount or extent of anticipated incidental take.

Inlet dredging and sand mining: Historically, there have been Federal navigation projects in the AIWW and in Masonboro Inlet for decades. In an unknown number of dredging events, the sediment has often been placed on the adjacent beach using pipelines.

Beach sand placement: The beaches of Wrightsville Beach were historically nourished with sand from Masonboro Inlet, generally every four years.

Beach scraping: Beach scraping or bulldozing has become more frequent on North Carolina beaches in the past 20 years, in response to storms and the continuing retreat of the shoreline with rising sea level. These activities primarily occur during the winter months. The Town of Wrightsville Beach has recently requested a renewal of its permit for beach bulldozing.

Beach Driving: No public driving is allowed on Wrightsville Beach, but local government vehicles generally traverse the entire length of beach in response to emergencies, for trash removal, and other purposes.

Shoreline stabilization: There are two existing rock revetments along the coast of North Carolina: one at Fort Fisher (approximately 3,040 lf), and another along Carolina Beach (approximately 2,050 lf).

Pedestrian Use of the Beach: There are a number of potential sources of pedestrians and pets, including those individuals originating from boats, beachfront, and nearby residences.

Sand fencing: There are a few stretches of sand fencing along the shoreline on Wrightsville Beach.

5.2.3. Tables for Environmental Baseline for Piping Plover

Table 5-3. Peak monthly abundance for piping plover individuals (banded and unbanded) reported by Audubon North Carolina and other observers within the Action Area, 2010 to 2016.

Year	Month											
	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
2010	0	0	0	0	0	0	1	0	0	0	0	0
2011	0	0	7	0	0	0	1*	1*	0	2*	4*	4*
2012	1*	3	0	2	0	NR	0	2	2*	5*	2*	3
2013	0	0	0	1	0	0	0	2	1	0	6	3
2014	3	8	34	7	0	NR	2	8	8	NR	NR	NR
2015	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2016	NR	NR	12	NR	NR	0	0	NR	NR	NR	NR	NR

NR = not reported

*Other observers

Table 5-4. Number of individually banded piping plovers observed migrating through or overwintering at Masonboro Inlet or Mason Inlet each year, 2006/2007 to 2015/2016. Data from Audubon North Carolina and NCWRC.

Year	Great Lakes breeding population	Atlantic	Northern Great Plains breeding population	Total Banded Birds
2006/07	0	0	1	1
2007/08	0	0	1	1
2008/09	3	0	2	5
2009/10	0	0	1	1
2010/11	0	0	0	0
2011/12	1	0	0	1
2012/13	1	0	0	1
2013/14	7	2	1	10
2014/15	9	2	6	17
2015/16	7	1	1	9

5.3. Effects of the Action on Piping Plover

This section analyzes the direct and indirect effects of the Action on the Piping Plover, which includes the direct and indirect effects of interrelated and interdependent actions. Direct effects are caused by the Action and occur at the same time and place. Indirect effects are caused by the Action but are later in time and reasonably certain to occur.

Applicable Science and Response Pathways

The Service expects the Action will result in direct and indirect, long-term effects to piping plovers.

Direct Effects:

Short-term and temporary impacts to piping plovers could result from project activities disturbing roosting plovers and degrading currently occupied adjacent foraging areas. Placement of dredged material on up to 15,560 lf of beach would occur within and adjacent to foraging and roosting habitats for migrating or wintering piping plovers.

The timing of project construction could directly and indirectly impact migrating and wintering piping plovers. Piping plovers may be present year-round in the Action Area; however, the project activities are most likely to affect migrating and nesting individuals since there are no recently reported breeding activities in the Action Area.

Indirect Effects:

Long-term and permanent impacts could preclude the creation of new habitat and increase recreational disturbance. The effects of the project construction include a long-term reduction in foraging habitat and a long-term decreased rate of change in coastal dynamics (e.g., sand movement to form shoals and other intertidal habitats) that may preclude habitat creation.

Indirect effects include reducing the potential for the formation of optimal habitats. The proposed project may limit the creation of optimal foraging and roosting habitat, and may increase the attractiveness of these beaches for recreation increasing recreational pressures within the Action Area. Recreational activities that potentially adversely affect plovers include disturbance by vehicles, unleashed pets, and pedestrians.

Responses and Interpretation of Effects

The Service anticipates potential adverse effects throughout the Action Area by limiting proximity to roosting and foraging habitat and by degrading occupied foraging habitat.

In winter and migration sites, human disturbance continues to decrease the amount of undisturbed habitat and appears to limit local piping plover abundance (Zonick and Ryan 1996). A decrease in the survival of piping plovers on the migration and winter grounds due to the lack of optimal habitat may contribute to decreased survival rates, decreased productivity on the breeding grounds, and increased vulnerability to the three populations. 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. Even small declines in adult and juvenile survival rates will cause increases in extinction risk (Ryan et al. 1993; Melvin and Gibbs 1996; Plissner and Haig 2000; Amirault et al. 2005; Calvert et al. 2006; Brault 2007; Gibson et al. 2018).

Disturbance also reduces the time migrating shorebirds spend foraging (Burger 1991). Pfister et al. (1992) implicate disturbance as a factor in the long-term decline of migrating shorebirds at staging areas. 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.

5.4. Cumulative Effects on Piping Plover

For purposes of consultation under ESA §7, cumulative effects are those caused by future state, tribal, local, or private actions that are reasonably certain to occur in the Action Area. Future Federal actions that are unrelated to the proposed action are not considered, because they require separate consultation under §7 of the ESA. It is reasonable to expect continued shoreline stabilization and beach renourishment projects in this area in the future since erosion and sea-level rise increases would impact the existing beachfront development. Potential cumulative effects are unknown at this time. Therefore, cumulative effects are not relevant to formulating our opinion for the Action.

5.5. Conclusion for Piping Plover

In this section, we summarize and interpret the findings of the previous sections for the piping plover (status, baseline, effects, and cumulative effects) relative to the purpose of a BO under §7(a)(2) of the ESA, which is to determine whether a Federal action is likely to:

a) jeopardize the continued existence of species listed as endangered or threatened; or
b) result in the destruction or adverse modification of designated critical habitat.

"Jeopardize the continued existence" means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species (50 CFR §402.02).

Status

North Carolina is the only state where the piping plover's breeding and wintering ranges overlap, and the birds are present year-round. Piping plovers in the Action Area may include individuals from all three breeding populations. 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.

Since its 1986 listing under the ESA, the Atlantic Coast population estimate has increased 234%, from approximately 790 pairs to an estimated 1,849 pairs in 2008, and the U.S. portion of the population has almost tripled, from approximately 550 pairs to an estimated 1,596 pairs.

Overall, it appears that the Northern Great Plains breeding population (including Canada) declined from 1991 through 2001, increased dramatically in 2006, and then declined again in 2011. The 2011 breeding census count was substantially lower than the count in 2006 (over 4,500 birds in 2006 and 2,249 in 2011) (Elliott-Smith et al. 2015).

The Great Lakes population has shown significant growth, from approximately 17 pairs at the time of listing in 1986, to 75 pairs in 2016 (Cavalieri pers. comm. 2016a). The total of 75 breeding pairs represents 50% of the current recovery goal of 150 breeding pairs for the Great Lakes population.

Baseline

The Action Area is quite developed. Residential/commercial development has steadily increased since the early to mid- 1900s. The entire Action Area is presently lined with structures, including homes, motels, restaurants, and gift shops. Recreational use in the Action Area is quite high from residents and tourists. A wide range of recent and on-going activities have altered the proposed Action Area and, to a greater extent, the North Carolina coastline, and many more are proposed along the coastline for the near future. Within the Action Area, wintering and migrating piping plovers are documented every year.

Effects

The Service anticipates potential adverse effects throughout the Action Area by limiting proximity to, or degrading roosting and foraging habitat.

In winter and migration sites, human disturbance continues to decrease the amount of undisturbed habitat and appears to limit local piping plover abundance (Zonick and Ryan 1996). A decrease in the survival of piping plovers on the migration and winter grounds due to the lack of optimal habitat may contribute to decreased survival rates, decreased productivity on the breeding grounds, and increased vulnerability to the three populations. 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. Even small declines in adult and juvenile survival rates will cause increases in extinction risk (Ryan et al. 1993; Melvin and Gibbs 1996; Plissner and Haig 2000; Amirault et al. 2005; Calvert et al. 2006; Brault 2007; Gibson et al. 2018).

Disturbance also reduces the time migrating shorebirds spend foraging (Burger 1991). Pfister et al. (1992) implicate disturbance as a factor in the long-term decline of migrating shorebirds at staging areas. 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.

The proposed sand placement will occur within and adjacent to habitat that is used by migrating and wintering piping plovers. Since piping plovers can be present in the Action Area almost year-round, construction is likely to occur while this species is present. Sand placement is expected to be a one-time event. The Service expects the Action will result in direct and indirect, long-term effects to piping plovers. Short-term and temporary impacts to piping plovers could result from equipment that flushes birds from roosting or foraging habitat. Long-term impacts could include a hindrance in the ability of migrating or wintering piping plovers to recuperate from their migratory flight from their breeding grounds, survive on their wintering areas, or to build fat reserves in preparation for migration.

It is reasonable to expect continued beach renourishment projects in this area in the future since erosion and sea-level rise increases would impact the existing beachfront development. These future projects are likely to require federal funding or federal permits and therefore, are not considered to be cumulative effects.

After reviewing the current status of the species, the environmental baseline for the Action Area, the effects of the Action and the cumulative effects, it is the Service's biological opinion that the Action is not likely to jeopardize the continued existence of the piping plover.

6. RED KNOT

6.1. Status of Red Knot

This section summarizes best available data about the biology and current condition of red knot (*Calidris canutus rufa*) throughout its range that are relevant to formulating an opinion about the Action. The Service published its decision to list the rufa red knot as threatened on December 11, 2014 (79 FR 73706). A Species Status Assessment (SSA) for the red knot was published in 2020 (USFWS 2020). Please see the 2020 SSA for more information on the status of the red knot.

6.1.1. Description of Red Knot

The red knot is a medium-sized shorebird about 9 to 11 in (23 to 28 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.

Critical habitat for red knot was proposed on July 15, 2021 for portions of the North Carolina shoreline; however, there is no proposed critical habitat in the Action Area.

6.1.2. Life History of Red Knot

The breeding grounds of the red knot are in the central Canadian Arctic. Red knots generally nest in dry, slightly elevated tundra locations, often on windswept slopes with little vegetation. Pair bonds form soon after the birds arrive on the breeding grounds, in late May or early June, and remain intact until shortly after the eggs hatch. Female rufa red knots lay only one clutch per season and do not appear to lay a replacement clutch if the first is lost (Niles et al. 2008). The usual clutch size is four eggs. 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. 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) males also abandon the newly fledged juveniles and move south. Not long after, they are followed by the juveniles.

The red knot migrates annually between its breeding grounds and several wintering regions, including the Southeast U.S. (Southeast), the Northeast Gulf of Mexico, northern Brazil, and Tierra del Fuego at the southern tip of South America. During both the northbound (spring) and southbound (fall) migrations, red knots use key staging and stopover areas to rest and feed. 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).

Each year some red knots make one of the longest distance migrations known in the animal kingdom, traveling up to 19,000 mi (30,000 km) annually between breeding grounds in the Arctic Circle and wintering grounds. Red knots undertake long flights that may span thousands of miles without stopping. As they 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, C. canutus requires stopovers rich in easily digested food to achieve adequate weight gain that fuels both the next migratory flight and, upon arrival in the Arctic, a body transformation to breeding condition. At some stages of migration, very high proportions of entire shorebird populations may use a single migration staging site to prepare for long flights. Large proportions of the red knot's rangewide population can occur together at a small number of nonbreeding locations, leaving populations vulnerable to loss of key resources. For example, Delaware Bay provides the final Atlantic coast stopover for an estimated 50 to 80 percent of all rufa red knots making their way to the arctic breeding grounds each spring. Although birds from all four wintering populations mix in Delaware Bay, several lines of evidence suggest that birds from the Southern wintering region are more reliant on this staging area relative to birds that winter elsewhere across the range. Individual red knots show moderate fidelity to particular migration staging areas between years.

Long-distance migrant shorebirds are highly dependent on the continued existence of quality habitat at a few key staging areas. These areas serve as steppingstones between wintering and breeding areas. Conditions or factors influencing shorebird populations on staging areas control much of the remainder of the annual cycle and survival of the birds (Skagen 2006; International Wader Study Group 2003). At some stages of migration, very high proportions of entire populations may use a single migration staging site to prepare for long flights. Red knots show some fidelity to particular migration staging areas between years (Duerr et al. 2011; Harrington 2001).

Habitats used by red knots in migration and wintering areas are similar in character, generally coastal marine and estuarine habitats with large areas of exposed intertidal sediments. In North America, red knots are commonly found along 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). The supra-tidal sandy habitats of inlets provide important areas for roosting, especially at higher tides when intertidal habitats are inundated (Harrington 2008).

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). Foraging activity is largely dictated by tidal conditions, as red knots rarely wade in water more than 0.8 to 1.2 in (2 to 3 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).

The primary prey of the rufa red knot in non-breeding habitats include blue mussel (*Mytilus edulis*) spat; *Donax* and *Darina* clams; snails 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 (but not exclusively) 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 also prey on horseshoe crab eggs when available in other states.

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 non-stop, 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.

6.1.3. Numbers, Reproduction, and Distribution of Red Knot

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 in the timing of the birds' annual migratory cycle relative to favorable food and weather conditions.

In the U.S., red knot populations declined sharply in the late 1800s and early 1900s due to excessive sport and market hunting, followed by hunting restrictions and signs of population recovery by the mid-1900s (Urner and Storer 1949; Stone 1937; Bent 1927). However, it is unclear whether the red knot population fully recovered its historical numbers (Harrington 2001) following the period of unregulated hunting. More recently, long-term survey data from two key areas (Tierra del Fuego wintering area and Delaware Bay spring stopover site) both show a roughly 75 percent decline in red knot numbers since the 1980s (Dey et al. 2011; Clark et al.

2009; Morrison et al. 2004; Morrison and Ross 1989; Kochenberger 1983; Dunne et al. 1982; Wander and Dunne 1982).

Counts in wintering areas are 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. Harrington et al. (1988) reported that the mean count of birds wintering in Florida was 6,300 birds (± 3,400) based on 4 aerial surveys conducted from October to January in 1980 to 1982. Based on these surveys and other work, the Southeast wintering group was estimated at roughly 10,000 birds in the 1970s and 1980s (Harrington 2005a).

Based on resightings of birds banded in South Carolina and Georgia from 1999 to 2002, the Southeast wintering population was estimated at 11,700 ± 1,000 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 (B. Harrington pers. comm. November 12, 2012), but field survey data are not available to corroborate this estimate.

Range-Wide Trends:

Wintering areas for the red knot include the Atlantic coasts of Argentina and Chile, the north coast of Brazil, the Northwest Gulf of Mexico from the Mexican State of Tamaulipas through Texas to Louisiana, and the Southeast U.S. from Florida to North Carolina (Newstead et al. 2013; L. Patrick pers. comm. August 31, 2012; Niles et al. 2008). Smaller numbers of knots winter in the Caribbean, and along the central Gulf coast, the mid-Atlantic, and the Northeast U.S. *Calidris canutus* is also known to winter in Central America and northwest South America, but it is not yet clear if all these birds are the *rufa* subspecies.

In some years, more red knots have been counted during a coordinated spring migration survey than can be accounted for at known wintering sites, suggesting there are unknown wintering areas. Geolocators have started revealing previously little-known wintering areas, particularly in the Caribbean (Niles et al. 2012; L. Niles pers. comm. January 8, 2013).

The core of the Southeast wintering area is thought to shift from year to year among Florida, Georgia, and South Carolina (Niles et al. 2008). However, the geographic limits of this wintering region are poorly defined. Although only small numbers are known, wintering knots extend along the Atlantic coast as far north as Virginia (L. Patrick pers. comm. August 31, 2012; Niles et al. 2006), Maryland (Burger et al. 2012), and New Jersey (BandedBirds.org 2012; H. Hanlon pers. comm. November 22, 2012; A. Dey pers. comm. November 19, 2012). Still smaller numbers of red knots have been reported between December and February from Long Island, New York, through Massachusetts and as far north as Nova Scotia, Canada (eBird.org 2012).

6.1.4. Conservation Needs of and Threats to Red Knot

A Recovery Plan for the red knot has not yet been finalized but is anticipated in mid-2022. Red knot resource needs are shown in **Table 6-1**.

Threats to the Red Knot

In the final listing rule, the Service determined that the rufa red knot is threatened under the ESA due to the following primary threats: loss of breeding and nonbreeding habitat (including sea level rise, coastal engineering, coastal development, and arctic ecosystem change); likely effects related to 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. More information about the threats to the red knot may be found in the 2021 SSA.

Table 4-3 lists sand placement projects since 2009 within the Action Area, all of which are included in the Environmental Baseline for this BO. In each of these BOs, a surrogate (linear footage of shoreline) was used to express the amount or extent of anticipated incidental take.

6.1.5. Summary of Red Knot Status

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 in the timing of the birds' annual migratory cycle relative to favorable food and weather conditions. Long-distance migrant shorebirds such as the red knot are highly dependent on the continued existence of quality habitat at a few key staging areas. These areas serve as steppingstones between wintering and breeding areas. Conditions or factors influencing shorebird populations on staging areas control much of the remainder of the annual cycle and survival of the birds (Skagen 2006; International Wader Study Group 2003).

Within the nonbreeding portion of the range, red knot habitat is primarily threatened by the highly interrelated effects of sea level rise, shoreline stabilization, and coastal development. Lesser threats to nonbreeding habitat include agriculture and aquaculture, invasive vegetation, and beach maintenance activities. Within the breeding portion of the range, the primary threat to red knot habitat is from climate change. With arctic warming, vegetation conditions in the breeding grounds are expected to change, causing the zone of nesting habitat to shift and perhaps contract. Arctic freshwater systems—foraging areas for red knots during the nesting season—are particularly sensitive to climate change.

6.1.6. Tables for Status of Red Knot

Table 6-1. Red Knot resource needs. From the 2021 SSA (USFWS 2020).

Season	Life Stage	Needs
Winter	Adults	Wide, sparsely vegetated beaches, shoals, tidal mud or sand flats, or mangrove-dominated shorelines, with ample small (generally ≤0.8 inch (20 mm) long) mollusk prey (typically snails, clams, and mussels). Arthropods and other invertebrate prey may be locally important.2 Foraging areas are intertidal, from the **wrack** line seaward to a water depth of 2 to 3 cm, with prey probed from the surface to a depth of 2 to 3 cm. Roosting areas are supratidal areas with open vistas, located near foraging areas.
Migration	Adults	- A reliable network of coastal and inland staging areas with abundant, high-quality prey timed to occur when birds are present and allowing particularly high rates of weight gain; AND - An ample supply of other coastal and inland stopover habitats distributed across the range, allowing birds to shift among habitat patches (on daily, seasonal, and annual scales) based on food, predators, disturbance, weather, tides, and other conditions. - Coastal staging and stopover habitats are generally similar to wintering habitats, except that in some areas the primary food shifts from small mollusks to horseshoe crab eggs. - Inland staging and stopover habitats are less well known. Alkaline or saline lakes in the northern plains (U.S. and Canada) may be both staging areas and stopover habitats. Other stopover habitats may include riverine wetlands and sandbars, and manmade impoundments
Year-round	Juveniles, Nonbreeding Adults	Generally thought to be similar to adult wintering and migration habitats, though juveniles may partially segregate from adults. All juveniles (<2 years old) and some adults (*e.g.*, those that lack adequate fitness to breed in a particular year) do not migrate to the arctic breeding grounds and remain in nonbreeding habitats throughout June and early July.
Breeding	Adults, Eggs, Chicks	Upland tundra for nesting, with low, sparse, herbaceous vegetation (e.g., Dryas spp., lichens, moss), located near freshwater wetland or lake-edge foraging areas with suitably timed insect hatch to provide abundant prey when chicks are present. In at least in some years, favorable weather conditions (e.g., suitably timed snowmelt for nesting) and low predation pressure, which together allow high rates of hatching and fledging.

6.2. Environmental Baseline for Red Knot

This section is an analysis of the effects of past and ongoing human and natural factors leading to the current status of the Red Knot, its habitat, and ecosystem within the Action Area. The environmental baseline is a "snapshot" of the species' health in the Action Area at the time of the consultation and does not include the effects of the Action under review.

6.2.1. Action Area Numbers, Reproduction, and Distribution of Red Knot

Red knots migrate through and overwinter in North Carolina. Red knots are most common in North Carolina during the migration seasons (mid-April through May and July to mid-October) and may be present in the state throughout the year (Fussell 1994; Potter et al. 1980). Migrating and overwintering hatch-year and adult red knots utilize the Action Area. Red knots may be present any month of the year, although they are less likely to be present during the height of the breeding season (July). Spring migration peaks in North Carolina in May-June, while fall migration peaks between mid-August and early September, though many individuals stay until November, and small flocks may stay for the entire winter (nc.audubon.org).

Red knots have been documented along Wrightsville Beach since at least 2006 through aerial surveys and pedestrian surveys (see **Table 6-2**). Data from NCWRC (ncpaws.org, accessed September 19, 2022) indicate that numbers of red knots in the Action Area are highest during spring migration. During other times of the year, red knots are present, but the numbers are typically less than 10.

6.2.2. Action Area Conservation Needs of and Threats to Red Knot

The Action Area is developed, mainly with residences. Residential and commercial development began in the mid-1900's. Large portions of the Action Area are presently lined with structures. Recreational use in the Action Area is quite high from residents and tourists. In recent years, shorebird nesting areas on the north end and south end of Wrightsville Beach have been protected during the breeding season, using posts and rope. These roped off areas may also provide areas for red knots to be free from human disturbance for a small portion of the year.

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, and negatively affect the birds' energy balances. 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 nonmotorized boats, fishing, kite surfing, aircraft, and research activities (Niles et al. 2008; Peters and Otis, 2007; Harrington 2005b; Meyer et al. 1999; Burger 1986) and by beach raking or cleaning.

<u>*Nourishment activities:*</u> Wrightsville Beach is regularly nourished with sand, historically from Masonboro Inlet or the AIWW.

Beach scraping: Beach scraping or bulldozing has become more frequent on North Carolina beaches in the past 20 years. The Town of Wrightsville Beach has recently requested a renewal of its permit for beach bulldozing. Work is proposed to be conducted during the winter work window.

Pedestrian use of the beach: There are a number of potential sources of pedestrians and pets, including those individuals originating from boats, beachfront, and nearby residences.

Beach driving: No public driving is allowed on Wrightsville Beach, but local government vehicles generally traverse the entire length of beach in response to emergencies, for trash removal, and other purposes.

Shoreline stabilization: There are two existing rock revetments along the coast of North Carolina: one at Fort Fisher (approximately 3,040 lf), and another along Carolina Beach (approximately 2,050 lf).

Sand fencing: There are a few stretches of sand fencing along the shoreline on Wrightsville Beach.

6.3. Effects of the Action on Red Knot

This section analyzes the direct and indirect effects of the Action on the red knot, which includes the direct and indirect effects of interrelated and interdependent actions. Direct effects are caused by the Action and occur at the same time and place. Indirect effects are caused by the Action, but are later in time and reasonably certain to occur. Our analyses are organized according to the description of the Action in S**ection 2.1** of this BO.

The proposed action has the potential to adversely affect wintering and migrating red knots and their habitat. Potential effects to red knots include direct loss of foraging and roosting habitat in the Action Area due to dredging of intertidal habitats.

Applicable Science and Response Pathways

The Service expects the Action will result in direct and indirect, long-term effects to red knots.

Direct Effects:

Short-term and temporary impacts to red knots could result from project activities disturbing roosting red knots and degrading currently occupied adjacent foraging and roosting areas.

The construction window will extend through the red knot migration and winter season. Since red knots can be present on these beaches year-round, construction is likely to occur while this species is utilizing the Action Area beaches and associated habitats. The timing of project construction could directly and indirectly impact migrating and wintering red knot. Red knots may be present year-round in the Action Area; however, the timing of project activities will likely occur during the migration and wintering period.

Indirect Effects:

Long-term and permanent impacts could preclude the creation of new habitat and increase recreational disturbance. The effects of the project construction include a long-term reduction in foraging habitat and a long-term decreased rate of change in coastal dynamics that may preclude habitat creation.

Indirect effects include reducing the potential for the formation of optimal habitats. The proposed project may limit the creation of optimal foraging and roosting habitat and may increase the attractiveness of these beaches for recreation increasing recreational pressures within the Action Area. Recreational activities that potentially adversely affect red knots on the inlet shoals include disturbance by boats, unleashed pets and pedestrians.

<u>Responses and Interpretation of Effects</u>

The Service anticipates potential adverse effects throughout the Action Area by limiting proximity to roosting and foraging and by degrading occupied foraging habitat.

A decrease in the survival of red knots on the migration and winter grounds due to the lack of optimal habitat may contribute to decreased survival rates, decreased productivity on the breeding grounds, and increased vulnerability of the species. Threats on the wintering grounds may impact red knots' breeding success if they start migration or arrive at the breeding grounds with a poor body condition. Disturbance also reduces the time migrating shorebirds spend foraging (Burger 1991). Pfister et al. (1992) implicate disturbance as a factor in the long-term decline of migrating shorebirds at staging areas. Information about the energetics of avian migration indicates that this might be a particularly critical time in the species' life cycle.

6.4. Cumulative Effects on Red Knot

For purposes of consultation under ESA §7, cumulative effects are those caused by future state, tribal, local, or private actions that are reasonably certain to occur in the Action Area. Future Federal actions that are unrelated to the proposed action are not considered, because they require separate consultation under §7 of the ESA. It is reasonable to expect shoreline stabilization, and beach renourishment projects in this area in the future since erosion and sea-level rise increases would impact the existing beachfront development.

6.4.1. Tables for Environmental Baseline for Red Knot

Table 6-2. Approximate number of red knot observations between 2006-2021 on Wrightsville Beach. Data from NCWRC.

Year	Red Knot observations
2006	5
2010	45
2011	15
2012	456
2013	57
2014	189, Multiple groups of 10-25 or more
2015	121
2016	27
2021	22

6.5. Conclusion for Red Knot

In this section, we summarize and interpret the findings of the previous sections for the Red Knot (status, baseline, effects, and cumulative effects) relative to the purpose of a BO under §7(a)(2) of the ESA, which is to determine whether a Federal action is likely to:

a) jeopardize the continued existence of species listed as endangered or threatened; or
b) result in the destruction or adverse modification of designated critical habitat.

"Jeopardize the continued existence" means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species (50 CFR §402.02).

Status

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 in the timing of the birds' annual migratory cycle relative to favorable food and weather conditions.

Baseline

The Action Area is quite developed. Residential/commercial development has steadily increased since the early to mid- 1900s. The entire Action Area is presently lined with structures, including homes, motels, restaurants, and gift shops. Recreational use in the Action Area is quite high from residents and tourists. A wide range of recent and on-going activities have altered the proposed Action Area and, to a greater extent, the North Carolina coastline, and many more are proposed along the coastline for the near future.

Migrating and overwintering hatch-year and adult red knots utilize the Action Area. Red knots may be present any month of the year, although they are less likely to be present during the height of the breeding season (July).

Effects

The proposed sand placement will occur within habitat that is used by migrating and wintering red knots. Since red knots can be present in the Action Area almost year-round, construction is likely to occur while this species is utilizing beach and associated habitats. Sand placement under this authorization is expected to be a one-time event. The Service expects the Action will result in direct and indirect, long-term effects to red knots. Short-term and temporary impacts to red knot activities could result from equipment flushing birds from roosting or foraging habitat. Long-term impacts could include a hindrance in the ability of migrating or wintering red knots to recuperate from their migratory flight from their breeding grounds, survive on their wintering areas, or to build fat reserves in preparation for migration.

After reviewing the current status of the species, the environmental baseline for the Action Area, the effects of the Action and the cumulative effects, it is the Service's biological opinion that the Action is not likely to jeopardize the continued existence of the red knot.

7. SEABEACH AMARANTH

7.1. Status of Seabeach Amaranth

7.1.1. Description of Seabeach Amaranth

Seabeach amaranth (*Amaranthus pumilus*) is an annual plant that grows on Atlantic barrier islands and ocean beaches currently ranging from South Carolina to New York. It was listed as threatened under the ESA on April 7, 1993 (58 FR 18035) because of its vulnerability to human and natural impacts and the fact that it had been eliminated from two-thirds of its historic range (USFWS 1996b). Seabeach amaranth stems are fleshy and pink-red or reddish, with small, rounded leaves that are 0.5 to 1.0 inches in diameter. The green leaves, with indented veins, are clustered toward the tip of the stems, and have a small notch at the rounded tip. Flowers and fruits are relatively inconspicuous, borne in clusters along the stems. Seabeach amaranth will be considered for delisting when the species exists in at least six states within its historic range and when a minimum of 75 percent of the sites with suitable habitat within each state are occupied by populations for l0 consecutive years (USFWS 1996b). The recovery plan states that mechanisms must be in place to protect the plants from destructive habitat alterations, destruction or decimation by off-road vehicles or other beach uses, and protection of populations from debilitating webworm predation. There is no designation of critical habitat for seabeach amaranth.

7.1.2. Life History of Seabeach Amaranth

Seabeach amaranth is an annual plant. Germination of seabeach amaranth seeds occurs over a relatively long period, generally from April to July. Upon germinating, this plant initially forms a small unbranched sprig, but soon begins to branch profusely into a clump. This clump often reaches one foot in diameter and consists of five to 20 branches. Occasionally, a clump may get as large as three feet or more across, with 100 or more branches. Flowering begins as soon as plants have reached sufficient size, sometimes as early as June, but more typically commencing in July and continuing until the death of the plant in late fall. Seed production begins in July or August and peaks in September during most years, but continues until the death of the plant. Weather events, including rainfall, hurricanes, and temperature extremes, and predation by webworms have strong effects on the length of the reproductive season of seabeach amaranth. Because of one or more of these influences, the flowering and fruiting period can be terminated as early as June or July. Under favorable circumstances, however, the reproductive season may extend until January or sometimes later (Radford et al. 1968; Bucher and Weakley 1990; Weakley and Bucher 1992).

7.1.3. Numbers, Reproduction, and Distribution of Seabeach Amaranth

Within North Carolina and across its range, seabeach amaranth numbers vary from year to year. Data in North Carolina is available from 1987 to 2013. Recently, the number of plants across the entire state dwindled from a high of 19,978 in 2005 to 165 in 2013. This trend of decreasing numbers is seen throughout its range. 249,261 plants were found throughout the species' range in 2000. By 2013, those numbers had dwindled to 1,320 plants (USFWS, unpublished data).

Seabeach amaranth is dependent on natural coastal processes to create and maintain habitat. However, high tides and storm surges from tropical systems can overwash, bury, or inundate seabeach amaranth plants or seeds, and seed dispersal may be affected by strong storm events. In September of 1989, Hurricane Hugo struck the Atlantic Coast near Charleston, South Carolina, causing extensive flooding and erosion north to the Cape Fear region of North Carolina, with less severe effects extending northward throughout the range of seabeach amaranth. This was followed by several severe storms that, while not as significant as Hurricane Hugo, caused substantial erosion of many barrier islands in the seabeach amaranth's range. Surveys for seabeach amaranth revealed that the effects of these climatic events were substantial (Weakley and Bucher 1992). In the Carolinas, populations of amaranth were severely reduced. In South Carolina, where the effects of Hurricane Hugo and subsequent dune reconstruction were extensive, amaranth numbers declined from 1,800 in 1988 to 188 in 1990, a reduction of 90 percent. A 74 percent reduction in amaranth numbers occurred in North Carolina, from 41,851 plants in 1988 to 10,898 in 1990. Although population numbers in New York increased in 1990, range-wide totals of seabeach amaranth were reduced 76 percent from 1988 (Weakley and Bucher 1992). The extent stochastic events have on long-term population trends of seabeach amaranth has not been assessed.

The species historically occurred in nine states from Rhode Island to South Carolina (USFWS 1996b). By the late 1980s, habitat loss and other factors had reduced the range of this species to New York, North Carolina, and South Carolina. Since 1990, seabeach amaranth has reappeared in several states that had lost their populations in earlier decades. However, threats like habitat loss have not diminished, and populations are declining overall. It is currently found in New York, New Jersey, Delaware, Maryland, Virginia, North Carolina, and South Carolina (USFWS 2018). The typical habitat where this species is found includes the lower foredunes and upper beach strands on the ocean side of the primary sand dunes and overwash flats at accreting spits or ends of barrier islands.

7.1.4. Conservation Needs of and Threats to Seabeach Amaranth

Seabeach amaranth has been and continues to be threatened by destruction or adverse alteration of its habitat. As a fugitive species dependent on a dynamic landscape and large-scale geophysical processes, it is extremely vulnerable to habitat fragmentation and isolation of small populations. Further, because this species is easily recognizable and accessible, it is vulnerable to taking, vandalism, and the incidental trampling by curiosity seekers. Seabeach amaranth is afforded legal protection in North Carolina by the General Statutes of North Carolina, Sections 106-202.15, 106- 202.19 (N.C. Gen. Stat. section 106 (Supp. 1991)), which provide for protection from intrastate trade (without a permit).

The most serious threats to the continued existence of seabeach amaranth are construction of beach stabilization structures, natural and man-induced beach erosion and tidal inundation, fungi (i.e., white wilt), beach grooming, herbivory by insects and mammals, and off-road vehicles. Herbivory by webworms, deer, feral horses, and rabbits is a major source of mortality and lowered fecundity for seabeach amaranth. However, the extent to which herbivory affects the species as a whole is unknown.

The predominant threat to seabeach amaranth is the destruction or alteration of suitable habitat, primarily because of beach stabilization efforts and storm-related erosion (USFWS 1993). Other important threats to the plant include beach grooming and vehicular traffic, which can easily break or crush the fleshy plant and bury seeds below depths from which they can germinate; and predation by webworms (caterpillars of small moths) (USFWS 1993). Webworms feed on the leaves of the plant and can defoliate the plants to the point of either killing them or at least reducing their seed production. Beach vitex (Vitex rotundifulia) is another threat to seabeach amaranth, as it is an aggressive, invasive, woody plant that can occupy habitat similar to seabeach amaranth and outcompete it (Invasive Species Specialist Group (ISSG) 2010).

Potential effects to seabeach amaranth from vehicle use on the beaches include vehicles running over, crushing, burying, or breaking plants, burying seeds, degrading habitat through compaction of sand and the formation of seed sinks caused by tire ruts. Seed sinks occur when blowing seeds fall into tire ruts, then a vehicle comes along and buries them further into the sand preventing germination. If seeds are capable of germinating in the tire ruts, the plants are usually destroyed before they can reproduce by other vehicles following the tire ruts. Those seeds and their reproductive potential become lost from the population.

Pedestrians also can negatively affect seabeach amaranth plants. Seabeach amaranth occurs on the upper portion of the beach which is often traversed by pedestrians walking from parking lots, hotels, or vacation property to the ocean. This is also the area where beach chairs and umbrellas

are often set up and/or stored. In addition, resorts, hotels, or other vacation rental establishments may set up volleyball courts or other sporting activity areas on the upper beach at the edge of the dunes. All of these activities can result in the trampling and destruction of plants. Pedestrians walking their dogs on the upper part of the beach, or dogs running freely on the upper part of the beach, may result in the trampling and destruction of seabeach amaranth plants.
The extent of the effects that dogs have on seabeach amaranth is not known.

Recovery Criteria

Delisting of seabeach amaranth will be considered when a minimum of 75 percent of the sites with suitable habitat within at least six of the nine historically occupied States are occupied by seabeach amaranth populations for 10 consecutive years.

7.2. Environmental Baseline for Seabeach Amaranth

7.2.1. Action Area Numbers, Reproduction, and Distribution of Seabeach Amaranth

The Corps conducts annual seabeach amaranth surveys every summer on beaches affected by federal projects. The highest numbers of individual plants in the Action Area have been historically found at the south end of Wrightsville Beach. The numbers of seabeach amaranth vary widely from year to year, but in general, numbers have plummeted in the past 15 years. See **Table 7-1** for data from the BA and from the Corps (USACE 2015).

7.2.2. Action Area Conservation Needs of and Threats

A wide range of recent and on-going beach disturbance activities have altered the proposed Action Area and, to a greater extent, the North Carolina coastline, and many more are proposed along the coastline for the near future. **Table 4-3** lists sand placement projects conducted within the Action Area since 2009.

Beach nourishment: The beaches of New Hanover County are regularly nourished with sand from the Corps and locally managed activities. Nourishment activities widen beaches, change their sedimentology and stratigraphy, alter coastal processes, and often plug dune gaps and remove overwash areas.

Beach scraping can artificially steepen beaches, stabilize dune scarps, plug dune gaps, and redistribute sediment distribution patterns. As chronic erosion catches up to structures throughout the Action Area, artificial dune systems are constructed and maintained to protect beachfront structures either by sand fencing or fill placement. Beach scraping or bulldozing has become more frequent on North Carolina beaches in the past 20 years, in response to storms and the continuing retreat of the shoreline with rising sea level. These activities primarily occur during the winter months. The Town of Wrightsville Beach has recently requested a renewal of its permit for beach bulldozing.

Beach raking and rock-picking: 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 may 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).

Pedestrian Use of the Beach: There are a number of potential sources of pedestrians and pets on Wrightsville Beach, including those individuals originating from beachfront, public access points, and nearby hotels, motels, and residences.

7.2.3. Tables for Environmental Baseline for Seabeach Amaranth

Table 7-1. Annual seabeach amaranth numbers on Wrightsville Beach, NC between 1992 and 2021. Data from the BA and from the Corps (USACE 2015)

Year	# Plants
1992	285
1993	157
1994	35
1995	1,323
1996	289
1997	22
1998	191
1999	1
2000	5
2001	64
2002	104
2003	735
2004	778
2005	238
2006	4
2007	9
2008	3
2009	0
2010	0
2011	2
2012	0
2013	0
2014	0
2015	0
2016	1
2017	0
2018	0
2019	0
2020	0
2021	0
Site Total	**4,246**

7.3. Effects of the Action on Seabeach Amaranth

The proposed action has the potential to adversely affect seabeach amaranth within the proposed Action Area. Potential effects include burying, trampling, or injuring plants as a result of construction operations and/or sediment disposal activities; burying seeds to a depth that would prevent future germination as a result of construction operations and/or sediment disposal activities; and destruction of plants by trampling or breaking as a result of increased recreational activities. The Corps may place sand during the growing season of seabeach amaranth. Therefore, there is the potential for sand placement to adversely impact plants in the Action Area.

Beneficial Effects: The placement of beach-compatible sand may benefit this species by providing additional suitable habitat or by redistributing seed sources buried during past storm events, beach disposal activities, or natural barrier island migration. Disposal of dredged sand may be compatible with seabeach amaranth provided the timing of beach disposal is appropriate and the material placed on the beach is compatible with the natural sand. Further studies are needed to determine the best methods of beach disposal in seabeach amaranth habitat (Weakley and Bucher 1992).

Direct Effects: Sand placement activities may bury or destroy existing plants, resulting in mortality, or bury seeds to a depth that would prevent future germination, resulting in reduced plant populations. Increased traffic from recreationists and their pets can also destroy existing plants by trampling or breaking the plants.

Indirect Effects: Future tilling on the beach may be necessary if beach compaction hinders sea turtle nesting activities. Thus, the placement of heavy machinery or associated tilling equipment on the beach may destroy or bury existing plants.

7.4. Cumulative Effects on Seabeach Amaranth

7.5. Conclusion for Seabeach Amaranth

In this section, we summarize and interpret the findings of the previous sections for seabeach amaranth (status, baseline, effects, and cumulative effects) relative to the purpose of a BO under §7(a)(2) of the ESA, which is to determine whether a Federal action is likely to:

a) jeopardize the continued existence of species listed as endangered or threatened; or
b) result in the destruction or adverse modification of designated critical habitat.

"Jeopardize the continued existence" means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species (50 CFR §402.02).

Status

The Service has determined that seabeach amaranth is threatened due to its vulnerability to human and natural impacts and the fact that it had been eliminated from two-thirds of its historic range (USFWS 1996b).

Baseline

The Action Area is quite developed. Residential/commercial development has steadily increased since the mid- 1900s. The entire Action Area is presently lined with structures, including homes, motels, restaurants, and gift shops. Recreational use in the Action Area is quite high from residents and tourists.

Seabeach amaranth was historically present on Wrightsville Beach, and most years prior to 2000, individuals numbered in the hundreds. The numbers of plants have plummeted in the last 15 years.

Effects

The proposed sand placement may cause direct effects to seabeach amaranth include burying, trampling, or injuring plants as a result of construction operations and/or sediment disposal activities; burying seeds to a depth that would prevent future germination as a result of construction operations and/or sediment disposal activities; and destruction of plants by trampling or breaking as a result of increased recreational activities. The Corps may place sand during the growing season of seabeach amaranth. Therefore, there is the potential for sand placement to adversely impact plants in the Action Area.

After reviewing the current status of the species, the environmental baseline for the Action Area, the effects of the Action and the cumulative effects, it is the Service's biological opinion that the Action is not likely to jeopardize the continued existence of seabeach amaranth.

8. INCIDENTAL TAKE STATEMENT

ESA §9(a)(1) and regulations issued under §4(d) prohibit the take of endangered and threatened fish and wildlife species without special exemption. The term "take" in the ESA means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (ESA §3(19)). In regulations, the Service further defines:

- "harm" as "an act which actually kills or injures wildlife. Such act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering;" (50 CFR §17.3) and

- "incidental take" as "takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or applicant" (50 CFR §402.02).

Under the terms of ESA §7(b)(4) and §7(o)(2), taking that is incidental to a Federal agency action that would not violate ESA §7(a)(2) is not considered prohibited, provided that such taking is in compliance with the terms and conditions of an incidental take statement (ITS).

The Action considered in this BO includes a conservation measure to relocate sea turtle nests throughout the project area. Through this statement, the Service authorizes this conservation measure as an exception to the prohibitions against trapping, capturing, or collecting listed species. We identify this conservation measure as a Reasonable and Prudent Measure below, and we provide Terms and Conditions for its implementation.

This BO evaluated effects of the Action on the threatened seabeach amaranth. ESA §7(b)(4) and §7(o)(2), which provide the authority for issuing an ITS, do not apply to listed plant species. However, ESA §9(a)(2) prohibits certain acts with respect to endangered plant species, including:

(a) remove and reduce to possession from areas under Federal jurisdiction;
(b) maliciously damage or destroy on areas under Federal jurisdiction; and
(c) remove, cut, dig up, or damage or destroy on any other area in knowing violation of any law or regulation of any State or in the course of any violation of a State criminal trespass law.

Regulations issued under ESA §4(d) extend the prohibition under (a) above to threatened plant species (50 CFR §17.71). The damage or destruction of endangered and threatened plants that is incidental to (not the purpose of) an otherwise lawful activity is not prohibited.

For the exemption in ESA §7(o)(2) to apply to the Action considered in this BO, the Corps must undertake the non-discretionary measures described in this ITS, and these measures must become binding conditions of any permit, contract, or grant issued for implementing the Action. Consistent with ESA section 7(b)(4)(C)(iv), the Corps has a continuing duty to regulate the Action activities covered by this ITS. The protective coverage of §7(o)(2) may lapse if the Corps fails to:

- assume and implement the terms and conditions; or
- require a permittee, contractor, or grantee to adhere to the terms and conditions of the ITS through enforceable terms that are added to the permit, contract, or grant document.

In order to monitor the impact of incidental take, the Corps must report the progress of the Action and its impact on the species to the Service as specified in this ITS.

8.1. Amount or Extent of Take

This section specifies the amount or extent of take of listed wildlife species that the Action is reasonably certain to cause, which we estimated in the "Effects of the Action" section of this BO.

8.1.1. Sea Turtles

The Service anticipates that the Action is reasonably certain to cause incidental take of individual sea turtles consistent with the definition of harassment and harm. The Service anticipates that the Action is reasonably certain to cause incidental take of individual eggs and hatchling sea turtles consistent with the definition of harm. See **section 4.3.1.** Take is expected to be in the form of:

(1) destruction of all nests that may be constructed and eggs that may be deposited and missed by a nest survey, nest mark and avoidance program, or egg relocation program within the boundaries of the proposed project;
(2) destruction of all nests deposited during the period when a nest survey, nest mark and avoidance, or egg relocation program is not required to be in place within the boundaries of the proposed project;
(3) reduced hatching success due to egg mortality during relocation and adverse conditions at the relocation site;
(4) harassment in the form of disturbing or interfering with female turtles attempting to nest within the construction area or on adjacent beaches as a result of construction activities;
(5) misdirection of nesting and hatchling turtles on beaches adjacent to the sand placement or construction area as a result of project lighting;
(6) behavior modification of nesting females due to escarpment formation within the Action Area during the nesting season, resulting in false crawls or situations where they choose marginal or unsuitable nesting areas to deposit eggs; and
(7) Destruction of nests from escarpment leveling within a nesting season when such leveling has been approved by the Service.

<u>Surrogate Measures for Monitoring</u>

For this and other sand placement BOs, the Service typically uses a surrogate to estimate the extent of take. The amount of take is directly proportional to the spatial/temporal extent of occupied habitat that the Action affects, and exceeding this extent would represent a taking that is not anticipated in this BO. The Service anticipates incidental take of sea turtles will be difficult to detect for the following reasons: (1) the turtles nest primarily at night and all nests are not found because [a] natural factors, such as rainfall, wind, and tides may obscure crawls and [b] human-caused factors, such as pedestrian and vehicular traffic, may obscure crawls, and result in nests being destroyed because they were missed during a nesting survey, nest mark and avoidance, or egg relocation program (2) the total number of hatchlings per undiscovered nest is unknown; (3) the reduction in percent hatching and emerging success per relocated nest over the natural nest site is unknown; (4) an unknown number of females may avoid the project beach and be forced to nest in a less than optimal area; (5) lights may misdirect an unknown number of hatchlings and cause death; and (6) escarpments may form and prevent an unknown number of females from accessing a suitable nesting site.

However, the level of take of these species can be anticipated by the sand placement activities on suitable turtle nesting beach habitat because: (1) turtles nest within the Action Area; (2) construction may extend into the nesting season; (3) the nourishment project(s) will modify the incubation substrate, beach slope, and sand compaction; and (4) artificial lighting will deter and/or misdirect nesting hatchling turtles.

When it is not practical to monitor take in terms of individuals of the listed species, the regulations at 50 CFR §402.14(i)(1)(i) indicate that an ITS may express the amount or extent of take using a surrogate (*e.g.,* a similarly affected species, habitat, or ecological conditions), provided that the Service also:

- describes the causal link between the surrogate and take of the listed species; and
- sets a clear standard for determining when the level of anticipated take has been exceeded.

We have identified surrogate measures in our analyses of effects that satisfy these criteria for monitoring take of the species named above during Action implementation. The table below lists the species, life stage, and surrogate measure for the anticipated taking. We describe procedures for this monitoring in **section 8.4**.

Anticipated Take of Sea Turtle Species

Common Name	Life Stage	Surrogate (units)	Quantity
Loggerhead Sea Turtle	Egg, Hatchling, and Adult	Linear feet of shoreline	15,560
Green Sea Turtle	Egg, Hatchling, and Adult	Linear feet of shoreline	15,560
Leatherback Sea Turtle	Egg, Hatchling, and Adult	Linear feet of shoreline	15,560
Kemp's ridley Sea Turtle	Egg, Hatchling, and Adult	Linear feet of shoreline	15,560
Hawksbill Sea Turtle	Egg, Hatchling, and Adult	Linear feet of shoreline	15,560

8.1.2. Piping Plover

The Service anticipates that beach nourishment activities are reasonably certain to cause incidental take of individual piping plovers consistent with the definition of harassment resulting from 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 (see **section 5.3.1).**

The Service anticipates that the Action is reasonably certain to cause incidental take of individual piping plovers consistent with the definition of harm resulting from direct loss of optimal foraging and roosting habitat in the critical habitat unit and along the shoreline (activities that affect or alter the use of optimal habitat or increase disturbance to the species may decrease the survival and recovery potential of the piping plover); burial, crushing, and suffocation of invertebrate prey species; delayed recovery of the benthic prey base or changes in their communities due to physical habitat changes; increased predation from avian and mammalian predators attracted to the Action Area by food waste; morphological changes to adjacent piping plover habitat that increase disturbance to the species and/ or decrease survival; a decrease in the creation of optimal foraging and roosting habitat; and an increase the attractiveness of these beaches for recreation increasing recreational pressures.

For this and other BOs for piping plover, the Service typically uses a surrogate to estimate the extent of take. The amount of take is directly proportional to the spatial/temporal extent of occupied habitat that the Action affects and exceeding this extent would represent a taking that is not anticipated in this BO. It is difficult for the Service to estimate the exact number of piping plovers that could be present within the Action Area at any point in time and place during and after project construction and maintenance events. Disturbance to suitable habitat resulting from placement of sand would affect the ability of an undetermined number of piping plovers to find suitable foraging and roosting habitat during construction and maintenance for an unknown length of time after construction. Incidental take of piping plovers will be difficult to detect for the following reasons:

(1) harassment to the level of harm may only be apparent on the breeding grounds the following year; and
(2) dead plovers may be carried away by waves or predators.

However, the level of take of this species can be anticipated by the proposed activities because:

(1) piping plovers migrate through and winter in the Action Area;
(2) the activities are expected to affect the coastal morphology and prevent early successional stages, thereby precluding the maintenance and creation of additional recovery habitat;
(3) increased levels of pedestrian and vehicular disturbance may be expected; and
(4) a temporary reduction of food base will occur.

Anticipated Take of Piping Plover

Life Stage	Form of Take	Surrogate Unit	Quantity
Adults and Subadults	Harass and Harm	Linear feet of shoreline	15,560

Due to the difficulty of detecting take of piping plovers caused by the Action, the Corps will monitor the extent of taking using the surrogate measure specified in the table above. Instructions for monitoring and reporting take are provided in **section 8.4**.

8.1.3. Red Knot

The Service anticipates that beach nourishment activities are reasonably certain to cause incidental take of individual red knots consistent with the definition of harassment resulting from 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 (see **section 6.3.1).** The Service anticipates that the Action is reasonably certain to cause incidental take of individual red knots consistent with the definition of harm resulting from direct loss of foraging and roosting habitat; burial, crushing, and suffocation of invertebrate prey species; delayed recovery of the benthic prey base or changes in their communities due to physical habitat changes; increased predation from avian and mammalian predators attracted to the Action Area by food waste; morphological changes to adjacent red knot habitat that increase disturbance to the species and/ or decrease survival; a decrease in the creation of optimal foraging and roosting habitat; and an increase the attractiveness of these beaches for recreation increasing recreational pressures.

For this and other BOs for red knot, the Service typically uses a surrogate to estimate the extent of take. The amount of take is directly proportional to the spatial/temporal extent of occupied habitat that the Action affects and exceeding this extent would represent a taking that is not anticipated in this BO. It is difficult for the Service to estimate the exact number of red knots that could be present within the Action Area at any point in time and place during and after sand placement, sand fence installation, or dune vegetation planting. Disturbance to suitable habitat resulting from the activities would affect the ability of an undetermined number of red knots to find suitable foraging and roosting habitat during construction and maintenance for an unknown length of time after construction. Incidental take of red knots will be difficult to detect for the following reasons:

(1) harassment to the level of harm may only be apparent on the breeding grounds the following year; and
(2) dead red knots may be carried away by waves or predators.

However, the level of take of this species can be anticipated by the proposed activities because:

(1) red knots migrate through and winter in the Action Area;
(2) the activities are expected to affect the coastal morphology and prevent early successional stages, thereby precluding the maintenance and creation of additional recovery habitat;
(3) increased levels of pedestrian and vehicular disturbance may be expected; and
(4) a temporary reduction of food base will occur.

Anticipated Take of Red Knot

Life Stage	Form of Take	Surrogate Unit	Quantity
Adults and Juveniles	Harass and Harm	Linear feet of shoreline	15,560

Due to the difficulty of detecting take of red knots caused by the Action, the Corps will monitor the extent of taking using the surrogate measure specified in the table above. Instructions for monitoring and reporting take are provided in **section 8.4**.

8.2. Reasonable and Prudent Measures

The Service believes the reasonable and prudent measures (RPMs) we describe in this section for the sea turtle species named in Table 8-1 are necessary or appropriate to minimize the impact, *i.e.,* the amount or extent, of incidental take caused by the Action.

RPM #1. Derelict Materials. All derelict material or other debris must be removed from the beach to the maximum extent possible, prior to sand placement.

RPM #2. Conservation Measures. Conservation Measures included in the permit applications/project plans must be implemented in the proposed project. If a RPM and T&C address the same requirement, the requirements of the RPM and T&C take precedent over the Conservation Measure.

RPM #3. Predator-Proof Trash Receptacles. During construction, trash and food items shall be disposed of properly either in predator-proof receptacles, or in receptacles that are emptied each night to minimize the potential for attracting predators of piping plovers, red knots, and sea turtles.

RPM #4. Pre-construction Meeting. A meeting between representatives of the Corps and the Corps' contractor(s), Service, NCWRC, the permitted sea turtle surveyor, and others as appropriate, must be held prior to the commencement of work on this project.

RPM #5. Coordinate Pipeline Placement. Pipeline placement must be coordinated with NCDCM, the Corps, the Service's Raleigh Field Office and the NCWRC.

RPM #6. Compatible Sand. Only beach compatible fill must be placed on the beach or in any associated dune system. Beach compatible fill must be sand that is similar to a native beach in the vicinity of the site that has not been affected by prior sand placement activity.

RPM #7. Daily Inspections. During dredging operations, material placed on the beach shall be inspected daily to ensure compatibility. If during the sampling process non-beach compatible material, including significant amounts of tire debris, is or has been placed on the beach all work shall stop immediately and the Service and NCWRC will be notified by the Corps and/or its contractors to assist in determining the appropriate plan of action.

RPM #8. Level Profile. From May 1 through November 15, to the maximum extent practicable, excavations and temporary alteration of beach topography (outside of the active construction zone) will be filled or leveled to the natural beach profile prior to 9 pm each day.

RPM #9. Sea Turtle Sightings. If any nesting turtles are sighted on the beach during construction, construction activities must cease immediately until the turtle has returned to the water, and the sea turtle permit holder responsible for nest monitoring has marked for avoidance or relocated any nest(s) that may have been laid. If a nesting sea turtle is observed at night, all work on the beach will cease and all lights will be extinguished (except for those absolutely necessary for safety) until after the female has finished laying eggs and returned to the water.

RPM #10. Nighttime Work Area. During the sea turtle nesting season, the contractor must not extend the beach fill more than 1,000 feet and must confine work activities within this area between dusk and the time of completion the following day's nesting survey to reduce the impact to emerging sea turtles and burial of new nests.

RPM #11. Lighting Plan. Prior to the beginning of the project, the Corps shall submit a lighting plan for the dredge that will be used in the project. The plan shall include a description of each light source that will be visible from the beach and the measures implemented to minimize this lighting.

RPM #12. Lighting. During the nesting season, lighting associated with the project must be minimized to reduce the possibility of disrupting and misdirecting nesting and/or hatchling sea turtles.

RPM #13. Nesting Surveys. Daily nesting surveys (before 9 am) for sea turtle nests are required if any portion of the sand placement occurs during the period from May 1 through November 15. If sand is placed on the beach at night, a nighttime monitor must survey the beach area that is affected that night, prior to the morning's normal nesting activity survey. No daytime movement of equipment up or down the beach (outside of the active nighttime construction area described in number 10, above) may commence until completion of the sea turtle nesting survey each morning. If nests are constructed in the project area, the nests must be marked and either avoided until completion of the project or relocated prior to commencement of construction for the day.

RPM #14. Vehicle Access: Access points for construction vehicles must be as close to the project site as possible. Construction vehicle travel down the beach must be limited to the maximum extent possible.

RPM #15. Staging. From May 1 through November 15, staging areas for construction equipment must be located off the beach. Nighttime storage of construction equipment not in use must be off the beach to minimize disturbance to sea turtle nesting and hatching activities. In addition, all construction pipes placed on the beach must be located as far landward as possible without compromising the integrity of the dune system.

RPM #16. Demobilization. Demobilization of equipment from the beach must be conducted only during daylight hours, after the daily survey for sea turtle nests has been completed.

Any nests that are identified must be marked for avoidance and avoided during all demobilization activities.

RPM #17. Beach raking and tire removal. The Corps must utilize enhanced measures to avoid tire and other debris reaching the shoreline, minimize the amount of debris being deposited by removing it before deposition, pick up debris that has made it past the screens, and perform timely remediation as appropriate along the entire length of the nourished shoreline.

RPM #18. Avoid tires in borrow area. The dredge should avoid areas of known debris in the borrow area and cease operations and move away from an area if large amounts of debris are found.

RPM #19. Dune design. If a dune system is already part of the project design, the placement and design of the dune must emulate the natural dune system to the maximum extent possible, including the dune configuration and shape.

RPM #20. Escarpments. Escarpment formation must be monitored and leveling must be conducted if needed to reduce the likelihood of impacting nesting and hatchling sea turtles.

RPM #21. Sand compaction. Sand compaction must be monitored and tilling must be conducted if needed to reduce the likelihood of impacting sea turtle nesting and hatching activities.

8.3. Terms and Conditions

In order for the exemption from the take prohibitions of §9(a)(1) and of regulations issued under §4(d) of the ESA to apply to the Action, the Corps must comply with the terms and conditions (T&Cs) of this statement, provided below, which carry out the RPMs described in the previous section. These T&Cs are mandatory. As necessary and appropriate to fulfill this responsibility, the Corps must require any contractor implement the T&Cs that apply to Action activities under its jurisdiction through enforceable terms that the Corps includes in the contract document.

T&C #1. Derelict Materials. All derelict concrete, metal, and coastal armoring geotextile material and other debris must be removed from the beach prior to any sand placement to the maximum extent possible. If debris removal activities take place during the sea turtle nesting season, the work must be conducted during daylight hours only and must not commence until completion of the sea turtle nesting survey each day.

T&C #2. Conservation Measures. Conservation Measures included in the permit applications/project plans must be implemented in the proposed project. If a RPM and T&C address the same requirement, the requirements of the RPM and T&C take precedent over the Conservation Measure.

T&C #3. Predator-Proof Trash Receptacles. During construction, trash and food items shall be disposed of properly either in predator-proof receptacles, or in receptacles that are emptied each night to minimize the potential for attracting predators of piping plovers, red knots, and sea turtles. All contractors and their employees must be briefed on the importance of not littering and keeping the Action Area free of trash and debris.

T&C #4. Pre-construction Meeting. A meeting between representatives of the contractor(s), the Corps, the Service, the NCWRC, the permitted sea turtle surveyor(s), and others, as appropriate, must be held prior to the commencement of work. At least 10 business days advance notice must be provided prior to conducting this meeting. The meeting will provide an opportunity for explanation and/or clarification of the sea turtle protection measures, as well as additional guidelines when construction occurs during the sea turtle nesting season, such as storing equipment, minimizing driving, and reporting within the work area, as well as follow-up meetings during construction.

T&C #5. Coordinate Pipeline Placement. Pipeline placement must be coordinated with NCDCM, the Corps, the Service's Raleigh Field Office and the NCWRC.

T&C #6. Compatible Sand. Only beach compatible fill must be placed on the beach or in any associated dune system. Beach compatible fill must be sand that is similar to a native beach in the vicinity of the site that has not been affected by prior sand placement activity. Beach compatible fill must be sand solely of natural sediment and shell material, containing no construction debris, toxic material, or other foreign matter, or large amounts of granular material, gravel, or rock. The beach compatible fill must be similar in both color and grain size distribution (sand grain frequency, mean and median grain size and sorting coefficient) to the native material in the Action Area. Beach compatible fill is material that maintains the general character and functionality of the material occurring on the beach and in the adjacent dune and coastal system.

T&C #7. Daily Inspections. During dredging operations, material placed on the beach shall be inspected daily to ensure compatibility. If during the sampling process non-beach compatible material, including significant amounts of tire debris, is or has been placed on the beach all work shall stop immediately and the Service and NCWRC will be notified by the Corps and/or its contractors to assist in determining the appropriate plan of action.

T&C #8. Level Profile. From May 1 through November 15, to the maximum extent practicable, excavations and temporary alteration of beach topography (outside of the active construction zone) will be filled or leveled to the natural beach profile prior to 9:00 p.m. each day.

T&C #9. Sea Turtle Sightings. If any nesting turtles are sighted on the beach during construction, construction activities must cease immediately until the turtle has returned to the water, and the sea turtle permit holder responsible for nest monitoring has marked for avoidance or relocated any nest(s) that may have been laid. If a nesting sea turtle is observed at night, all work on the beach will cease and all lights will be extinguished (except for those absolutely necessary for safety) until after the female has finished laying eggs and returned to the water.

T&C #10. Nighttime Work Area. During the sea turtle nesting season, the contractor must not extend the beach fill more than 1,000 feet along the shoreline and must confine work activities within this area between dusk and dawn of the following day until the daily nesting survey has been completed and the beach cleared for fill advancement. A permitted sea turtle surveyor must be present on-site to ensure no nesting and hatchling sea turtles are present within the work area. Once the beach has been cleared and the necessary nest relocations have been completed, the contractor will be allowed to proceed with the placement of fill and work activities during daylight hours until dusk at which time the 1,000-foot length limitation must apply. If a nesting sea turtle is sighted on the beach within the immediate construction area, activities must cease immediately until the turtle has returned to the water and the sea turtle permit holder responsible for nest monitoring has relocated the nest.

If movement of equipment up or down the beach (outside of the active nighttime construction area) is required between dusk and dawn, an additional nighttime monitor must accompany vehicles operating on the beach, watching for signs of turtle activity ahead of the vehicle. If activity is discovered, the vehicle must stop or reverse direction until the activity ceases and the monitor clears the forward progress of the vehicle. Movement of equipment up or down the beach during nighttime operations would be conducted from the off-beach access point to the construction area and vice-versa (traveling from the off-beach access point to the construction area).

T&C #11. Lighting Plan. If any work on the beach is conducted during the sea turtle nesting season (May 1 through November 15), the Corps shall submit a lighting plan for the equipment and dredge that will be used in the project. The plan shall include a description of each light source that will be visible on or from the beach and the measures implemented to minimize this lighting. The plan shall be reviewed for approval by the Service.

T&C #12. Lighting. Direct lighting of the beach and nearshore waters must be limited to the immediate construction area during the nesting season and must comply with safety requirements. Lighting on all equipment must be minimized through reduction, shielding, lowering, and appropriate placement to avoid excessive illumination of the water's surface and nesting beach while meeting all Coast Guard, Corps EM 385-1-1, and OSHA requirements. Light intensity of lighting equipment must be reduced to the minimum standard required by OSHA for General Construction areas, in order to not misdirect sea turtles. Shields must be affixed to the light housing and be large enough to block light from all on-beach lamps from being transmitted outside the construction area or to the adjacent sea turtle nesting beach (**Figure 8-1**).

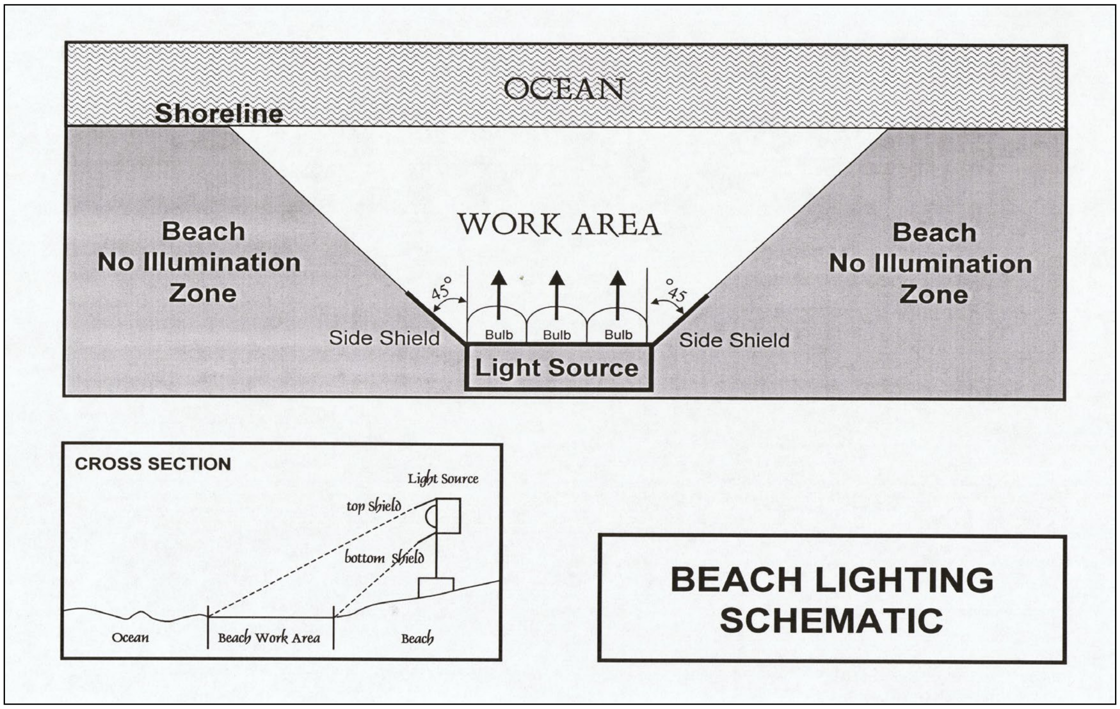

Figure 8-1. Beach lighting schematic.

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T&C #13. Nesting Surveys. Daily (before 9 am) nesting surveys and egg relocation must be conducted if any portion of the sand placement occurs during the period from May 1 through November 15. If sand is placed on the beach at night, a nighttime monitor must survey the beach area that is affected that night, prior to the morning's normal nesting activity survey. No daytime movement of equipment up or down the beach (outside of the active nighttime construction area described in number 10, above) may commence until completion of the sea turtle nesting survey each morning. If nests are constructed in the project area, the nests must be marked and either avoided until completion of the project or relocated.

a. Nesting surveys must be initiated by May 1 and must continue through the end of the project. If nests are constructed in areas where they may be affected by construction activities, the eggs must be relocated to minimize sea turtle nest burial, crushing of eggs, or nest excavation.
b. Nesting surveys and nest marking will only be conducted by personnel with prior experience and training in these activities, and who are duly authorized to conduct such activities through a valid permit issued by the Service or the NCWRC. Nesting surveys must be conducted daily between sunrise and 9 am.
c. Only those nests that may be affected by construction or sand placement activities will be relocated. Nest relocation must not occur upon completion of the project. For demobilization, nests will be marked and avoided. Nests requiring relocation must be moved no later than 9 am the morning following deposition to a nearby self-release beach site in a secure setting where artificial lighting will not interfere with hatchling orientation. Relocated nests must not be placed in organized groupings. Relocated nests must be randomly staggered along the length and

width of the beach in settings that are not expected to experience daily inundation by high tides or known to routinely experience severe erosion and egg loss, predation, or subject to artificial lighting. Nest relocations in association with construction activities must cease when construction activities no longer threaten nests.

d. Nests deposited within areas where construction activities have ceased or will not occur for 65 days must be marked for avoidance and left in situ unless other factors threaten the success of the nest. Nests must be marked with four stakes at a 10-foot distance around the perimeter of the nest for the buffer zone. The turtle permit holder must install an on-beach marker at the nest site and a secondary marker at a point as far landward as possible to assure that future location of the nest will be possible should the on-beach marker be lost. No activities that could result in impacts to the nest will occur within the marked area. Nest sites must be inspected daily to assure nest markers remain in place and the nest has not been disturbed by the project activity.

T&C #14. Vehicle Access: Access points for construction vehicles, including vehicles needed for debris removal, must be as close to the project site as possible. Construction vehicle travel down the beach must be limited to the maximum extent possible.

T&C #15. Staging. From May 1 through November 15, staging areas for construction equipment must be located off the beach. Nighttime storage of construction equipment not in use must be off the beach to minimize disturbance to sea turtle nesting and hatching activities. In addition, all construction pipes placed on the beach must be located as far landward as possible without compromising the integrity of the dune system. Pipes placed parallel to the dune must be 5 to 10 feet away from the toe of the dune if the width of the beach allows. If pipes are stored on the beach, they must be placed in a manner that will minimize the impact to nesting habitat and must not compromise the integrity of the dune systems.

T&C #16. Demobilization. Demobilization of equipment from the beach must be conducted only during daylight hours, after the daily survey for sea turtle nests has been completed. Any nests that are identified must be marked for avoidance as described in T&C #13.d. above, and avoided during all demobilization activities.

T&C #17. Avoid tires in borrow area. The dredge should avoid areas of known debris in the borrow area and cease operations and move away from an area if large amounts of debris are found. The Corps must coordinate with the Service, BOEM, and NCWRC A map showing areas dredged and relative amounts of debris should be developed and distributed to the Service and other agencies weekly. Records should be kept regarding the timing of when the debris containers are emptied.

T&C # 18. Cease pumping when exchanging debris containers. When a container of screened material is full, pumping should cease until an empty replacement container can be installed. Containers should not be allowed to overflow.

T&C #19. Remove debris to upland location. Tire material and other debris shall not be stockpiled on the beach, but removed to an upland location when a container is full.

T&C #20. Beach raking. Beach raking of areas where construction is complete must be conducted only during daylight hours, after the daily survey for sea turtle nests has been completed. Any nests that are identified must be marked for avoidance as described in T&C #13.d. above, and avoided during all beach raking activities.

T&C #21. Debris removal to 36-inch depth. Tire debris must be removed from all stretches of nourished beach, to at least a depth of 36 inches. Raking equipment must utilize the smallest mesh or tines possible to maximize debris removal. If needed, future debris removal efforts (after 2022) will be addressed in a separate BO.

T&C #22. Dune design. The design of a restored or constructed dune should include as steep a waterward slope as possible. The restored/constructed dune should tie into the pre-existing dune without loss of elevation, to avoid development of a "trough" between the existing dune and the constructed dune.

T&C #23. Escarpments. Visual surveys for escarpments along the Action Area must be made immediately after completion of sand placement, and within 30 days prior to May 1 for two subsequent years after any construction or sand placement event. Escarpments that interfere with sea turtle nesting or that exceed 18 inches in height for a distance of 100 feet must be leveled and the beach profile must be reconfigured to minimize scarp formation by the dates listed above. Any escarpment removal must be reported by location. If the sand placement activities are completed during the early part of the sea turtle nesting and hatching season (May 1 through May 30), escarpments must be leveled immediately, while protecting nests that have been relocated or left in place. The Service must be contacted immediately if subsequent reformation of escarpments that interfere with sea turtle nesting or that exceed 18 inches in height for a distance of 100 feet occurs during the nesting and hatching season to determine the appropriate action to be taken. If it is determined that escarpment leveling is required during the nesting or hatching season, the Service or NCWRC will provide a brief written authorization within 30 days that describes methods to be used to reduce the likelihood of impacting existing nests. An annual summary of escarpment surveys and actions taken must be submitted to the Service's Raleigh Field Office.

T&C #24. Sand compaction. Sand compaction must be qualitatively evaluated at least once after each sand placement event. If the Service or NCWRC determine that additional inspections are needed, a second inspection may be required prior to May 1 of the following year. Compaction monitoring and remediation are not required if the placed material no longer remains on the beach. Within 14 days of completion of sand placement and prior to any tilling (if needed), a field meeting shall be held with the Service and/or NCWRC to inspect the project area for compaction and determine whether tilling is needed.

a. If tilling is needed, the area must be tilled to a depth of 36 inches. All tilling activities shall be completed prior to May 1 of any year.
b. Tilling must occur landward of the wrack line and avoid all vegetated areas that are 3 square feet of greater, with a 3 square feet buffer around all vegetation.
c. If tilling occurs during the shorebird nesting season (after April 1, shorebird surveys are required prior to tilling per the Migratory Bird Treaty Act.
d. A summary of the compaction assessments and the actions taken shall be included in the annual report to NCDCM, the Corps and the Service's Raleigh Field Office.
e. These conditions will be evaluated and may be modified if necessary to address and identify sand compaction problems.

8.4. Monitoring and Reporting Requirements

In order to monitor the impacts of incidental take, the Corps must report the progress of the Action and its impact on the species to the Service as specified in the ITS (50 CFR §402.14(i)(3)). This section provides the specific instructions for such monitoring and reporting (M&R), including procedures for handling and disposing of any individuals of a species actually killed or injured. These M&R requirements are mandatory.

As necessary and appropriate to fulfill this responsibility, the Corps must require any contractor to accomplish the M&R through enforceable terms that the Corps includes in the contract document(s). Such enforceable terms must include a requirement to immediately notify the Corps and the Service if the amount or extent of incidental take specified in this ITS is exceeded during Action implementation.

M&R #1. Sea Turtle Nest Monitoring.

Sea turtle nesting surveys must be conducted within the project area between May 1 and November 15 of each year, during the construction year and for at least two consecutive nesting seasons after completion of construction. Acquisition of readily available sea turtle nesting data from qualified sources (volunteer organizations, other agencies, etc.) is acceptable. However, in the event that data from other sources cannot be acquired, the Corps will be responsible to collect the data. Data collected by the Corps for each nest should include, at a minimum, the information in **Table 8-1**, below. This information will be provided to the Service's Raleigh Field Office in the annual report, and will be used to periodically assess the cumulative effects of these types of projects on sea turtle nesting and hatchling production and monitor suitability of post construction beaches for nesting.

Table 8-1. Minimum Data Required for Sea Turtle Nesting Surveys.

Parameter	Measurement	Variable
Number of False Crawls	Visual Assessment of all false crawls	Number/location of false crawls in nourished areas; any interaction of turtles with obstructions, such as sandbags or scarps, should be noted.
Nests	Number	The number of sea turtle nests in nourished areas should be noted. If possible, the location of all sea turtle nests should be marked on a project map, and approximate distance to scarps or sandbags measured in meters. Any abnormal cavity morphologies should be reported as well as whether turtle touched sandbags or scarps during nest excavation.
Nests	Lost Nests	The number of nests lost to inundation or erosion or the number with lost markers.
Nests	Relocated nests	The number of nests relocated and a map of the relocation area(s). The number of successfully hatched eggs per relocated nest.
Lighting Impacts	Disoriented sea turtles	The number of disoriented hatchlings and adults

M&R #2. Annual Report. A report describing any actions taken must be submitted to the Service's Raleigh Field Office following completion of the proposed work for each year when a sand placement activity has occurred. The report must include the following information:

a) Project location (latitude and longitude);
b) Project description (linear feet of beach, actual fill template, access points, and borrow areas);
c) Dates of actual construction activities;
d) Names and qualifications of personnel involved in sea turtle nesting surveys and relocation activities (separate the nesting surveys for nourished and non-nourished areas);

e) Descriptions and locations of self-release beach sites; and
f) Sand compaction, escarpment formation, and other monitoring results.

At the time of the preconstruction meeting, the Corps shall provide to the Service the form at the link below. This form shall be emailed to the Service at <seaturtle@fws.gov>.
Link:
<http://www.fws.gov/northflorida/SeaTurtles/Docs/Corp%20of%20Engineers%20Sea%20Turtle%20Permit%20Information.pdf>.

Information required in these Reporting Requirements should be submitted to the following address:

Pete Benjamin, Supervisor
Raleigh Field Office
U.S. Fish and Wildlife Service
Post Office Box 33726
Raleigh, North Carolina 27636-3726
(919) 856-4520

M&R #3. Disposition of Dead or Injured Sea Turtles, Hatchlings, or Eggs

Upon locating a dead, injured, or sick individual of an endangered or threatened species, initial notification must be made to the Service's Law Enforcement Office below. Additional notification must be made to the Service's Ecological Services Field Office identified above and to the NCWRC at (252) 241-7367. NCWRC staff will determine the appropriate course of action. Care should be taken in handling sick or injured individuals and in the preservation of specimens in the best possible state for later analysis of cause of death or injury.

Jason Keith
U.S. Fish and Wildlife Service
551-F Pylon Drive
Raleigh, NC 27606
919-856-4786, extension 34

9. CONSERVATION RECOMMENDATIONS

§7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by conducting conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary activities that an action agency may undertake to avoid or minimize the adverse effects of a proposed action, implement recovery plans, or develop information that is useful for the conservation of listed species. The Service offers the following recommendations that are relevant to the listed species addressed in this BO and that we believe are consistent with the authorities of the Corps.

For the benefit of sea turtles, the Service recommends the following conservation recommendations:

1. Construction activities for this project and similar future projects should be planned to take place outside of the sea turtle nesting and hatching season.
2. Educational programs for beachfront businesses, homeowners, and renters should be developed or continued (as appropriate) to explain the importance of minimizing lights visible from the beach. The Service has educational materials that may be helpful in this effort.
3. For activities that utilize vehicles and other equipment on the beach, work should be completed during the winter work window (November 16 to April 30), particularly if the work is not associated with a beach sand placement project.
4. If a vehicle is required during the sea turtle nesting season, we recommend an ATV/UTV, to avoid and minimize impacts to sea turtles, seabeach amaranth, and shorebirds.
5. Use of sand fences and sand scraping should be limited.
6. Only plant native dune species. Hosier (2018), Rogers and Nash (2003), and the U.S. Department of Agriculture (USDA) (Shadow 2007; Lamphere 2006) recommend the following planting seasons for three commonly planted species:

    - American beachgrass (*Ammophila breviligulata*): Plant plugs from fall through spring.
    - Seaside panicum (*Panicum amarum*): Sprig in late winter, spring, or fall.
    - Sea Oats (*Uniola paniculata*): Plant in spring or fall.

In order for the Service to be kept informed of actions minimizing or avoiding adverse effects or benefitting listed species or their habitats, the Service requests notification of the implementation of any conservation recommendations.

10. REINITIATION NOTICE

Formal consultation for the Action considered in this BO is concluded. Reinitiating consultation is required if the Corps retains discretionary involvement or control over the Action (or is authorized by law) when:

a. the amount or extent of incidental take is exceeded;
b. new information reveals that the Action may affect listed species or designated critical habitat in a manner or to an extent not considered in this BO;
c. the Action is modified in a manner that causes effects to listed species or designated critical habitat not considered in this BO; or
d. a new species is listed or critical habitat designated that the Action may affect.

In instances where the amount or extent of incidental take is exceeded, the Corps is required to immediately request a reinitiation of formal consultation.

11. LITERATURE CITED

Ackerman, R.A. 1980. Physiological and ecological aspects of gas exchange by sea turtle eggs. American Zoologist 20:575-583.

Ackerman, R.A., R.C. Seagrave, R. Dmi'el and A. Ar. 1985. Water and heat exchange between parchment-shelled reptile eggs and their surroundings. Copiea. 1985:703-711.

Addison, L. 2016. Personal Communication. October 13, 2016 Email from Lindsay Addison to Kathryn Matthews. Re: Question about Addison_PIPL Habitat Master spreadsheet. Coastal Biologist, Audubon North Carolina. Wilmington, North Carolina.

American Bird Conservancy. 2007. Pesticide profile – fenthion. Accessed on 27 February 2009 at http://www.abcbirds.org/abcprograms/policy/pesticides/Profiles/ fenthion.html 2007.

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.

Ashton, A.D., J.P. Donnelly, and R.L. Evans. 2007. A discussion of the potential impacts of climate change on the shorelines of the northeastern USA. Unpublished report prepared for the Northeast Climate Impacts Assessment, Union of Concerned Scientists, Woods Hole Oceanographic Institution, Woods Hole, MA, Available at <http://www.georgetownclimate.org/resources/a-discussion-of-the-potential-impacts-of-climate-change-on-the-shorelines-of-the-northeast>.

Association of Fish and Wildlife Agencies. 2015. Protecting the Piping Plover and other Shorebirds in the Bahamas. Report on Accomplishments 2014-2015. Available at <http://www.fishwildlife.org/files/SouthernWingsReportMarch2015.pdf>.

Association of Fish and Wildlife Agencies. 2009. Voluntary guidance for states to incorporate climate change into state wildlife action plans and other management plans. November 2009.

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>.

Audubon Society. 2012. Solving the Piping Plover Puzzle. Available at https://www.audubon.org/magazine/november-december-2012/solving-piping-plover-puzzle.

Audubon Society. 2015. New Bahamas National Park will Protect Migratory Piping Plovers, Red Knots, Other Atlantic Coast Birds. Available at < https://www.audubon.org/news/new-bahamas-national-park-will-protect-migratory-piping-plovers-red-knots-other>.

Audubon Society. 2017. Meet Old Man Plover, the Pride of the Great Lakes. Available at https://www.audubon.org/news/meet-old-man-plover-pride-great-lakes.

Bagnold, R.A. 1941 The Physics of Blown Sand and Desert Dunes. Chapman and Hall, London, UK, 265 pp.

Bahamas National Trust. 2015. BNT Congratulates the Government on Protecting the Bahamas' Future. 9/2/2015 Press Release. Available at < http://www.bnt.bs/_m1840/press-releases/BNT-Congratulates-the-Government-on-Protecting-The-Bahamas-Future>.

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.

Baker, S. and B. Higgins. 2003. Summary of CWT project and recoveries, tag detection, and protocol for packaging and shipping Kemp's ridley flippers. Unpublished presentation at the Sea Turtle Stranding and Salvage Network annual meeting. February 2003.

Baldwin, R., G.R. Hughes, and R.I.T. Prince. 2003. Loggerhead turtles in the Indian Ocean. Pages 218-232 in Bolten, A.B. and B.E. Witherington (editors). Loggerhead Sea Turtles. Smithsonian Books, Washington D.C.

Bandedbirds.org. 2012. Bandings and resightings, Available at <http://www.bandedbirds.org>.

Baptist, M.J., J.E. Tamis, B.W. Borsje, and J.J. Van der Werf. 2009. Review of the Geomorphological, Benthic Ecological and Biogeomorphological Effects of Nourishments on the Shoreface and Surf Zone of the Dutch Coast (No. C113/08) IMARES/Deltares.

Barber, H. and Sons. 2009. Beach cleaning equipment and beach cleaning machines. http://www.hbarber.com/Cleaners/Beach_Cleaning_Equipment.html. Accessed August 30, 2012.

Beggs, J.A., J.A. Horrocks, and B.H. Krueger. 2007. Increase in hawksbill sea turtle *Eretmochelys imbricata* nesting in Barbados, West Indies. Endangered Species Research 3:159-168.

Bent, A.C. 1927. Life histories of North American shore birds: Order Limicolae (Part 1). Smithsonian Institution U.S. National Museum Bulletin (142):131-145.

Bent, A.C. 1929. Life histories of North American Shorebirds. U.S. Natural Museum Bulletin 146:236-246.

Bimbi, M. 2011. Electronic mail from Melissa Bimbi, USFWS to Karen Terwilliger, Terwilliger Consulting, Inc. in regards to response protocols for oil spills.

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.

Bimbi, M. 2015. Biologist. Conference Call April 16, 2015. Discussion of red knot preferred prey items in South Carolina, and recent studies. U.S. Fish and Wildlife Service internal conference call on research priorities for the red knot.

Bishop, M. J., C. H. Peterson, H. C. Summerson, H. S. Lenihan, and J. H. Grabowski. 2006. Deposition and long-shore transport of dredge spoils to nourish beaches: impacts on benthic infauna of an ebb-tidal delta. Journal of Coastal Research 22(3):530-546.

Bjorndal, K.A., A.B. Meylan, and B.J. Turner. 1983. Sea turtles nesting at Melbourne Beach, Florida, I. Size, growth and reproductive biology. Biological Conservation 26:65-77.

Blair, K. 2005. Determination of sex ratios and their relationship to nest temperature of loggerhead sea turtle (*Caretta caretta*, L.) hatchlings produced along the southeastern Atlantic coast of the United States. Unpublished Master of Science thesis. Florida Atlantic University, Boca Raton, Florida.

Bleakney, J.S. 1955. Four records of the Atlantic ridley turtle, Lepidochelys kempi, from Nova Scotia. Copeia 2:137.

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.

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.
Botton M.L., Harrington BA, Tsipoura N, Mizrahi DS (2003) Synchronies in migration: shorebirds, horseshoe crabs and Delaware Bay. In: Shuster C.N., Barlow R.B., Brockmann, H.J. (eds) The American Horseshoe Crab. Harvard University Press, Cambridge, pp 5–32.
Boss, SK and CW Hoffman. 1999. Sand Resources of the North Carolina Outer Banks 2nd Interim Report: Assessment of 3 Buxton Study Area. Prepared for the Outer Banks Task Force and the North Carolina Department of Transportation.
Boyd, R.L. 1991. First Nesting Record for the Piping Plover in Oklahoma. The Wilson Bulletin 103(2): 305-308.
Brault, S. 2007. Population Viability Analysis for the New England population of the Piping Plover (*Charadrius melodus*). Prepared for Cape Wind Associates, January 2007. 34 pp.
Breese, G. 2010. Compiled by Gregory Breese from notes and reports. Unpublished report to U.S. Fish and Wildlife Service, Shorebird Technical Committee.
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.
Brown, A.C. and A. McLachlan. 2002. Sandy shore ecosystems and the threats facing them: some predictions for the year 2025. Environmental Conservation 29 (I): 62-71.
Bucher, M. A., and A. S. Weakley. 1990. Status survey of seabeach amaranth (Amaranthus pumilus Rafinesque) in North and South Carolina. Report to the North Carolina Plant Conservation Program, Raleigh, NC and the U.S. Fish and Wildlife Service, Asheville, NC.
Buonaiuto, F.S., Jr., H.J. Bokuniewicz, and D.M. FitzGerald. 2008. Principal component analysis of morphology change at a tidal inlet: Shinnecock Inlet, New York. Journal of Coastal Research 24(4):867-875.
Burchfield, P.M. and J.L Peña. 2011. Final report on the Mexico/United Stated of America population for the Kemp's Ridley sea turtle, *Lepidochelys kempii*, on the coasts of Tamaulipas, Mexico. 2011. Annual report to Fish and Wildlife Service. 43 pp.
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.
Bush, D. M., O. H. Pilkey, Jr., and W. J. Neal. 1996. Living by the rules of the sea. Durham, North Carolina: Duke University Press. 179 pp.
Cairns, W.E. 1977. Breeding Biology and Behaviour of the Piping Plover (*Charadrius melodus*) in Southern Nova Scotia. M.S. Thesis, Dalhousie University.
Cairns, W.E. 1982. Biology and behavior of breeding Piping Plovers. Wilson Bulletin. 94:531-545.
Cairns, W.E. and I.A. McLauren 1980. Status of the Piping Plover on the East Coast of North America: A summary of our recent knowledge of this Blue-listed species. American Birds 34(2): 206-208.

Caldwell, D.K. 1959. The loggerhead turtles of Cape ROmain, South Carolina. Bull. Florida State Mus. Biol. Sci. 4:319-348.

Caldwell, D.K. 1962. Comments on the nesting behavior of Atlantic loggerhead sea turtles, based primarily on tagging returns. Quarterly Journal of the Florida Academy of Sciences 25(4):287-302.

Calvert, A.M., D.L. Amirault, F. Shaffer, R. Elliott, A. Hanson, J. McKnight, and P.D. Taylor. 2006. Population assessment of an endangered shorebird: the Piping Plover (*Charadrius melodus melodus*) in eastern Canada. Avian Conservation and Ecology – Ecologie et conservation des olseaux 1(3): 4.

Carr, A. 1963. Panspecific reproductive convergence in *Lepidochelys kempii*. Ergebnisse der Biologie 26:298-303.

Carr, A. and L. Ogren. 1960. The ecology and migrations of sea turtles, 4. The green turtle in the Caribbean Sea. Bulletin of the American Museum of Natural History 121(1):1-48.

Carter, D.B., K.B. and Cole, P. Arndt. 2007. Ensuring Habitat Considerations in Beach and Shoreline Management Along Delaware Bay – A Bay-wide Perspective. In Guilfoyle, M.P., R.A. Fischer, D.N. Pashley, and C.A. Lott (eds). 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>.

Carver, L. 2011. Electronic mail dated 11 January 2011 from Laura Ann Carver, Biologist-Oil-Spill Coordinator, Louisiana Department of Wildlife and Fisheries to Michael Seymour, Scientific Collecting Permits Coordinator Louisiana Department of Wildlife & Fisheries Louisiana Natural Heritage Program in regards to how many oil spills occur on average in a year in the Gulf.

Catlin, D. 2012a. Electronic mail dated 25 June 2012 from Daniel H. Catlin, Virginia Polytechnic Institute and State University, Blacksburg, Virginia to Carol Aron, USFWS North Dakota Field Office regarding piping plovers banded in the Great Lakes and Northern Great Plains and resighted in the Bahamas.

Catlin, D. 2012b. Electronic mail dated 20 March 2012 from Daniel H. Catlin, Virginia Polytechnic Institute and State University, Blacksburg, Virginia to Anne Hecht, USFWS Northeast Region regarding cold weather and plover weights.

Catlin, D. 2016a. Electronic mail dated 28 September, 2016 from Daniel H. Catlin, Virginia Polytechnic Institute and State University, Blacksburg, Virginia to Sarah Saunders, Michigan State University regarding Rich Inlet population projection.

Catlin, D. 2016b. Electronic mail dated 7 December 2016 from Daniel H. Catlin, Virginia Polytechnic Institute and State University, Blacksburg, Virginia to Kathryn Matthews, USFWS Raleigh ES Field Office regarding Request for modeling of Kiawah numbers.

Cava, J. A., A.D. Richardson, E.A. Jacobs, R.N. Rosenfield. 2014. Breeding Range Expansion of Taiga Merlins (*Falco columbarius columbarius*) in Wisonsin Reflects Continental Changes. J. Raptor Res. 48(2): 182-188.

Cavalieri, V. 2011. Electronic mail dated 22 December 2011 from Vincent Cavalieri, USFWS Michigan Field Office to Anne Hecht, USFWS Northeast Region regarding detection of contaminants in piping plovers breeding in the Great Lakes.

Cavalieri, V. 2016a. Personal Communication. August 1, 2016 email to Kathryn Matthews. FEIS for Figure Eight Island Terminal Groin Project. Number of Great Lakes breeding pairs for 2016. Fish and Wildlife Biologist. USFWS. East Lansing, Michigan.

Cavalieri, V. 2016b. Personal Communication. August 16, 2016. Phone call with Kathy Matthews concerning the Great Lakes population of piping plover and population information. Fish and Wildlife Biologist. USFWS. East Lansing, Michigan.

Cavalieri, V. 2016c. Personal Communication. September 23, 2016 email to Kathryn Matthews. Re: Rich Inlet PIPL Impacts. Providing population numbers for Great Lakes piping plover. Fish and Wildlife Biologist. USFWS. East Lansing, Michigan.

Cavalieri, V. 2016d. Personal Communication. October 19, 2016 email to Kathryn Matthews. Re: Number of Canada nests and fledglings this year? Providing population numbers for Canada Great Lakes piping plover breeding pairs. Fish and Wildlife Biologist. USFWS. East Lansing, Michigan.

Chaloupka, M. 2001. Historical trends, seasonality and spatial synchrony in green sea turtle egg production. Biological Conservation 101:263-279.

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.

Christens, E. 1990. Nest emergence lag in loggerhead sea turtles. Journal of Herpetology 24(4):400-402.

Cialone, M. A. and D. K. Stauble. 1998. Historical findings on ebb shoal mining. Journal of Coastal Research 14(2):537-563.

Clark, K.E., R.R. Porter, and J.D. Dowdell. 2009. The shorebird migration in Delaware Bay. New Jersey Birds 35(4):85-92.

Clark, K. E. "Horseshoe crabs and the shorebird connection." In *Proceedings of the horseshoe crab forum: Status of the resource*, edited by J. Farrell and C. Martin, 23–25. Newark, Delaware: University of Delaware Sea Grant Publications, 1996 (DEL-SG-05-97).

Cleary, W. J. and D. M. Fitzgerald. 2003. Tidal inlet response to natural sedimentation processes and dredging-induced tidal prism changes: Mason Inlet, North Carolina. Journal of Coastal Research 19(4):1018-1025.

Cleary, W. J. and T. Marden. 1999. Shifting shorelines: a pictorial atlas of North Carolina inlets. North Carolina Sea Grant Publication UNC-SG-99-4. 51 pp.

Coastal Engineering Research Center. 1984. Shore protection manual, Volumes I and II. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.

CSE (Coastal Science and Engineering). 2013. Shoreline erosion assessment and plan for beach restoration, Rodanthe and Buxton areas, Dare County, North Carolina. Feasibility Report for Dare County Board of Commissioners, Manteo, NC. Coastal Science & Engineering Inc, Columbia, SC, 159 pp with synopsis plus appendices.

CSE. 2014. Monitoring and analyses of the 2011 Nags Head beach nourishment project. Year 3 (2014) beach monitoring report for Town of Nags Head, NC. CSE, Columbia (SC), 128 pp + appendices.

Cohen, J.B., and C. Gratto-Trevor. 2011. Survival, site fidelity, and the population dynamics of Piping Plovers in Saskatchewan. J. Field Ornithol. 82(4):379-394.

Cohen, J. B., J. D. Fraser, and D. H. Catlin. 2006. Survival and site fidelity of piping plovers on Long Island, New York. Journal of Field Ornithology 77:409-417.

Cohen, J.B., S.M. Karpanty, D.H. Catlin, J.D. Fraser, and R.A. Fischer. 2008. Winter ecology of piping plovers at Oregon Inlet, North Carolina. Waterbirds 31:472-479.

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.

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.

Colosio, F., M. Abbiati, and L. Airoldi. 2007. Effects of beach nourishment on sediments and benthic assemblages. Marine Pollution Bulletin 54(2007):1197-1206.

Committee on the Status of Endangered Wildlife in Canada [COSEWIC]. 2001. Canadian species at risk, May 2001. Committee on the Status of Endangered Wildlife Species in Canada. Ottawa, Ontario, Canada.

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>.

Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's turtles (Emydoidea blandingii): implications for conservation and management of long-lived organisms. Conservation Biology 7(4):826-833.

Conrad et al. 2011. Experimental Study of dune vegetation impact and control on leatherback sea turtle (*Dermochelys coriacea*) nests. Endangered Species Research 15:13-27.

Corliss, L.A., J.I. Richardson, C. Ryder, and R. Bell. 1989. The hawksbills of Jumby Bay, Antigua, West Indies. Pages 33-35 in Eckert, S.A., K.L. Eckert, and T.H. Richardson (compilers). Proceedings of the Ninth Annual Workshop on Sea Turtle Conservation and Biology. NOAA Technical Memorandum NMFS-SEFC-232.

Council Conservation of Arctic Flora and Fauna [CAFF]. 2010. Arctic Biodiversity Trends 2010 – Selected indicators of change. CAFF, Akureyri, Iceland, Available at <http://www.caff.is/publications/view_document/162-arctic-biodiversity-trends-2010-selected-indicators-of-change>.

Coutu, S.D., J.D. Fraser, J.L. McConnaughy, and J.P. Loegering. 1990. Piping plover distribution and reproductive success on Cape Hatteras National Seashore. Unpublished report to the National Park Service.

Crain, D.A., A.B. Bolten, and K.A. Bjorndal. 1995. Effects of beach nourishment on sea turtles: review and research initiatives. Restoration Ecology 3(2):95-104.

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 (*Charadrius melodus*) at Chincoteague National Wildlife Refuge, Virginia. M.A. Thesis, The College of William and Mary.

Crouse, D. 1999. Population modeling and implications for Caribbean hawksbill sea turtle management. Chelonian Conservation and Biology 3(2):185-188.

Cummings, V., J. Hewitt, A. Van Rooyen, K. Currie, S. Beard, S. Thrush, J. Norkko, N. Barr, P. Heath, N.J. Halliday, and et al. 2011. Ocean acidification at high latitudes: Potential effects on functioning of the Antarctic bivalve *Laternula elliptica*. PLoS ONE 6(1):e16069.

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, MI.

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, MI.

Cuthbert, F.J., and S. Saunders. 2013. Piping plover breeding biology and management in the Great Lakes, 2013. Report submitted to the US Fish and Wildlife Service, East Lansing, MI. 34 pp.

CZR Incorporated (CZR) and CSE. 2014. Nags Head Beach 2011 Nourishment Project: Biological Monitoring Post-Year 2 and Final Report. Prepared for the Town of Nags Head, Dare County, NC. May 2014.

Dahlen, M.K., R. Bell, J.I. Richardson, and T.H. Richardson. 2000. Beyond D-0004: Thirty-four years of loggerhead (*Caretta caretta*) research on Little Cumberland Island, Georgia, 1964-1997. Pages 60-62 in Abreu-Grobois, F.A., R. Briseno-Duenas, R. Marquez, and L. Sarti (compilers). Proceedings of the Eighteenth International Sea Turtle Symposium. NOAA Technical Memorandum NMFS-SEFSC-436.

Davis, G.E. and M.C. Whiting. 1977. Loggerhead sea turtle nesting in Everglades National Park, Florida, U.S.A. Herpetologica 33:18-28.

Dean, C. 1999. Against the tide: the battle for America's beaches. Columbia University Press; New York, 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 81:1–12.

Dickerson, D.D. and D.A. Nelson. 1989. Recent results on hatchling orientation responses to light wavelengths and intensities. Pages 41-43 in Eckert, S.A., K.L. Eckert, and T.H. Richardson (compilers). Proceedings of the 9th Annual Workshop on Sea Turtle Conservation and Biology. NOAA Technical Memorandum NMFS-SEFC-232.

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.

Dodd, C.K., Jr. 1988. Synopsis of the biological data on the loggerhead sea turtle *Caretta caretta* (Linnaeus 1758). U.S. Fish and Wildlife Service, Biological Report 88(14).

Dodd, M.G. and A.H. Mackinnon. 1999. Loggerhead turtle (*Caretta caretta*) nesting in Georgia, 1999: implications for management. Georgia Department of Natural Resources report

Dodd, M.G. and A.H. Mackinnon. 2000. Loggerhead turtle (*Caretta caretta*) nesting in Georgia, 2000: implications for management. Georgia Department of Natural Resources unpublished report.

Dodd, M.G. and A.H. Mackinnon. 2001. Loggerhead turtle (*Caretta caretta*) nesting in Georgia, 2001. Georgia Department of Natural Resources. Report to the U.S. Fish and Wildlife Service, Jacksonville, Florida..

Dodd, M.G. and A.H. Mackinnon. 2002. Loggerhead turtle (*Caretta caretta*) nesting in Georgia, 2002. Georgia Department of Natural Resources. Report submitted to the U.S. Fish and Wildlife Service, Jacksonville, Florida.

Dodd, M.G. and A.H. Mackinnon. 2003. Loggerhead turtle (*Caretta caretta*) nesting in Georgia, 2003. Georgia Department of Natural Resources. Report submitted to the U.S. Fish and Wildlife Service, Jacksonville, Florida.

Dodd, M.G. and A.H. Mackinnon. 2004. Loggerhead turtle (*Caretta caretta*) nesting in Georgia, 2004. Georgia Department of Natural Resources. Report submitted to the U.S. Fish and Wildlife Service, Jacksonville, Florida.

Dodge, K.D., R. Prescott, D. Lewis, D. Murley, and C. Merigo. 2003. A review of cold stun strandings on Cape Cod, Massachusetts from 1979-2003. Unpublished Poster NOAA, Mass Audubon, New England Aquarium. http://galveston.ssp.nmfs.gov/research/protectedspecies/

Donnelly, C., N. Kraus, and M. Larson. 2006. State of knowledge on measurement and modeling of coastal overwash. Journal of Coastal Research 22(4):965-991.

Douglas, B. C., M. Kearney, and S. Leatherman. 2001. Sea-level rise: history and consequences. Academic Press, Inc., New York, New York.

Drake, K.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. R. 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.

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, J. E. and D. M. Hubbard. 2006. Ecological responses to coastal armoring on exposed sandy beaches. Shore and Beach 74(1):10-16.

Dugan, J. E. and D. M. Hubbard. 2010. Loss of coastal strand habitat in southern California: The role of beach grooming. Estuaries and Coasts 33:67-77.

Dutton, D.L., P.H. Dutton, M. Chaloupka, and R.H. Boulon. 2005. Increase of a Caribbean leatherback turtle *Dermochelys coriacea* nesting population linked to long-term nest protection. Biological Conservation 126:186-194.

eBird.org. 2020. eBird: An online database of bird distribution and abundance [web application]. Available at http://www.ebird.org/. [Accessed March 30, 2020].

eBird.org. 2014. eBird: An online database of bird distribution and abundance [web application]. Cornell Lab of Ornithology, Ithaca, New York. , Available at http://www.ebird.org/.

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/.

Ehrhart, L.M. 1989. Status report of the loggerhead turtle. Pages 122-139 *in* Ogren, L., F. Berry, K. Bjorndal, H. Kumpf, R. Mast, G. Medina, H. Reichart, and R. Witham (editors). Proceedings of the 2nd Western Atlantic Turtle Symposium. NOAA Technical Memorandum NMFS-SEFC-226.

Ehrhart, L.M., D.A. Bagley, and W.E. Redfoot. 2003. Loggerhead turtles in the Atlantic Ocean: geographic distribution, abundance, and population status. Pages 157-174 in Bolten, A.B. and B.E. Witherington (editors). Loggerhead Sea Turtles. Smithsonian Books, Washington D.C.

Elias, S. P., J. D. Fraser, and P. A. Buckley. 2000. Piping plover brood foraging ecology on New York barrier islands. Journal of Wildlife Management 64:346–354.

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. and S. M. Haig. 2004. Piping plover (*Charadrius melodus*), in The birds of North America online (A. Poole, ed). Ithaca: Cornell Lab of Ornithology. Available at http://bna.birds.cornell.edu/bna/species/002/articles/introduction, accessed May 2017.

Elliott-Smith, E., Haig, S.M., and Powers, B.M. 2009. Data from the 2006 International Piping Plover Census: U.S. Geological Survey Data Series 426, 332 pp.

Elliott-Smith, E., Bidwell, M., Holland, A.E., and Haig, S.M. 2015. Data from the 2011 International Piping Plover Census: U.S. Geological Survey Data Series 922. 296 pp. Available at http://dx.doi.org/10.3133/ds922.

Environment Canada. 2006. Recovery Strategy for the Piping Plover (*Charadrius melodus circumcinctus*) in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa.

Environment Canada. 2007. Addendum to the final recovery strategy for the piping plover (*Charadrius melodus circumcinctus*) in Canada RE: identification of critical habitat. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa.

Environment Canada. 2012. Recovery strategy for the piping plover (*Charadrius melodus melodus*) in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa.

Erickson Consulting Engineers Staff, 2003. Midnight Pass Reopening Project. Erickson Consulting Engineers, Inc., Technical Report, 43p.

Ernest, R.G. and R.E. Martin. 1993. Sea turtle protection program performed in support of velocity cap repairs, Florida Power & Light Company St. Lucie Plant. Applied Biology, Inc., Jensen Beach, Florida.

Ernest, R.G. and R.E. Martin. 1999. Martin County beach nourishment project: sea turtle monitoring and studies. 1997 annual report and final assessment. Unpublished report prepared for the Florida Department of Environmental Protection.

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.

Espoz, C., A. Ponce, R. Matus, O. Blank, N. Rozbaczylo, H.P. Sitters, S. Rodriguez, A.D. Dey, and L.J. Niles. 2008. Trophic ecology of the red knot *Calidris canutus* rufa at Bahía Lomas, Tierra del Fuego, Chile. Wader Study Group Bulletin 115(2):69-76.

Essink, K. 1999 “Ecological Effects of Dumping of Dredged Sediments; Options for Management.” Journal of Coastal Conservation, vol. 5: 69-80.

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. 293 pp.

Fletemeyer, J. 1980. Sea turtle monitoring project. Unpublished report prepared for the Broward County Environmental Quality Control Board, Florida.

Florida Fish and Wildlife Conservation Commission (FWC). 2007. Light sources contributing to reported disorientation events in Florida, 2007. http://www.myfwc.com/docs/WildlifeHabitats/Seaturtle_DisorientationEvents2007.pdf

Florida Fish and Wildlife Conservation Commission/Florida Fish and Wildlife Research Institute (FWC/FWRI). 2021. Loggerhead Nesting Data, 2016-2020. FWC/FWRI Statewide Nesting

Beach Survey Program Database as of 9 February 2021. https://myfwc.com/media/23244/loggerheadnestingdata5years.pdf
Florida Oceans and Coastal Council. 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, Florida, Available at http://www.floridaoceanscouncil.org/reports/Climate_Change_and_Sea_Level_Rise.pdf
Foley, A., B. Schroeder, and S. MacPherson. 2008. Post-nesting migrations and resident areas of Florida loggerheads. Pages 75-76 in Kalb, H., A. Rohde, K. Gayheart, and K. Shanker (compilers). Proceedings of the Twenty-fifth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-582.
Foote, J., J. Sprinkel, T. Mueller, and J. McCarthy. 2000. An overview of twelve years of tagging data from *Caretta caretta* and *Chelonia mydas* nesting habitat along the central Gulf coast of Florida, USA. Pages 280-283 in Kalb, H.J. and T. Wibbels (compilers). Proceedings of the Nineteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-443.
Frair, W., R.G. Ackerman, and N. Mrosovsky. 1972. Body temperature of *Dermochelys coriacea*: warm water turtle from cold water. Science 177:791-793.
Francisco-Pearce, A.M. 2001. Contrasting population structure of *Caretta caretta* using mitochondrial and nuclear DNA primers. Unpublished Master of Science thesis. University of Florida, Gainesville, Florida.
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.
Frazer, N.B. and J.I. Richardson. 1985. Annual variation in clutch size and frequency for loggerhead turtles, *Caretta-caretta*, nesting at Little Cumberland Island, Georgia, USA. Herpetologica 41(3):246-251.
Frink, L., C. D. Jenkins, Jr., L. Niles, K. Clark, and E. A. Miller. 1996. Anitra Spill: responding to oiled shorebirds. Tri-State Bird Rescue and Research, Inc. and New Jersey Division of Fish, Game and Wildlife.
Frumhoff, P.C., J.J. McCarthy, J.M. Melillo, S.C. Moser, and D.J. Wuebbles. 2007. Confronting climate change in the U.S. Northeast: Science, impacts, and solutions. Synthesis report of the Northeast Climate Impacts Assessment (NECIA). Union of Concerned Scientists (UCS), Cambridge, MA.
Fussell, John. O. III. 1994. A Birder's Guide to Coastal North Carolina. University of North Carolina Press. 540 pp.
Fussell, J. O. 1990. Census of piping plovers wintering on the North Carolina Coast - 1989-1990. Unpublished report to the North Carolina Wildlife Resources Commission. 54 pp.
Galbraith, H., R. Jones, R. Park, J. Clough, S. Herrod-Julius, B. Harrington, and G. Page. 2002. Global climate changes and sea level rise: Potential loss of intertidal habitat for shorebirds. Waterbirds 25:173-183.
Gaylord, B., T.M. Hill, E. Sanford, E.A. Lenz, L.A. Jacobs, K.N. Sato, A.D. Russell, and A. Hettinger. 2011. Functional impacts of ocean acidification in an ecologically critical foundation species. Journal of Experimental Biology 214:2586-2594.
Gerrodette, T. and J. Brandon. 2000. Designing a monitoring program to detect trends. Pages 36-39 in Bjorndal, K.A. and A.B. Bolten (editors). Proceedings of a Workshop on Assessing

Abundance and Trends for In-water Sea Turtle Populations. NOAA Technical Memorandum NMFS-SEFSC-445.
Gibson, D. 2016. Personal Communication. October 13, 2016 Email to Kathryn Matthews et al. Piping plover annual apparent survival for several inlets on the Atlantic coast. Department of Fish and Wildlife Conservation, Virginia Polytechnic Institute and State University.
Gibson, D. 2017. Personal Communication. April 19, 2017 Email to Kathy Matthews, Dan Catlin, and Melissa Bimbi. Providing annual apparent survival rates for Rich and Topsail Inlets. Department of Fish and Wildlife Conservation, Virginia Polytechnic Institute and State University.
Gibson, D. M. K. Chaplin, K.L. Hunt, M.J. Hunt, C.E. Weithman, L.M. Addison, V. Cavalieri, S. Coleman, F. J. Cuthbert, J.D. Frasier, W. Golder, D. HoffmanS. M. Karpanty, A.V. Zoeren, and D. H. Catlin. 2018. Impacts of anthropogenic disturbance on body condition, survival, and site fidelity of nonbreeding Piping Plovers. The Condor, Volume 120, 2018, pp. 566-580.
Gibson, D., D.H. Catlin, K.L. Hunt, J.D. Frasier, S.M. Karpanty, M.J. Friedrich, M.K. Bimbi, J.B. Cohen, S.B. Maddock. 2017. Evaluating the impact of man-made disasters on imperiled species: Piping plovers and the Deepwater Horizon oil spill. Biological Conservation 212 (2017) 48-62.
Gibson, D., K.L. Hunt, D.H. Catlin, M.J. Friedrich, C.E. Weithman, J.D. Fraser, S.M. Karpanty. 2016. Annual Operations Report: Winter survival of piping plovers on the Atlantic coast through habitat changes and its relationship to multiple breeding populations. Virginia Tech Shorebird Program.
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 - 58th 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 chickedema disease. Journal of Toxicology and Environmental Health 33:455-520.
Glenn, L. 1998. The consequences of human manipulation of the coastal environment on hatchling loggerhead sea turtles (*Caretta caretta*, L.). Pages 58-59 in Byles, R., and Y. Fernandez (compilers). Proceedings of the Sixteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-412.
Glen, F. and N. Mrosovsky. 2004. Antigua revisited: the impact of climate change on sand and nest temperatures at a hawksbill turtle (*Eretmochelys imbricata*) nesting beach. Global Change Biology 10:2036-2045.
Godfrey M. H., R. Barreto. 1995. Beach vegetation and seafinding orientation of turtle hatchlings. Biological Conservation 74:29–32
Godfrey, M.H. and N. Mrosovsky. 1997. Estimating the time between hatching of sea turtles and their emergence from the nest. Chelonian Conservation and Biology 2(4):581-585.
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 '78 Symposium on Technical, Environmental Socioeconomic and Regulatory Aspects of Coastal Zone Management. Vol. II, San Francisco, California.
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.
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.
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.
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., A.J. Baker, and M.E. Echave. 2006. Annual survival of red knots (*Calidris canutus* rufa) using the San Antonio Oeste stopover site is reduced by domino effects involving late arrival and food depletion in Delaware Bay. Hornero 21(2):109-117.
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.
Gratto-Trevor, C., D. Amirault-Langlais, D. Catlin, F. Cuthbert, J. Fraser, S. Maddock, E. Roche, and F. Shaffer. 2012. Connectivity in piping plovers: do breeding populations have distinct winter distributions? Journal of Wildlife Management 76:348-355.
Gratto-Trevor, C. 2012a. Electronic mail dated 21 May 2012 from Cheri Gratto-Trevor, Science and Technology Branch of Environment Canada to Anne Hecht, USFWS Northeast Region regarding preliminary results from Bahamas piping plover study.
Gratto-Trevor, C. 2012b. Electronic mail dated 25 June 2012 from Cheri Gratto-Trevor, Science and Technology Branch of Environment Canada to Carol Aron, USFWS North Dakota Field Office regarding piping plovers banded in the Great Lakes and Northern Great Plains and resighted in the Bahamas.
Green, M.A., G.G. Waldbusser, S.L. Reilly, K. Emerson, and S. O'Donnell. 2009. Death by dissolution: Sediment saturation state as a mortality factor for juvenile bivalves. Limnology and Oceanography 54(4):1037-1047.
Greene, K. 2002. Beach nourishment: A review of the biological and physical impacts. ASMFC Habitat Management Series # 7. ASMFC, Washington, DC., Available at <http://www.asmfc.org/publications/habitat/beachNourishment.pdf>
Greer, A.E., J.D. Lazell, Jr., and R.M. Wright. 1973. Anatomical evidence for counter-current heat exchanger in the leatherback turtle (*Dermochelys coriacea*). Nature 244:181.
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>.

Gutierrez, B. T., N. G. Plant, and E. R. Thieler. 2011. A Bayesian network to predict coastal vulnerability to sea level rise. Journal of Geophysical Research 116 (F02009) doi: 10.1029/2010JF001891.

Gyuris E. 1994. The rate of predation by fishes on hatchlings of the green turtle. Coral Reefs 12:137.

Haas, S.C.G. 2011. Merlin (*Falco columbarius*). In A.T. Chartier, J.J. Baldy, and J.M. Brenneman [EDS.], The second Michigan breeding bird atlas. Kalamazoo Nature Center, Kalamazoo, MI U.S.A. http://www.mibirdatlas. org/Portals/12/MBA2010/MERLaccount.pdf (last accessed 6 December 2012).

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 A. Poole (eds.), The Birds of North America Online. Ithaca: Cornell Laboratory of Ornithology; Retrieved from The Birds of North American Online database: 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. and J.H. Plissner. 1992. Distribution and Abundance of Piping Plovers: Results and Implications of the 1991 International Census. The Condor 95:145-156.

Haig, S.M., and C.L. Ferland, F.J. Cuthbert, J. Dingledine, 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.

Hailman, J.P. and A.M. Elowson. 1992. Ethogram of the nesting female loggerhead (*Caretta caretta*). Herpetologica 48:1-30.

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.

Hanson, J., T. Wibbels, and R.E. Martin. 1998. Predicted female bias in sex ratios of hatchling loggerhead sea turtles from a Florida nesting beach. Canadian Journal of Zoology 76(10):1850-1861.

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. 2006. Are Atlantic Coastal Inlets a Sustaining Habitat of Non-breeding, Migratory Shorebirds? In Guilfoyle, M.P., R.A. Fischer, D.N. Pashley, and C.A. Lott (eds). 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>.

Harrington, B.R. 2008. Coastal inlets as strategic habitat for shorebirds in the southeastern United States. DOER Technical Notes Collection. ERDC TN-DOER-E25. Vicksburg, MS: U.S. Army Engineer Research and Development Center. http://el.erdc.usace.army.mil/dots/doer.

Harrison, R. 2017. Personal Communication. Email from Rebecca Harrison to Kathryn Matthews. March 6, 2017. "red knot data." Supervisory Wildlife Biologist, USFWS, Manteo, NC.

Hawkes, L.A., A.C. Broderick, M.H. Godfrey, and B.J. Godley. 2005. Status of nesting loggerhead turtles *Caretta caretta* at Bald Head Island (North Carolina, USA) after 24 years of intensive monitoring and conservation. Oryx 39(1):65-72.

Hawkes, L.A., A.C. Broderick, M.H. Godfrey, and B.J. Godley. 2008. Climate change and marine turtles. Endangered Species Research 7:137-154.

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.

Hays, G.C. 2000. The implications of variable remigration intervals for the assessment of population size in marine turtles. Journal of Theoretical Biology 206:221-227.

Helmers, D.L. 1992. Shorebird management manual. Western Hemisphere Shorebird Reserve. Network, Manomet, Massachusetts, USA.

Hendrickson, J.R. 1958. The green sea turtle *Chelonia mydas* (Linn.) in Malaya and Sarawak. Proceedings of the Zoological Society of London 130:455-535.

Heppell, S.S. 1998. Application of life-history theory and population model analysis to turtle conservation. Copeia 1998(2):367-375.

Heppell, S.S., L.B. Crowder, and T.R. Menzel. 1999. Life table analysis of long-lived marine species with implications for conservation and management. Pages 137-148 in Musick, J.A. (editor). Life in the Slow Lane: Ecology and Conservation of Long-lived Marine Animals. American Fisheries Society Symposium 23, Bethesda, Maryland.

Heppell, S.S., L.B. Crowder, D.T. Crouse, S.P. Epperly, and N.B. Frazer. 2003. Population models for Atlantic loggerheads: past, present, and future. Pages 225-273 in Bolten, A.B. and B.E. Witherington (editors). Loggerhead Sea Turtles. Smithsonian Books, Washington D.C.

Heppell, S.S., D.T. Crouse, L.B. Crowder, S.P. Epperly, W. Gabriel, T. Henwood, R. Marquez, and N.B. Thompson. 2005. A population model to estimate recovery time, population size, and management impacts on Kemp's ridley sea turtles. Chelonian Conservation and Biology 4(4):767-773.

Herod, H. 2012. Electronic mail dated 6 November 2012 from Holly Herod, USFWS Southeast Regional Office to Anne Hecht, USFWS Northeast Region regarding the Deepwater Horizon oil spill clean-up operations.

Herren, R.M. 1999. The effect of beach nourishment on loggerhead (*Caretta caretta*) nesting and reproductive success at Sebastian Inlet, Florida. Unpublished Master of Science thesis. University of Central Florida, Orlando, Florida. 138 pp.

Herrington, T. O. 2003. Manual for coastal hazard mitigation. New Jersey Sea Grant College Program, Publication NJSG-03-0511. 108 pp. Available at http://www.state.nj.us/dep/cmp/coastal_hazard_manual.pdf.

Hildebrand, H.H. 1963. Hallazgo del área de anidación de la tortuga marina "lora" Lepidochelys kempi (Garman), en la coasta occidental del Golfo de México. Sobretiro de Ciencia, México 22:105-112.

Hirth, H.F. 1997. Synopsis of the biological data on the green turtle *Chelonia mydas* (Linnaeus 1758). U.S. Fish and Wildlife Service, Biological Report 97(1).

Hoffman, D. J., C. P. Rice, and T. J. Kubiak. 1996. PCBs and dioxins in birds. Ch. 7, pp.165-207 in: W.N. Beyer, G.H. Heinz, and A.W. Redmon-Norwood (eds) Environmental contaminants in wildlife: interpreting tissue concentrations. CRC Press, Inc., New York, New York.

Hoopes, E.M. 1993. Relationships between human recreation and piping plover foraging ecology and chick survival. M.S. Thesis. University of Massachusetts, Amherst, Massachusetts.

Hopkins, S.R. and T.M. Murphy. 1980. Reproductive ecology of *Caretta caretta* in South Carolina. South Carolina Wildlife Marine Resources Department Completion Report.

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.

Hosier, P. E. 2018. Seacoast Plants of the Carolinas, A New Guide for Plant Identification and Use in the Coastal Landscape. The University of North Carolina Press. Chapel Hill, North Carolina.

Hosier, P.E., M. Kochhar, and V. Thayer. 1981. Off-road vehicle and pedestrian track effects on the sea –approach of hatchling loggerhead turtles. Environmental Conservation 8:158-161.

Houghton, J.D.R. and G.C. Hays. 2001. Asynchronous emergence by loggerhead turtle (*Caretta caretta*) hatchlings. Naturwissenschaften 88:133-136.

Howard, B. and P. Davis. 1999. Sea turtle nesting activity at Ocean Ridge in Palm Beach County, Florida 1999. Palm Beach County Department of Environmental Resources Management, West Palm Beach, Florida.

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.

Hughes, E. 2017. Personal Communication. Presentation: 2017 Corps Dredge Plan. Presented at March 2, 2017 North Carolina Waterbird Committee Meeting, Hammocks Beach State Park. Environmental Resources Section, Wilmington District, U.S. Army Corps of Engineers.

Hughes, A.L. and E.A. Caine. 1994. The effects of beach features on hatchling loggerhead sea turtles. Pages 237 in Bjorndal, K.A., A.B. Bolten, D.A. Johnson, and P.J. Eliazar (compilers). Proceedings of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-351.

Humiston and Moore Engineers. 2001. "Naples Beach Erosion Control Project 1-Year Post Construction Monitoring Report." Prepared for The City of Naples, Florida.

Hunt, K., D.Gibson, and D. Catlin. 2018. Atlantic Flyway Disturbance Project Biological Data Collection Report. Virginia Tech Shorebird Program report for the National Audubon Society and the National Fish and Wildlife Foundation. 87 pp. https://www.vtshorebirds.org/disturbance [Accessed March 30, 2020].

Ims, R.A., and E. Fuglei. 2005. Trophic interaction cycles in tundra ecosystems and the impact of climate change. BioScience 55(4):311-322.
Insacco, G. and F. Spadola. 2010. First record of Kemp's ridley sea turtle, *Lepidochelys kempii* (Garman 1880) (Cheloniidae), from the Italian waters (Mediterranean Sea). Acta Herpetologica 5(1):113-117.
Intergovernmental Panel on Climate Change (IPCC). 2007a. Summary for Policymakers. In Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Avery, M. Tignor and H.L. Miller (editors). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, and New York, New York, USA.
Intergovernmental Panel on Climate Change(IPCC). 2007b. Summary for Policymakers. In Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Avery, M. Tignor and H.L. Miller (editors). Climate Change 2007: Climate Change Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, and New York, New York, USA.
International Wader Study Group. 2003. Wader Study Group Workshop 26 September 2003 - Are waders world-wide in decline? Reviewing the evidence. Wader Study Group Bulletin 101/102:8-41.
Invasive Species Specialist Group. 2009. ISSG Global Invasive Species Database: Impact information for *Vitex rotundifolia*. Accessed November 11, 2010: http://www.issg.org/database/species/impact_info.asp?si=1110&fr=1&sts=&lang=EN
Jimenez, M.C., A. Filonov, I. Tereshchenko, and R.M. Marquez. 2005. Time-series analyses of the relationship between nesting frequency of the Kemp's ridley sea turtle and meteorological conditions. Chelonian Conservation and Biology 4(4):774-780.
Johnson, C.M. 2019. 2019 Breeding Season Report for the Piping Plover in North Carolina. Unpublished report. 7 pp.
Johnson, C.M. 2020 Breeding Season Report for the Piping Plover in North Carolina. Unpublished report. 7 pp.
Jones, S.J., F.P. Lima, and D.S. Wethey. 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.
Jones, T.T., M.D. Hastings, B.L. Bostrom, D. Pauly, and D.R. Jones. 2011. Growth of captive leatherback turtles, *Dermochelys coriacea*, with inferences on growth in the wild: Implications for population decline and recovery. Journal of Experimental Marine Biology and Ecology 399:84-92.
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.
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.
Kalejta, B. 1992. Distribution, biomass and production of *Ceratonereis erythraeensis* (Fauvel) and *Ceratonereis keiskama* (Day) at the Berg River estuary, South Africa. S. Afr. J. Zool. 27: 121-129.

Kalejta, B. 1992. Distribution, biomass and production of Ceratonereis erythraeensis (Fauvel) and Ceratonereis keiskama (Day) at the Berg River estuary, South Africa. S. Afr. J. Zool. 27: 121-129.
Kamezaki, N., Y. Matsuzawa, O. Abe, H. Asakawa, T. Fujii, K. Goto, S. Hagino, M. Hayami, M. Ishii, T. Iwamoto, T. Kamata, H. Kato, J. Kodama, Y. Kondo, I. Miyawaki, K. Mizobuchi, Y. Nakamura, Y. Nakashima, H. Naruse, K. Omuta, M. Samejima, H. Suganuma, H. Takeshita, T. Tanaka, T. Toji, M. Uematsu, A. Yamamoto, T. Yamato, and I. Wakabayashi. 2003. Loggerhead turtles nesting in Japan. Pages 210-217 in Bolten, A.B. and B.E. Witherington (editors). Loggerhead Sea Turtles. Smithsonian Books, Washington D.C.
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.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.
Kaufman, W. and O. Pilkey. 1979. The Beaches are Moving: The Drowning of America’s Shoreline. Anchor Press/Doubleday, Garden City, New York.
Kery, M., and M. Schaub. 2012. Bayesian Population Analysis Using WinBUGS: A Hierarchical Perspective. Waltham, Massachusetts: Academic Press.
Klein, R. J. T., R. J. Nicholls, S. Ragoonaden, M. Capobianco, J. Aston, and E. N. Buckley. 2001. Technological options for adaptation to climate change in coastal zones. Journal of Coastal Research 17(3):531-543.
Komar, P.D. 1983. Coastal erosion in response to the construction of jetties and breakwaters. Pages 191-204 in Komar, P.D. (editor). CRC Handbook of Coastal Processes and Erosion. CRC Press. Boca Raton, Florida.
Kozak, C. 2016. “Hatteras Inlet Dredging Finished, But Problems Persist.” Island Free Press, January 13, 2016. Available at http://islandfreepress.org/2016Archives/01.13.2016-HatterasInletDredgingFinishedButProblemsPersist.html.
Kraus, N. C. 2007. Coastal inlets of Texas, USA. Proceedings Coastal Sediments ’07:1475-1488. ASCE Press, Reston, Virginia. Available at http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA481728.
Kraus, N.C., Zarillo, G.A., and Tavolaro, J.F. 2003. Hypothetical relocation of Fire Island Inlet, New York. Proceedings of Coastal Sediments ’03, (Clearwater Beach, Florida), CR-ROM.
Labisky, R.F., M.A. Mercadante, and W.L. Finger. 1986. Factors affecting reproductive success of sea turtles on Cape Canaveral Air Force Station, Florida, 1985. Final report to the United States Air Force. United States Fish and Wildlife Service Cooperative Fish and Wildlife Research Unit, Agreement Number 14-16-0009-1544, Research Work Order Number 25.
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.
Lamphere, J. 2006. Plant Guide for bitter panicum (*Panicum amarum* Ell.). USDA-Natural Resources Conservation Service, Golden Meadows Plant Materials Center, Galliano, LA. https://plants.usda.gov/plantguide/pdf/pg_paam2.pdf.

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.

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.

LeDee, O. E., K. C. Nelson, and F. J. Cuthbert. 2010a. The challenge of threatened and endangered species management in coastal areas. Coastal Management 38:337-353.

LeDee, O.E., T. W. Arnold, E.A. Roche, and F. J. Cuthbert. 2010b. Use of breeding and nonbreeding encounters to estimate survival and Breeding-site fidelity of the piping plover at the Great Lakes. The Condor 112(4):637-643.

Leon, Y.M. and C.E. Diez. 1999. Population structure of hawksbill turtles on a foraging ground in the Dominican Republic. Chelonian Conservation and Biology 3(2):230-236.

Limpus, C.J. 1971. Sea turtle ocean finding behaviour. Search 2(10):385-387.

Limpus, C.J., and D.J. Limpus. 2003. Loggerhead Turtles in the Equatorial and Southern Pacific Ocean. Pages 199-209 in Bolten, A.B. and B.E. Witherington (editors). Loggerhead Sea Turtles. The Smithsonian Institution.

Limpus, C.J., V. Baker, and J.D. Miller. 1979. Movement induced mortality of loggerhead eggs. Herpetologica 35(4):335-338.

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.

Lohmann, K.J. and C.M.F. Lohmann. 2003. Orientation mechanisms of hatchling loggerheads. Pages 44-62 in Bolten, A.B. and B.E. Witherington (editors). Loggerhead Sea Turtles. Smithsonian Books, Washington D.C.

Lord, A., J. R. Waas, J. Innes, M. J. Whittingham. 2001. Effects of human approaches to nests of northern New Zealand dotterels. Biological Conservation 98:233-240.

Loss, S.R., T. Will, P.P. Mara. 2012. The impact of free-ranging domestic cats on wildlife of the United States. Nature Communications 4:1396 doi:10.1038/ncomms2380.

Lott, C. A. 2009. The distribution and abundance of piping plovers (*Charadrius melodus*) and snowy plovers (*Charadrius alexandrinus*) on the west coast of Florida relative to beach nourishment and dune restoration before and after the 2004-2005 hurricane seasons. U.S. Army Corps of Engineers, Dredging Operations and Environmental Research Program, Engineer Research and Development Center, Technical Report.

Lott, C.A., P.A. Durkee, W.A. Gierhart, and P.P. Kelly. 2009a. Florida coastal engineering and bird conservation geographic information system (GIS) manual. US Army Corps of Engineers, Dredging Operations and Environmental Research Program, Engineer Research and Development Center, Technical Report, 42 pp.

Lott, C.A., C.S. Ewell Jr., and K.L. Volansky. 2009b. Habitat associations of shoreline-dependent birds in barrier island ecosystems during fall migration in Lee County, Florida. Prepared for U.S. Army Corps of Engineers, Engineer Research and Development Center, Technical Report. 103 pp.

Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority. 1998. Coast 2050: toward a sustainable coastal Louisiana. Louisiana Department of Natural Resources. Baton Rouge, Louisiana.

Lutcavage, M.E., P. Plotkin, B. Witherington, and P.L. Lutz. 1997. Human impacts on sea turtle survival. Pages 387-409 in Lutz, P.L. and J.A. Musick (editors). The Biology of Sea Turtles. CRC Press. Boca Raton, Florida.

Lyons, J. E, W. L. Kendall, J. A. Royle, S. J. Converse, B. A. Andres, and J. B. Buchanan. 2015. Population size and stopover duration estimation using mark-resight data and Bayesian analysis of a superpopulation model. Biometrics DOI: 10.1111/biom.12393

Lyons, J.E., B. Winn, T. Teyes, and K.S. Kalasz. 2017. Post-Breeding Migration and Connectivity of Red Knots in the Western Atlantic. The Journal of Wildlife Management 82(Supplement 1):1-14.

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.

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. 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.

Magliocca, N.R., D.E. McNamara, and A.B. Murray. 2011. Long-Term, Large-Scale Morphodynamic Effects of Artificial Dune Construction along a Barrier Island Coastline. Journal of Coastal Research (2011) 27 (5) 918-930.

Mann, T.M. 1977. Impact of developed coastline on nesting and hatchling sea turtles in southeastern Florida. Unpublished Master of Science thesis. Florida Atlantic University, Boca Raton, Florida.

Manning, L.M., C.H. Peterson, and M.J. Bishop. 2014. Dominant macrobenthic populations experience sustained impacts from annual disposal of fine sediments on sandy beaches. Marine Ecology Progress Series 508:1-15.

Manning, L.M., C.H. Peterson, and S.R. Fegley 2013 "Degradation of Surf-Fish Foraging Habitat Driven by Persistent Sedimentological Modifications Caused by Beach Nourishment." Bulletin of Marine Science, vol. 89: 83-106.

Margaritoulis, D., R. Argano, I. Baran, F. Bentivegna, M.N. Bradai, J.A. Camiñas, P. Casale, G. De Metrio, A. Demetropoulos, G. Gerosa, B.J. Godley, D.A. Haddoud, J. Houghton, L. Laurent, and B. Lazar. 2003. Loggerhead turtles in the Mediterranean Sea: present knowledge and conservation perspectives. Pages 175-198 in Bolten, A.B. and B.E. Witherington (editors). Loggerhead Sea Turtles. Smithsonian Books, Washington D.C.

Márquez, M.R., A. Villanueva O., and M. Sánchez P. 1982. The population of the Kemp's ridley sea turtle in the Gulf of Mexico – *Lepidochelys kempii*. Pages 159-164 in Bjorndal, K.A. (editor). Biology and Conservation of Sea Turtles. Washington, D.C. Smithsonian Institute Press.

Marquez, M.R., M.A. Carrasco, C. Jimenez, R.A. Byles, P. Burchfield, M. Sanchez, J. Diaz, and A.S. Leo. 1996. Good news! Rising numbers of Kemp's ridleys nest at Rancho Nuevo, Tamaulipas, Mexico. Marine Turtle Newsletter 73:2-5.

Marquez-Millan, R. 1994. Synopsis of biological data on the Kemp's ridley sea turtle, Lepidochelys kempi (Garman, 1880). NOAA Technical Memorandum NMFS-SEFC-343.

Martin, R.E. 1992. Turtle nest relocation on Jupiter Island, Florida: an evaluation. Presentation to the Fifth Annual National Conference on Beach Preservation Technology, February 12-14, 1992, St. Petersburg, Florida.

Mason, C. and R. M. Sorensen. 1971. Properties and stability of a Texas barrier beach inlet. Texas A&M University Sea Grant Program Publication No. TAMU-SG-71-217. 177 p. Available at http://nsgl.gso.uri.edu/tamu/tamut71009.pdf.

Masterson, R. P., Jr., J. L. Machemehl, and V. V. Cavaroc. 1973. Sediment movement in Tubbs Inlet, North Carolina. University of North Carolina Sea Grant Report No. 73-2. 117 p. Available at http://nsgl.gso.uri.edu/ncu/ncut73013.pdf.

Maxar Technologies. 2016. Google Earth Pro V 7.3.3.7786 (64-bit). July 27, 2016. Cape Hatteras Island, North Carolina, USA. 35.190772°N, -72.746254°W, eye alt 31,299 feet. Maxar Technologies. Accessed January 13, 2021. http://www.google.com/earth/index.html.

Maxar Technologies. 2019. Google Earth Pro V 7.3.3.7786 (64-bit). September 10, 2019. Cape Hatteras Island, North Carolina, USA. 35.190772°N, -72.746254°W, eye alt 31,299 feet. Maxar Technologies. Accessed January 13, 2021. http://www.google.com/earth/index.html.

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.

McDonald, D.L. and P.H. Dutton. 1996. Use of PIT tags and photoidentification to revise remigration estimates of leatherback turtles (*Dermochelys coriacea*) nesting in St. Croix, U.S. Virgin Islands, 1979-1995. Chelonian Conservation and Biology 2(2):148-152.

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.

McGehee, M.A. 1990. Effects of moisture on eggs and hatchlings of loggerhead sea turtles (Caretta caretta). Herpetologica 46(3):251-258.

McLachlan, A. 1996. Physical factors in benthic ecology: effects of changing sand particle size on beach fauna." Marine Ecology Progress 24 Series, vol. 131 (1996): 205-217.

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>.

Melvin, S.M. and J.P Gibbs. 1996. Viability analysis for the Atlantic coast population of piping plovers. Appendix E (Pages 175-186) in U.S. Fish and Wildlife Service. Piping Plover (*Charadrius melodus*), Atlantic Coast Population, Revised Recovery Plan. Hadley, Massachusetts.

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.

Mercier, F. and R. McNeil. 1994. Seasonal variations in intertidal density of invertebrate prey in a tropical lagoon and effects of shorebird predation. Canadian Journal of Zoology. 72:1755-1763.

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.
Meylan, A. 1982. Estimation of population size in sea turtles. Pages 135-138 in Bjorndal, K.A. (editor). Biology and Conservation of Sea Turtles. Smithsonian Institution Press, Washington, D.C.
Meylan, A. 1992. Hawksbill turtle *Eretmochelys imbricata*. Pages 95-99 in Moler, P.E. (editor). Rare and Endangered Biota of Florida, Volume III. University Press of Florida, Gainesville, Florida.
Meylan, A.B. 1999. Status of the hawksbill turtle (*Eretmochelys imbricata*) in the Caribbean region. Chelonian Conservation and Biology 3(2):177-184.
Meylan, A.B. and M. Donnelly. 1999. Status justification for listing the hawksbill turtle (*Eretmochelys imbricata*) as critically endangered on the 1996 IUCN Red List of Threatened Animals. Chelonian Conservation and Biology 3(2):200-224.
Meylan, A., B. Schroeder, and A. Mosier. 1995. Sea turtle nesting activity in the State of Florida 1979-1992. Florida Marine Research Publications Number 52, St. Petersburg, Florida.
Mierzykowski, S. E. 2009. Summary of existing information pertinent to environmental contaminants and oil spills on breeding Atlantic Coast piping plovers. USFWS. Spec. Proj. Rep. FY09-MEFO-7-EC. Maine Field Office. Old Town, Maine.
Mierzykowski, S. E. 2010. Environmental contaminants in two composite samples of piping plover eggs from Delaware. USFWS. Special Project Report FY10-MEFO-2-EC. Maine Field Office. Orono, Maine.
Mierzykowski, S. E. 2012. Environmental contaminants in piping plover eggs from Rachel Carson National Wildlife Refuge and Monomoy National Wildlife Refuge. USFWS. Special Project Report FY12-MEFO-1-EC. Maine Field Office. Orono, Maine.
Mierzykowski, S. 2012. Electronic mail dated 10 January 2012 from Steve Mierzykowski, USFWS Maine Field Office to Anne Hecht, USFWS Northeast Region regarding results of opportunistic tests of Atlantic Coast piping plover eggs for contaminants.
Militello, A, and N.C. Kraus. 2001. Shinnecock Inlet, New York, Site Investigation Report 4, Evaluation of Flood and Ebb Shoal Sediment Source Alternatives for the West of Shinnecock Interim Project, New York. Coastal Inlets Research Program, Technical Report ERDC-CHL-TR-98-32. U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi.
Miller, J.D. 1997. Reproduction in sea turtles. In P.L. Lutz and J.A. Musick (eds.) The biology of sea turtles, 51-80. Boca Raton, FL: CRC Press.
Miller, K., G.C. Packard, and M.J. Packard. 1987. Hydric conditions during incubation influence locomotor performance of hatchling snapping turtles. Journal of Experimental Biology 127:401-412.
Moody, K. 1998. The effects of nest relocation on hatching success and emergence success of the loggerhead turtle (Caretta caretta) in Florida. Pages 107-108 in Byles, R. and Y. Fernandez (compilers). Proceedings of the Sixteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-412.
Mizrahi, D.S. 2020. Aerial Surveys for Shorebirds Wintering along Northern South America's Atlantic Coast with an emphasis on Semipalmated Sandpipers and Red Knots – Phase 2. Report to National Fish and Wildlife Foundation, Project # 59145. New Jersey Audubon Society, Cape May Court House, New Jersey. 26 pp.

Morrier, A. and R. McNeil. 1991. Time-activity budget of Wilson's and semipalmated plovers in a tropical environment. Wilson Bulletin 103:598-620.

Morris, F. W., IV, R. Walton, and B. A. Christensen. 1978. Hydrodynamic factors involved in Finger Canal and Borrow Lake Flushing in Florida's coastal zone. Volume I. Florida Sea Grant Publication FLSGP-T-78-003. Gainesville, Florida. 765 pp.

Morrison, R.I.G., K. Ross, and L.J. Niles. 2004. Declines in wintering populations of red knots in southern South America. The Condor 106:60-70.

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. 2008. Historical changes in the Mississippi-Alabama barrier-island chain and the roles of extreme storms, sea level, and human activities. Journal of Coastal Research 24(6):1587-1600.

Morton, R., G. Tiling, and N. Ferina. 2003. Causes of hot-spot wetland loss in the Mississippi delta plain. Environmental Geosciences 10:71-80.

Mrosovsky, N. 1968. Nocturnal emergence of hatchling sea turtles: Control by thermal Inhibition of activity. Nature 220, 1338–1339 (1968). https://doi.org/10.1038/2201338a0

Mrosovsky, N. and A. Carr. 1967. Preference for light of short wavelengths in hatchling green sea turtles (*Chelonia mydas*), tested on their natural nesting beaches. Behavior 28:217-231.

Mrosovsky, N. and J. Provancha. 1989. Sex ratio of hatchling loggerhead sea turtles: data and estimates from a five year study. Canadian Journal of Zoology 70:530-538.

Mrosovsky, N. and S.J. Shettleworth. 1968. Wavelength preferences and brightness cues in water finding behavior of sea turtles. Behavior 32:211-257.

Mrosovsky, N. and C.L. Yntema. 1980. Temperature dependence of sexual differentiation in sea turtles: implications for conservation practices. Biological Conservation 18:271-280.

Murphy, T.M. and S.R. Hopkins. 1984. Aerial and ground surveys of marine turtle nesting beaches in the southeast region. Unpublished report prepared for the National Marine Fisheries Service.

Musick, J.A. 1999. Ecology and conservation of long-lived marine mammals. Pages 1-10 in Musick, J.A. (editor). Life in the Slow Lane: Ecology and Conservation of Long-lived Marine Animals. American Fisheries Society Symposium 23, Bethesda, Maryland.

National Aeronautics and Space Administration (NASA) and US Geological Survey (USGS) 1998 Google Earth Pro V 7.3.3.7786 (64-bit). February 14, 1998. Cape Hatteras Island, North Carolina, USA. 35.190772°N, -75.746254°W, eye alt 31,299 feet. NASA, US Geological Survey. Accessed January 13, 2021. http://www.google.com/earth/index.html.

NASA, US Department of Agriculture (USDA) Farm Service Agency, and USGS 2006 Google Earth Pro V 7.3.3.7786 (64-bit). February 23, 2006. Cape Hatteras Island, North Carolina, USA. 35.190772°N, -72.746254°W, eye alt 31,299 feet. NASA, USDA Farm Service Agency, US Geological Survey. Accessed January 13, 2021. http://www.google.com/earth/index.html.

National Marine Fisheries Service (NMFS). 2001. Stock assessments of loggerhead and leatherback sea turtles and an assessment of the impact of the pelagic longline fishery on the loggerhead and leatherback sea turtles of the Western North Atlantic. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFSC-455.

National Marine Fisheries Service (NMFS). 2009a. Loggerhead Sea Turtles (*Caretta caretta*). National Marine Fisheries Service, Office of Protected Resources. Silver Springs, Maryland. http://www.nmfs.noaa.gov/pr/species/turtles/loggerhead.htm

NMFS. 2009b. Green Sea Turtles (*Chelonia mydas*). National Marine Fisheries Service, Office of Protected Resources. Silver Springs, Maryland. http://www.nmfs.noaa.gov/pr/species/turtles/green.htm

NMFS. 2009c. Leatherback Sea Turtles (*Dermochelys coriacea*). National Marine Fisheries Service, Office of Protected Resources. Silver Springs, Maryland. http://www.nmfs.noaa.gov/pr/species/turtles/leatherback.htm

NMFS. 2009d. Hawksbill Turtles (*Eretmochelys imbricata*). National Marine Fisheries Service, Office of Protected Resources. Silver Springs, Maryland. http://www.nmfs.noaa.gov/pr/species/turtles/hawksbill.htm

NMFS and U.S. Fish and Wildlife Service (USFWS). 1991. Recovery plan for U.S. population of Atlantic green turtle (*Chelonia mydas*). National Marine Fisheries Service, Washington, D.C.

NMFS and USFWS. 1992. Recovery plan for leatherback turtles (*Dermochelys coriacea*) in the U.S. Caribbean, Atlantic, and Gulf of Mexico. National Marine Fisheries Service, Washington, D.C.

NMFS and USFWS. 1993. Recovery plan for hawksbill turtle (*Eretmochelys imbricata*) in the U.S. Caribbean, Atlantic, and Gulf of Mexico. National Marine Fisheries Service, St. Petersburg, Florida.

NMFS and USFWS. 1998a. Recovery plan for U.S. Pacific populations of the green turtle (*Chelonia mydas*). National Marine Fisheries Service, Silver Spring, Maryland.

NMFS and USFWS. 1998b. Recovery plan for U.S. Pacific populations of the hawksbill turtle (*Eretmochelys imbricata*). National Marine Fisheries Service, Silver Spring, Maryland.

NMFS and USFWS. 2007a. Green sea turtle (*Chelonia mydas*) 5-year review: summary and evaluation. 102 pp.

NMFS and USFWS. 2007b. Leatherback sea turtle (*Dermochelys coriacea*) 5-year review: summary and evaluation. 79 pp.

NMFS and USFWS. 2007c. Hawksbill sea turtle (*Eretmochelys imbricata*) 5-year review: summary and evaluation. 90 pp.

NMFS and USFWS. 2008. Recovery plan for the Northwest Atlantic population of the loggerhead sea turtle (*Caretta caretta*), second revision. National Marine Fisheries Service, Silver Spring, Maryland.

NMFS, USFWS, and SEMARNAT. 2011. Bi-national recovery plan for the Kemp's ridley sea turtle (*Lepidochelys kempii*), second revision. National Marine Fisheries Service, Silver Spring, Maryland.

National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center. 2001. Guidance for Benthic Habitat Mapping: An Aerial Photographic Approach by Mark Finkbeiner [and by] Bill Stevenson and Renee Seaman, Technology Planning and Management Corporation, Charleston, SC. (NOAA/CSC/20117-PUB). Available at https://coast.noaa.gov/data/digitalcoast/pdf/bhm-guide.pdf

NOAA. 2012. Linear mean sea level (MSL) trends and standard errors in mm/yr. Available at <http://tidesandcurrents.noaa.gov/sltrends/msltrendstable.htm>.

NOAA. 2013. Regional climate trends and scenarios for the U.S. national climate assessment. Part 1. Climate of the northeast U.S. NOAA technical report NESDIS 142-1. NOAA,

Washington, DC, Available at <http://scenarios.globalchange.gov/report/regional-climate-trends-and-scenarios-us-national-climate-assessment-part-1-climate-northeast>.
National Park Service (NPS). 2021. February 5, 2021, Addendum to the Biological Assessment for the Sediment Management Framework within Dare and Hyde Counties, North Carolina, Cape Hatteras National Seashore. National Park Service, U.S. Department of Interior, National Parks of Eastern North Carolina. 14 pp.
National Park Service (NPS). 2020. December 15, 2020, Biological Assessment for the Sediment Management Framework within Dare and Hyde Counties, North Carolina, Cape Hatteras National Seashore. National Park Service, U.S. Department of Interior, National Parks of Eastern North Carolina. 80 pp.
National Park Service (NPS). 2019. Shorebird Monitoring and Management at Cape Hatteras National Seashore: 2018 Annual Report. Fort Collins, CO: National Park Service.
NPS. 2013. Inventory of coastal engineering projects in Cape Hatteras National Seashore. Natural Resource Technical Report. Fort Collins, CO: National Park Service.
NPS. 2012. National Park Service Beach Nourishment Guidance. Natural Resources Technical Report. Fort Collins, CO: National Park Service.
NPS. 2010. Final Off-Road Vehicle Management Plan/EIS. Cape Hatteras National Seashore. US Department of Interior. National Park Service. 274 pp.
NPS. 2007. Cape Hatteras National Seashore 2007 annual piping plover (*Charadrius melodus*) report. Cape Hatteras National Seashore, Manteo, North Carolina.
NPS. 2003. Abundance and distribution of non-nesting piping plovers (*Charadrius melodus*) at Cape Lookout National Seashore, North Carolina, 2000-2003. Unpublished report. Cape Lookout National Seashore, Harkers Island, NC.
National Research Council (NRC). 1987. Responding to changes in sea level: Engineering Implications. National Academy Press, Washington, D.C.
National Research Council (NRC). 1988. Saving Cape Hatteras Lighthouse from the Sea: Options and Policy Implications. Committee on Options for Preserving Cape Hatteras Lighthouse, National Research Council; National Academy Press, National Academy of Sciences, Washington, DC, 150 pp.
NRC. 1990a. Decline of the sea turtles: causes and prevention. National Academy Press; Washington, D.C.
NRC. 1990b. Managing coastal erosion. National Academy Press; Washington, D.C.
NRC. 1995. Beach nourishment and protection. National Academy Press; Washington, D.C.
NRC. 2010. Advancing the science of climate change. The National Academies Press, Washington, DC. Available at <http://www.nap.edu/catalog.php?record_id=12782>.
Neal, W.J., O.H. Pilkey, and J.T. Kelley. 2007. Atlantic coast beaches: a guide to ripples, dunes, and other natural features of the seashore. Mountain Press Publishing Company, Missoula, Montana. 250 pp.
Nelson, D.A. 1987. The use of tilling to soften nourished beach sand consistency for nesting sea turtles. Unpublished report of the U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.
Nelson, D.A. 1988. Life history and environmental requirements of loggerhead turtles. U.S. Fish and Wildlife Service Biological Report 88(23). U.S. Army Corps of Engineers TR EL-86-2 (Rev.).
Nelson, D.A. and B. Blihovde. 1998. Nesting sea turtle response to beach scarps. Page 113 in Byles, R., and Y. Fernandez (compilers). Proceedings of the Sixteenth Annual Symposium

on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-412.
Nelson, D.A. and D.D. Dickerson. 1987. Correlation of loggerhead turtle nest digging times with beach sand consistency. Abstract of the 7th Annual Workshop on Sea Turtle Conservation and Biology.
Nelson, D.A. and D.D. Dickerson. 1988a. Effects of beach nourishment on sea turtles. In Tait, L.S. (editor). Proceedings of the Beach Preservation Technology Conference '88. Florida Shore & Beach Preservation Association, Inc., Tallahassee, Florida.
Nelson, D.A. and D.D. Dickerson. 1988b. Hardness of nourished and natural sea turtle nesting beaches on the east coast of Florida. Unpublished report of the U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.
Nelson, D.A. and D.D. Dickerson. 1988c. Response of nesting sea turtles to tilling of compacted beaches, Jupiter Island, Florida. Unpublished report of the U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.
Nelson, D.A., K. Mauck, and J. Fletemeyer. 1987. Physical effects of beach nourishment on sea turtle nesting, Delray Beach, Florida. Technical Report EL-87-15. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.
Newstead, D.J., Niles, L.J., Porter, R.R., Dey, A.D., Burger, J. & Fitzsimmons, O.N. 2013. Geolocation reveals mid-continent migratory routes and Texas wintering areas of Red Knots (*Calidris canutus* rufa). Wader Study Group Bull. 120(1): 53–59.
Newstead, D. 2012a. June 20, 2012 telephone communication from David Newstead, Coastal Bend Bays and Estuaries Program to Robyn Cobb, USFWS Corpus Christi Field Office, about piping plover movements in the area of the Kennedy/Kleberg County wind farms. Documented in Note to File.
Newstead, D. 2012b. Electronic mail dated 2 March and 10 September 2012 from David Newstead, Coastal Bend Bays and Estuaries Program to Anne Hecht, USFWS Northeast Region regarding plover mortalities in Laguna Madre/Padre Island study area.
Nicholas, M. Electronic mail dated 8 March 2005 from Mark Nicholas, Gulf Islands National Seashore, Gulf Breeze, Florida to Patricia Kelly, USFWS, Panama City, Florida Field Office providing documentation of Great Lakes piping plover sightings post-hurricane.
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 selection and interspecific associations of piping plovers along the Atlantic and Gulf Coasts of the United States. Wilson Bulletin 102:581-590.
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. Espoza. 2008. Status of the red knot (*Calidris canutus* rufa) in the Western Hemisphere. Studies in Avian Biology 36:1-185.
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.

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., and J.M. McCluskey. 1985. The effects of houses and sand fences on the eolian sediment budget at Fire Island New York. Journal of Coastal Research Volume 1, Number 1, 39-46. Fort Lauderdale FL.

Nordstrom, K.F., N.L. Jackson, A.H.F. Klein, D.J. Sherman, and P.A. Hesp. 2006. Offshore Aeolian transport across a low foredune on a developed barrier island. Journal of Coastal Research. Volume 22., No. 5. 1260-1267.

North Carolina Office of Administrative 1 Hearings (OAH). 2014. "15A NCAC 07H.0312 Technical Standards for Beach Fill Projects." North Carolina Administrative Code. Amended effective August 2014.

North Carolina Wildlife Resources Commission (NCWRC). 2017. Portal Access to Wildlife Systems (PAWS) database. Accessed on December 1, 2020.

Nudds, R.L. and D.M. Bryant. 2000. The energetic cost of short flight in birds. Journal of Experimental Biology 203:1561-1572.

Ogren, L.H. 1989. Distribution of juvenile and subadult Kemp's ridley turtles: preliminary results from the 1984-1987 surveys. Pages 116-123 in Caillouet, C.W., Jr., and A.M. Landry, Jr. (eds.). Proceedings of the First International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation and Management. Texas A&M University Sea Grant College Program TAMU-SG-89-105.

Otvos, E. G. 2006. Discussion of Froede, C.R., Jr., 2006. The impact that Hurricane Ivan (September 16, 2004) made across Dauphin Island, Alabama. Journal of Coastal Research, 22(2), 562-573. Journal of Coastal Research 22(6):1585-1588.

Otvos, E. G. and G. A. Carter. 2008. Hurricane degradation – barrier development cycles, northeastern Gulf of Mexico: Landform evolution and island chain history. Journal of Coastal Research 24(2):463-478.

Packard, M.J. and G.C. Packard. 1986. Effect of water balance on growth and calcium mobilization of embryonic painted turtles (Chrysemys picta). Physiological Zoology 59(4):398-405.

Packard, G.C., M.J. Packard, and T.J. Boardman. 1984. Influence of hydration of the environment on the pattern of nitrogen excretion by embryonic snapping turtles (Chelydra serpentina). Journal of Experimental Biology 108:195-204.

Packard, G.C., M.J. Packard, and W.H.N. Gutzke. 1985. Influence of hydration of the environment on eggs and embryos of the terrestrial turtle Terrapene ornata. Physiological Zoology 58(5):564-575.

Packard,G.C., M.J. Packard, T.J. Boardman, and M.D. Ashen. 1981. Possible adaptive value of water exchange in flexible-shelled eggs of turtles. Science 213:471-473.

Packard G.C., M.J. Packard, K. Miller, and T.J. Boardman. 1988. Effects of temperature and moisture during incubation on carcass composition of hatchling snapping turtles (*Chelydra serpentina*). Journal of Comparative Physiology B 158:117-125.

Parmenter, C.J. 1980. Incubation of the eggs of the green sea turtle, *Chelonia mydas*, in Torres Strait, Australia: the effect of movement on hatchability. Australian Wildlife Research 7:487-491.

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., and M.J. Bishop. 2005. Assessing the environmental impacts of beach nourishment. BioScience 55(10):887-896.

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.

Peterson, C.H., and L. Manning. 2001. How beach nourishment affects the habitat value of intertidal beach prey for surf fish and shorebirds and why uncertainty still exists. Pages 2 In Proceedings of the coastal ecosystems & federal activities technical training symposium, August 20-22, 2001, Available at <http://www.fws.gov/nc-es/ecoconf/ppeterson%20abs.pdf>.

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, vol. 16: 368-378.

Pfeffer, W.T., J.T. Harper, and S. O'Neel. 2008. Kinematic constraints on glacier contributions to 21st-century sea-level rise. Science 321(5894):1340-1343.

Pfister, C., B.A. Harrington, and M. Lavine. 1992. The impact of human disturbance on shorebirds at a migration staging area. Biol. Conserv. 60:115-126.

Philibosian, R. 1976. Disorientation of hawksbill turtle hatchlings (*Eretmochelys imbricata*) by stadium lights. Copeia 1976:824.

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):2171-185.

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.

Pietrafesa, L.J. 2012. On the Continued Cost of Upkeep Related to Groins and Jetties. J. Coastal Research 28(5):iii-ix.

Pilkey, O.H. and K.L. Dixon. 1996. The Corps and the shore. Island Press; Washington, D.C.

Pilkey, O. H. and R. Young. 2009. The rising sea. Island Press, Washington. 203 pp.

Pilkey, Jr., O.H., D.C. Sharma, H.R. Wanless, L.J. Doyle, O.H. Pilkey, Sr., W. J. Neal, and B.L. Gruver. 1984. Living with the East Florida Shore. Duke University Press, Durham, North Carolina.

Pittman, C. 2001. Mosquito spray deadly to birds. St. Petersburg Times online Tampa Bay January 28, 2001. Accessed April 2017 at: http://www.sptimes.com/News/012801/news_pf/TampaBay/Mosquito_spray_deadly.shtml.

Plant, N.G. and G.B. Griggs. 1992. Interactions between nearshore processes and beach morphology near a seawall. Journal of Coastal Research 8(1): 183-200.

Plissner, J.H. and S.M. Haig. 2000a. Status of the broadly distributed endangered species: results and implications of the second International Piping Plover Census. Can. J. Zool. 78: 128-139.

Plissner, J. H. and S. M. Haig. 2000b. 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.

Potter, E.F., J.F. Parnell, and R.P. Teulings. 1980. Birds of the Carolinas. University of North Carolina Press. 402 pp.

Pritchard, P.C.H. 1982. Nesting of the leatherback turtle, *Dermochelys coriacea* in Pacific Mexico, with a new estimate of the world population status. Copeia 1982(4):741-747.

Pritchard, P.C.H. 1992. Leatherback turtle *Dermochelys coriacea*. Pages 214-218 in Moler, P.E. (editor). Rare and Endangered Biota of Florida, Volume III. University Press of Florida; Gainesville, Florida.

Provancha, J.A. and L.M. Ehrhart. 1987. Sea turtle nesting trends at Kennedy Space Center and Cape Canaveral Air Force Station, Florida, and relationships with factors influencing nest site selection. Pages 33-44 in Witzell, W.N. (editor). Ecology of East Florida Sea Turtles: Proceedings of the Cape Canaveral, Florida Sea Turtle Workshop. NOAA Technical Report NMFS-53.

Rabon, D.R., Jr., S.A. Johnson, R. Boettcher, M. Dodd, M. Lyons, S. Murphy, S. Ramsey, S. Roff, and K. Stewart. 2003. Confirmed leatherback turtle (*Dermochelys coriacea*) nests from North Carolina, with a summary of leatherback nesting activities north of Florida. Marine Turtle Newsletter 101:4-8.

Radford, A. E., H. E. Ahles, and C. R. Bell. 1968. Manual of the vascular flora of the Carolinas. University of North Carolina Press, Chapel Hill, NC.

Rahmstorf, S. 2007. A Semi-Empirical Approach to Projecting Future Sea-Level Rise. Science 315: 368-370.

Rahmstorf, S., A. Cazenave, J. U. Church, J. E. Hansen, R. F. Keeling, D. E. Parker, and R. C. J. Somerville. 2007. Recent climate observations compared to projections. Science 316:709.

Rakocinski, C. F., R. W. Heard, S. E. LeCroy, J. A. McLelland, and T. Simons. 1996. Responses by macrobenthic assemblages to extensive beach restoration at Perdido Key, Florida, USA. Journal of Coastal Research 12(1):326-353.

Rand, G. M. and S. R. Petrocelli. 1985. Fundamentals of aquatic toxicology. Hemisphere Publishing Corporation, Washington, D.C.

Rattner, B. A. and B. K. Ackerson. 2008. Potential environmental contaminant risks to avian species at important bird areas in the northeastern United States. Integrated Environmental Assessment and Management 4(3):344-357.

Raymond, P.W. 1984. The effects of beach restoration on marine turtles nesting in south Brevard County, Florida. Unpublished Master of Science thesis. University of Central Florida, Orlando, Florida.

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.

Reina, R.D., P.A. Mayor, J.R. Spotila, R. Piedra, and F.V. Paladino. 2002. Nesting ecology of the leatherback turtle, *Dermochelys coriacea*, at Parque Nacional Marino Las Baulas, Costa Rica: 1988-1989 to 1999-2000. Copeia 2002(3):653-664.

Rice, K. 2009. In-office conversation dated 13 March 2009, between Ken Rice, Contaminants specialist and Robyn Cobb, Endangered Species Recovery program, both of USFWS Corpus Christi Ecological Services Field Office, Texas regarding sources of oil spills that have affected the Texas Gulf coast.

Rice, T.M. 2017. Inventory of Habitat Modifications to Sandy Oceanfront Beaches in the U.S. Atlantic Coast Breeding Range of the Piping Plover (*Charadrius melodus*) as of 2015: Maine to North Carolina. Report submitted to the U.S. Fish and Wildlife Service, Hadley, Massachusetts. 295 pp.

Rice, T.M. 2016. Inventory of Habitat Modifications to Tidal Inlets in the U.S. Atlantic Coast Breeding Range of the Piping Plover (*Charadrius melodus*) as of 2015: Maine to North Carolina. Report submitted to the U.S. Fish and Wildlife Service, Hadley, Massachusetts. 94 pp.

Rice, T.M. 2012a. 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, U.S. Fish and Wildlife Service. 35 pp.

Rice, T.M. 2012b. 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, U.S. Fish and Wildlife Service. 40 pp.

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.

Richardson, T.H., J.I. Richardson, C. Ruckdeschel, and M.W. Dix. 1978. Remigration patterns of loggerhead sea turtles (*Caretta caretta*) nesting on Little Cumberland Island and Cumberland Island, Georgia. Pages 39-44 in Henderson, G.E. (editor). Proceedings of the Florida and Interregional Conference on Sea Turtles. Florida Marine Research Publications Number 33.

Riggs, S.R., D.V. Ames, S.J. Culver, D.J. Mallinson, D.R. Corbett, and J.P. Walsh. 2009. Eye of a Hurricane: Pea Island, Oregon Inlet, and Bodie Island, northern Outer Banks, North Carolina. In: America's Most Vulnerable Coastal Communities, eds., Kelly, J.T., Pilkey, O.H., and Cooper, J.A.G. Geological Society of America Special Paper 460-04, p. 43-72.

Roche, E. A., J. B. Cohen, D. H. Catlin, D. L. Amirault-Langlais, F. J. Cuthbert, C. L. Gratto-Trevor, J, Felio, and J. D. Fraser. 2010. Range-wide piping plover survival: correlated patterns and temporal declines. Journal of Wildlife Management 74:1784-1791.

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. 2009. Range-wide estimation of apparent survival in the piping plover. Report submitted to the U.S. Fish and Wildlife Service, East Lansing, Michigan.

Roche, E.A., F. J. Cuthbert, T.W. Arnold. 2008. Relative fitness of wild and captive-reared piping plovers: Does egg salvage contribute to recovery of the endangered Great Lakes

population? Biological Conservation. Volume 141, Issue 12, December 2008, Pages 3079-3088.
Roche, E. 2010. PowerPoint presentation at December 2010 Non-breeding piping plover conservation workshop in Fernandina Beach, Florida about partitioning annual survival in Great Lakes piping plovers.
Roche, E. 2012. Electronic mail dated 13 March 2012 from Erin Roche, University of Tulsa to Anne Hecht, USFWS Northeast Region regarding winter range temperature and spring survival of piping plovers.
Rogers, S and D Nash. 2003. The Dune Book. North Carolina Sea Grant Program, Publication UNC-SG-03-03. 32 00. Available at https://ncseagrant.ncsu.edu/ncseagrant_docs/products/2000s/dune_book.pdf.
Rosov, B., S. Bush, T. Roberts Briggs, and N. Elko. 2016. "The state of understanding the impacts of beach nourishment activities on infaunal communities." Shore and Beach, vol. 84 (2016): 51-55.
Rostal, D.C. 2007. Reproductive physiology of the ridley sea turtle. Pages 151-165 in Plotkin P.T. (editor). Biology and Conservation of Ridley Sea Turtles. Johns Hopkins University Press, Baltimore, Maryland.
Routa, R.A. 1968. Sea turtle nest survey of Hutchinson Island, Florida. Quarterly Journal of the Florida Academy of Sciences 30(4):287-294.
Rumbold, D.G., P.W. Davis, and C. Perretta. 2001. Estimating the effect of beach nourishment on *Caretta caretta* (loggerhead sea turtle) nesting. Restoration Ecology 9(3):304-310.
Ryan, M.R., B.G. Root, and P.M. Mayer. 1993. Status of piping plovers in the great plains of North America: a demographic simulation model. Conservation Biology 7(3): 581-585.
Salmon, M. and J. Wyneken. 1987. Orientation and swimming behavior of hatchling loggerhead turtles *Caretta caretta* L. during their offshore migration. J. Exp. Mar. Biol. Ecol. 109: 137–153.
Salmon, M., J. Wyneken, E. Fritz, and M. Lucas. 1992. Seafinding by hatchling sea turtles: role of brightness, silhouette and beach slope as orientation cues. Behaviour 122 (1-2):56-77.
Saunders, S. P., T. W. Arnold, E. A. Roche, and F. J. Cuthbert. 2014. Age-specific survival and recruitment of piping plovers *Charadrius melodus* in the Great Lakes region. Journal of Avian Biology 45:1–13.
Saunders, S.P. 2015. The Causes and Consequences of Individual Variation in Survival and Fecundity of Great Lakes Piping Plovers (*Charadrius melodus*). Ph.D. Dissertation. University of Minnesota. Minneapolis, MN.
Saunders, S.P. 2016. Personal Communication. 09/27/2016 Email to Kathy Matthews and others. Re: Data request for assessment of Rich Inlet, NC PIPL impacts. Post-doctoral Research Associate. Michigan State University. East Lansing, Michigan.
Sax, D. F. and S. D. Gaines. 2008. Species invasions and extinction: the future of native biodiversity on islands. Proceedings of the National Academy of Sciences USA 105 (Supplement 1):11490-11497.
Scavia, D., J.C. Field, D.F. Boesch, R.W. Buddemeier, V. Burkett, D.R. Cayan, M. Fogarty, M.A. Harwell, R.W. Howarth, C. Mason, D.J. Reed, T.C. Royer, A.H. Sallenger, and J.G. Titus. 2002. Climate change impacts on U.S. coastal and marine ecosystems. Estuaries 25:149-164.
Schlacher, T., D. Richardson, and I. McLean. 2008. Impacts of off-road vehicles (ORVs) on macrobenthic assemblages on sandy beaches. Environmental Management 41:878-892.

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.

Schoeman, D. S., A. McLachlan, and J. E. Dugan. 2000. Lessons from a disturbance experiment in the intertidal zone of an exposed sandy beach. Estuarine, Coastal and Shelf Science 50: 869-884.

Schroeder, B.A. 1981. Predation and nest success in two species of marine turtles (*Caretta caretta* and *Chelonia mydas*) at Merritt Island, Florida. Florida Scientist 44(1):35.

Schroeder, B.A. 1994. Florida index nesting beach surveys: are we on the right track? Pages 132-133 in Bjorndal, K.A., A.B. Bolten, D.A. Johnson, and P.J. Eliazar (compilers). Proceedings of the 14th Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-351.

Schroeder, B.A., A.M. Foley, and D.A. Bagley. 2003. Nesting patterns, reproductive migrations, and adult foraging areas of loggerhead turtles. Pages 114-124 in Bolten, A.B. and B.E. Witherington (editors). Loggerhead Sea Turtles. Smithsonian Books, Washington D.C.

Schwarzer, A.C., J.A. Collazo, L.J. Niles, J.M. Brush, N.J. Douglass, and H.F. Percival. 2012. Annual survival of red knots (*Calidris canutus* rufa) wintering in Florida. The Auk 129(4):725-733.

Schweitzer, S.H. 2017. Personal Communication. Email from Sara Schweitzer to Kathryn Matthews. March 16, 2017. Re: PIPL and REKN data for Statewide Programmatic BO. North Carolina Wildlife Resources Commission.

Schweitzer, S.H. 2015. 2015 Breeding Season Report for the Piping Plover in North Carolina. Unpublished report. 6 pp.

Schweitzer, S.H. 2017. 2017 Breeding Season Report for the Piping Plover in North Carolina. Unpublished report. 6 pp.

Schweitzer, S.H. 2018. 2018 Breeding Season Report for the Piping Plover in North Carolina. Unpublished report. 7 pp.

Schweitzer, S., and M. Abraham. 2014. 2014 Breeding Season Report for the Piping Plover in North Carolina. North Carolina Wildlife Commission. 6 pp.

Scott, J.A. 2006. Use of satellite telemetry to determine ecology and management of loggerhead turtle (*Caretta caretta*) during the nesting season in Georgia. Unpublished Master of Science thesis. University of Georgia, Athens, Georgia.

Shadow, R.A. 2007. Plant fact sheet for Sea oats (*Uniola paniculata* L.). Published October, 2007. USDA-Natural Resources Conservation Service, East Texas Plant Material Center, Nacogdoches, TX 75964

Shaver, D.J. 2002. Research in support of the restoration of sea turtles and their habitat in national seashores and areas along the Texas coast, including the Laguna Madre. Final NRPP Report. U.S. Geological Survey, Department of the Interior.

Shaver, D.J. 2005. Analysis of the Kemp's ridley imprinting and headstart project at Padre Island National Seashore, Texas, 1978-88, with subsequent nesting and stranding records on the Texas coast. Chelonian Conservation and Biology 4(4):846-859.

Shaver, D.J. 2006a. Kemp’s ridley sea turtle project at Padre Island National Seashore and Texas sea turtle nesting and stranding 2004 report. National Park Service, Department of the Interior.

Shaver, D.J. 2006b. Kemp's ridley sea turtle project at Padre Island National Seashore and Texas sea turtle nesting and stranding 2005 report. National Park Service, Department of the Interior.

Shaver, D.J. 2007. Texas sea turtle nesting and stranding 2006 report. National Park Service, Department of the Interior.

Shaver, D. 2008. Personal communication via e-mail to Sandy MacPherson, U.S. Fish and Wildlife Service, Jacksonville, Florida, on Kemp's ridley sea turtle nesting in Texas in 2008. National Park Service.

Shaver, D.J. 2008. Texas sea turtle nesting and stranding 2007 report. National Park Service, Department of the Interior.

Shaver, D.J. and C.W. Caillouet, Jr. 1998. More Kemp's ridley turtles return to south Texas to nest. Marine Turtle Newsletter 82:1-5.

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. 2006. Migration stopovers and the conservation of Arctic-breeding Calidridine sandpipers. The Auk 123:313-322.

Smith, B.S. 2007. 2006-2007 Nonbreeding shorebird survey, Franklin and Wakulla Counties, Florida. Final report to the USFWS in fulfillment of Grant #40181-7-J008. Apalachicola Riverkeeper, Apalachicola, Florida. 32 pp.

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, C. G., S. J. Culver, S. R. Riggs, D. Ames, D. R. Corbett, and D. Mallinson. 2008. Geospatial analysis of barrier island width of two segments of the Outer Banks, North Carolina, USA: Anthropogenic curtailment of natural self-sustaining processes. Journal of Coastal Research 24(1):70-83.

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.

Snover, M. 2005. Personal communication to the Loggerhead Sea Turtle Recovery Team. National Marine Fisheries Service.

Snover, M.L., A.A. Hohn, L.B. Crowder, and S.S. Heppell. 2007. Age and growth in Kemp's ridley sea turtles: evidence from mark-recapture and skeletochronology. Pages 89-106 in Plotkin P.T. (editor). Biology and Conservation of Ridley Sea Turtles. John Hopkins University Press, Baltimore, Maryland.

Sobel, D. 2002. A photographic documentation of aborted nesting attempts due to lounge chairs. Page 311 in Mosier, A., A. Foley, and B. Brost (compilers). Proceedings of the Twentieth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-477.

Solow, A.R., K.A. Bjorndal, and A.B. Bolten. 2002. Annual variation in nesting numbers of marine turtles: the effect of sea surface temperature on re-migration intervals. Ecology Letters 5:742-746.

South Carolina Department of Natural Resources (SCDNR). 2011. Kiawah Island East End Erosion and Beach Restoration Project: survey of changes in potential macroinvertebrate prey communities in piping lover foraging habitats. Final Report. 74 pp.

Speybroeck, J., D. Bonte, W. Courtens, T. Gerskiere, P. Groutaert, J. Maelfait, M. Mathys, S. Provoost, D. Sabbe, E.W.M. Stienen, V. Van Lancker, M. Vincx, and S. Degraer 2006 "Beach Nourishment: An Ecologically Sound Coastal Defence Alternative? A Review." Aquatic Conservation: Marine and Freshwater Ecosystems, vol. 16: 419-435.

Spotila, J.R., E.A. Standora, S.J. Morreale, G.J. Ruiz, and C. Puccia. 1983. Methodology for the study of temperature related phenomena affecting sea turtle eggs. U.S. Fish and Wildlife Service Endangered Species Report 11.

Spotila, J.R., A.E. Dunham, A.J. Leslie, A.C. Steyermark, P.T. Plotkin, and F.V. Paladino. 1996. Worldwide population decline of *Dermochelys coriacea*: are leatherback turtles going extinct? Chelonian Conservation and Biology 2(2):290-222.

Spotila, J.R. R.D. Reina, A.C. Steyermark, P.T. Plotkin, and F.V. Paladino. 2000. Pacific leatherback turtles face extinction. Nature 405:529-530.

Staine, K.J., and J. Burger. 1994. Nocturnal foraging behavior of breeding piping plovers (*Charadrius melodus*) in New Jersey. Auk 111:579-587

Stancyk, S.E., O.R. Talbert, and J.M. Dean. 1980. Nesting activity of the loggerhead turtle *Caretta caretta* in South Carolina, II: protection of nests from raccoon predation by transplantation. Biological Conservation 18:289-298.

Stancyk, S.E. 1995. Non-human predators of sea turtles and their control. Pages 139-152 in Bjorndal, K.A. (editor). Biology and Conservation of Sea Turtles, Revised Edition. Smithsonian Institution Press. Washington D.C.

Stegmann,E.W., R.B. Primac, and G.S. Elimore. 1988. Absorption of nutrient exudates from terrapin eggs by roots of *Ammophila breviligulata* (Gaminaceae). Canadian Journal of Botany 66:714-718.

Steinitz, M.J., M. Salmon, and J. Wyneken. 1998. Beach renourishment and loggerhead turtle reproduction: a seven year study at Jupiter Island, Florida. Journal of Coastal Research 14(3):1000-1013.

Sternberg, J. 1981. The worldwide distribution of sea turtle nesting beaches. Center for Environmental Education, Washington, D.C.

Stewart, K.R. 2007. Establishment and growth of a sea turtle rookery: the population biology of the leatherback in Florida. Unpublished Ph.D. dissertation. Duke University, Durham, North Carolina. 129 pp.

Stewart, K.R. and J. Wyneken. 2004. Predation risk to loggerhead hatchlings at a high-density nesting beach in Southeast Florida. Bulletin of Marine Science 74(2):325-335.

Stewart, K., M. Sims, A. Meylan, B. Witherington, B. Brost, and L.B. Crowder. 2011. Leatherback nests increasing significantly in Florida, USA; trends assessed over 30 years using multilevel modeling. Ecological Applications 21(1):263-273.

Stockdon, H. F., K. S. Doran, and K. A. Serafin. 2010. Coastal change on Gulf Islands National Seashore during Hurricane Gustav: West Ship, East Ship, Horn, and Petit Bois Islands. U.S. Geological Survey Open-File Report 2010-1090. 14 pp.

Stone, W. 1937. Bird studies at Old Cape May: An ornithology of coastal New Jersey. Dover Publications, New York.

Stratton, A.C. 1957. Beach erosion control in the Cape Hatteras National Seashore recreational area. Shore & Beach 25(1): pp 4-8.

Stucker, J. H., F. J. Cuthbert, B. Winn, B. L. Noel, S. B. Maddock, P. R. Leary, J. Cordes, and L. C. Wemmer. 2010. Distribution of non-breeding Great Lakes piping plovers (*Charadrius melodus*) along Atlantic and Gulf of Mexico coastlines: ten years of band sightings. Waterbirds: 33:22-32.

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, MI.

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 US Fish and Wildlife Service, East Lansing, MI.

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.

Tait, J.F. and G.B. Griggs. 1990. Beach response to the presence of a seawall. Shore and Beach, April 1990:11-28.

Talbert, O.R., Jr., S.E. Stancyk, J.M. Dean, and J.M. Will. 1980. Nesting activity of the loggerhead turtle (*Caretta caretta*) in South Carolina I: a rookery in transition. Copeia 1980(4):709-718.

Tanacredi, J.T., M.L. Botton, and D. Smith. 2009. Biology and conservation of horseshoe crabs. Springer, New York.

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.

Tarr, N.M. 2008. Fall migration and vehicle disturbance of shorebirds at South Core Banks, North Carolina. North Carolina State University, Raleigh, NC.

Tebaldi, C., B.H. Strauss, and C.E. Zervas. 2012. Modeling sea level rise impacts on storm surges along US coasts. Environmental Research Letters 7:014032.

Thieler, E.R., and E.S. Hammar-Klose. 1999. National assessment of coastal vulnerability to sea-level rise: Preliminary results for the U.S. Atlantic coast. Open-file report 99-593. U.S. Geological Survey, Woods Hole, MA, Available at http://pubs.usgs.gov/of/1999/of99-593/.

Thieler, E.R., and E.S. Hammar-Klose. 2000. National assessment of coastal vulnerability to sea-level rise: Preliminary results for the U.S. Gulf of Mexico coast. Open-file report 00-179. U.S. Geological Survey, Woods Hole, MA, Available at http://pubs.usgs.gov/of/2000/of00-179/.

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.

Thrush, S. F., R. B. Whitlatch, R. D. Pridmore, J. E. Hewitt, V. J. Cummings, and M. R. Wilkinson. 1996. Scale-dependent recolonization: the role of sediment stability in a dynamic sandflat habitat. Ecology 77: 2472–2487.

Titus, J.G., D.E. Hudgens, D.L. Trscott, M. Craghan, W.H. Nukols, C.H. Hershner, J.M. Kassakian, C.J. Linn, P.G. Merritt, T.M. McCue, J.F. O'Connell, J. Tanski, and J. Wang. 2009. State and local governments plan for development of most land vulnerable to rising sea level along the US Atlantic coast. Environmental Research Letters 4 (2009) 044008.

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.

Trembanis, A.C., O.H. Pilkey, and H.R. Valverde. 1999. Comparison of Beach Nourishment along the U.S. Atlantic, Great Lakes, Gulf of Mexico, and New England Shorelines. Coastal Management 27:329-340.

Trindell, R. 2005. Sea turtles and beach nourishment. Florida Fish and Wildlife Conservation Commission, Imperiled Species Management Section. Invited Instructor, CLE Conference.

Trindell, R. 2007. Personal communication. Summary of lighting impacts on Brevard County beaches after beach nourishment. Florida Fish and Wildlife Conservation Commission, Imperiled Species Management Section, Tallahassee, Florida to Lorna Patrick, U. S. Fish and Wildlife Service, Panama City, Florida.

Trindell, R., D. Arnold, K. Moody, and B. Morford. 1998. Post-construction marine turtle nesting monitoring results on nourished beaches. Pages 77-92 in Tait, L.S. (compiler). Proceedings of the 1998 Annual National Conference on Beach Preservation Technology. Florida Shore & Beach Preservation Association, Tallahassee, Florida.

Tsipoura, N. and J. Burger. 1999. Shorebird diet during spring migration stopover on Delaware Bay. Condor 101: 635-644.

Turtle Expert Working Group (TEWG). 1998. An assessment of the Kemp's ridley (*Lepidochelys kempii*) and loggerhead (*Caretta caretta*) sea turtle populations in the western North Atlantic. NOAA Technical Memorandum NMFS-SEFSC-409.

TEWG. 2000. Assessment for the Kemp's ridley and loggerhead sea turtle populations in the western North Atlantic. NOAA Technical Memorandum. NMFS-SEFSC-444.

TEWG. 2007. An assessment of the leatherback turtle population in the Atlantic Ocean. NOAA Technical Memorandum NMFS-SEFSC-555.

UK CEED 2000. A review of the effects of recreational interactions within UK European marine sites. Countryside Council for Wales (UK Marine SACs Project). 264 pp.

U.S. Army Corps of Engineers (USACE). 1992. Inlets along the Texas Gulf coast. Planning Assistance to States Program, Section 22 Report. U.S. Army Engineer District, Galveston, Southwestern Division. 56 p. Available at http://cirp.usace.army.mil/pubs/archive/Inlets_Along_TX_Gulf_Coast.pdf.

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-point-nj.aspx

USACE. 2013. Public Notice of an Emergency Permit for North Carolina Department of Transportation Oregon Inlet Dredging, Dare County, NC. 17 Day Public Notice, Public Notice No. SAW-2013-02272, December 6, 2013. Wilmington District, U.S. Army Corps of Engineers, Wilmington, NC. 2 pp.

USACE. 2015. 2015 Seabeach amaranth (*Amaranthus pumilus*) survey. December 2015. Report to U.S. Fish and Wildlife Service, Raleigh Field Office. 72 pp.

USACE. 2016. Fire Island Inlet to Montauk Point Draft EIS, Appendix I: Breach Response Protocols. 12 pp. https://www.nan.usace.army.mil/Portals/37/docs/civilworks/projects/ny/coast/fimp/FIMP%20EIS/EISAppendixI-BCP.pdf?ver=2016-07-19-172046-943.

U.S. Climate Change Science Program (CCSP). 2009. Coastal sensitivity to sea-level rise: A focus on the Mid-Atlantic Region. U.S. Climate Change Science Program synthesis and assessment product 4.1. U.S. Geological Survey, Reston, VA, Available at <http://downloads.globalchange.gov/sap/sap4-1/sap4-1-final-report-all.pdf>.

USDA Farm Agency and Maxar Technologies. 2011. Google Earth Pro V 7.3.3.7786 (64-bit). March 12, 2011. Cape Hatteras Island, North Carolina, USA. 35.190772°N, -72.746254°W, eye alt 31,299 feet. USDA Farm Service Agency, Maxar Technologies. Accessed January 13, 2021. http://www.google.com/earth/index.html.

U.S. Environmental Protection Agency (USEPA). 2013. Coastal zones and sea level rise.

USEPA. 2012. Climate Change Indicators in the United States, 2012. U.S. Environmental Protection Agency, 12200 Pennsylvania Avenue, N.W. (6207), Washington, D.C. 20460. EPA 430-R-12-004.

USEPA. 2009. Coastal Zones and sea level rise. Accessed on 29 January 2009 at http://www.epa.gov/climatechange/effects/coastal/ index/html.

U.S. Fish and Wildlife Service (USFWS). 1970. United States List of Endangered Native Fish and Wildlife. Federal Register 35(199):16047.

USFWS. 1985. Determination of endangered and threatened status for the piping plover. Federal Register 50:50726-50734.

USFWS. 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.

USFWS. 1993. Endangered and threatened wildlife and plants; determination of seabeach amaranth (*Amaranthus pumilus*) to a threatened species. Federal Register 58(65)18035-18042

USFWS. 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, MN. 99 pp.

USFWS. 1996a. Piping Plover (*Charadrius melodus*), Atlantic Coast Population, Revised Recovery Plan. Hadley, Massachusetts. 258 pp.

USFWS. 1996b. Recovery plan for seabeach amaranth (Amaranthus pumilus). U.S. Fish and Wildlife Service, Atlanta, GA.

USFWS. 2001a. Final determination of critical habitat for the Great Lakes breeding population of the piping plover. Federal Register 66:22938-22969.

USFWS. 2001b. Final determination of critical habitat for wintering piping plovers. Federal Register 66:36037-36086.

USFWS. 2002. Final designation of critical habitat for the Northern Great Plains breeding population of the piping plover. Federal Register. 67:57637-57717.

USFWS. 2003a. Recovery plan for the Great Lakes piping plover (*Charadrius melodus*). Fish and Wildlife Service, Fort Snelling, Minnesota.

USFWS. 2003b. Delaware Bay shorebird-horseshoe crab assessment report and peer review. ASMFC, Arlington, VA, Available at <http://digitalmedia.fws.gov/cdm/ref/collection/document/id/1418>.

USFWS. 2005. Report on the Mexico/United States of America population restoration project for the Kemp's ridley sea turtle, *Lepidochelys kempii*, on the coasts of Tamaulipas and Veracruz, Mexico 2005. Fish and Wildlife Service Technical Report.

USFWS. 2006. Strategic Habitat Conservation. Final Report of the National Ecological Assessment Team to the U.S. Fish and Wildlife Service and U.S. Geologic Survey.

USFWS. 2007. Draft communications plan on the U.S. Fish and Wildlife Service's Role in Climate Change.

USFWS. 2008. Revised designation of critical habitat for the wintering population of the piping plover (*Charadrius melodus*) in North Carolina. Federal Register 73:62816-62840.

USFWS. 2009a. Piping Plover 5-year Review: Summary and Evaluation. 214pp.
USFWS. 2009b. Revised designation of critical habitat for the wintering population of the piping plover (*Charadrius melodus*) in Texas. Federal Register 74:23476-23524.
USFWS. 2010. Final report on the Mexico/United States of America population restoration project for the Kemp's ridley sea turtle, *Lepidochelys kempii*, on the coasts of Tamaulipas and Veracruz, Mexico.
USFWS. 2011. Abundance and productivity estimates – 2010 update: Atlantic Coast piping plover population. Sudbury, Massachusetts. 4 pp.
USFWS and Conserve Wildlife Foundation of New Jersey. 2012. Cooperative agreement. Project title: Identify juvenile red knot wintering areas
USFWS. 2012. Comprehensive Conservation Strategy for the Piping Plover in its Coastal Migration and Wintering Range in the Continental United States. East Lansing, Michigan. Available at http://www.fws.gov/midwest/EastLansing/.
USFWS. 2013a. Endangered and Threatened Wildlife and Plants; Proposed Threatened Status for the Rufa Red Knot (*Calidris canutus* rufa). 78 FR 60024-60098. Docket FWS-R5-ES-2013-0097 (September 30, 2013). Available at www.regulations.gov.
USFWS. 2013b. Rufa Red Knot Ecology and Abundance. Supplement to Endangered and Threatened Wildlife and Plants; Proposed Threatened Status for the Rufa Red Knot (*Calidris canutus* rufa) [FWS–R5–ES–2013–AY17].
USFWS. 2013c. Preventing the Spread of Avian Botulism in Piping Plovers. Available at: http://www.fws.gov/midwest/insider3/October13Story4.htm.
USFWS. 2014. Rufa red knot background information and threats assessment. Supplement to Endangered and Threatened Wildlife and Plants; Final Threatened Status for the Rufa Red Knot (*Calidris canutus* rufa) [Docket No. FWS–R5–ES–2013–0097; RIN AY17]. Pleasantville, New Jersey. 376 pp. + Appendices. https://www.fws.gov/northeast/redknot/pdf/20141125_REKN_FL_supplemental_doc_FINAL.pdf [Accessed March 30, 2020]
USFWS. 2015. Recovery Plan for the Northern Great Plains piping plover (*Charadrius melodus*) in two volumes. Volume I: Draft breeding recovery plan for the Northern Great Plains piping plover (*Charadrius melodus*) 132 pp. and Volume II: Draft revised recovery plan for the wintering range of the Northern Great Plains piping plover (*Charadrius melodus*) and Comprehensive conservation strategy for the piping plover (*Charadrius melodus*) in its coastal migration and wintering range in the continental United States. Denver, Colorado. 166 pp.
USFWS. 2017. Statewide Programmatic Biological Opinion for North Carolina Beach Sand Placement. Raleigh, NC. 304 pp.
USFWS. 2018. Seabeach Amaranth (*Amaranthus pumilus*) 5-Year Review: Summary and Evaluation. Raleigh Ecological Services Field Office, Raleigh, North Carolina. 31 pp. + appendices.
USFWS. 2019. Recovery Outline for the Rufa Red Knot (*Calidris canutus* rufa). Northeast Region, Hadley, Massachusetts. 15 pp. + appendices. https://ecos.fws.gov/docs/recovery_plan/20190409%20Red%20Knot%20Recovery%20Outline%20final%20signed.pdf [Accessed April 16, 2020].
USFWS. 2020. Species status assessment report for the rufa red knot (*Calidris canutus* rufa). Version 1.1. Ecological Services New Jersey Field Office, Galloway, New Jersey.

USFWS and NMFS. 1978. Listing and Protecting Loggerhead Sea Turtles as Threatened Species and Populations of Green and Olive Ridley Sea Turtles as Threatened Species or Endangered Species. Federal Register 43(146):32800-32811.

USFWS and NMFS. 2016. Definition of Destruction or Adverse Modification of Critical Habitat. Federal Register 81(28):7214-7226.

U.S. Geological Survey (USGS). 1986. The Outer Banks of North Carolina: Professional Paper 1177-B. Denver, CO: US Geological Survey in cooperation with National Park Service.

U.S. Global Change Research Program (USGCRP). 2009. Global climate change impacts in the United States. Cambridge University Press, New York, NY, Available at <http://library.globalchange.gov/2009-global-climate-change-impacts-in-the-united-states>.

University of Minnesota. 2017. https://www.waterbirds.umn.edu/piping-plovers/banding. Accessed June 28, 2017.

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 Gils, J.A., P.F. Battley, T. Piersma, and R. Drent. 2005. 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.

Verkuil Y., A. Dekinga, A. Koolhaas, J. van der Winden, T. van der Have, and I.I. Chernichko. 2006. Migrating broad-billed sandpipers achieve high fuelling rates by taking a multi-course meal. Wader Study Group Bulletin 110:15–20.

Vermeer, M. and S. Rahmstorf. 2009. Global sea level linked to global temperature. Proceedings of the Nation Academy of Sciences (PNAS) 106(51):21527-21532. Available at http://www.pnas.org/content/early/2009/12/04/0907765106.full.pdf.

Virginia Tech Shorebird Program. 2016. Everything you always wanted to know about the use of piping plover banding resight reports. October 20, 2016 Webinar. Available online at: https://mmancusa.webex.com/mmancusa/ldr.php?RCID=822ccc545e68890d4ffb2f56d41d4aeb.

Virginia Tech Shorebird Project. 2013. Survival of piping plovers wintering on the Atlantic coast and its relationship to population growth of endangered Great Lakes breeders. Annual Operations Report. Department of Fish and Wildlife Conservation, Virginia Tech. Blacksburg VA. 15pp.

Wamsley, T. V. and N. C. Kraus. 2005. Coastal barrier island breaching, part 2: mechanical breaching and breach closure. U.S. Army Corps of Engineers Technical Note ERDC/CHL CHETN-IV-65. 21p.

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.

Weakley, A. S., and M. A. Bucher. 1992. Status survey of seabeach amaranth (Amaranthus pumilus Rafinesque) in North and South Carolina, second edition (after Hurricane Hugo). Report to North Carolina Plant Conservation Program, North Carolina Department of Agriculture, Raleigh, NC and Endangered Species Field Office, U.S. Fish and Wildlife Service, Asheville, NC.

Weishampel, J.F., D.A. Bagley, and L.M. Ehrhart. 2006. Intra-annual loggerhead and green turtle spatial nesting patterns. Southeastern Naturalist 5(3):453-462.

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.

Wetterer, J.K., L.D. Wood, C. Johnson, H. Krahe, and S, Fitchett. 2007. Predaceous ants, beach replenishment, and nest placement by sea turtles. Environmental Entymology 36(5): 1084-1091 (2007).

Wibbels, T., D.W. Owens, and D.R. Rostal. 1991. Soft plastra of adult male sea turtles: an apparent secondary sexual characteristic. Herpetological Review 22:47-49.

Wilber, D.H., D.G. Clarke, and M.H. Burlas 2006 "Suspended Sediment Concentrations Associated with a Beach Nourishment Project on the Northern Coast of New Jersey." Journal of Coastal Research, vol. 22: 1035-1042.

Wilber, D.H. and D.G. Clarke. 2007. "Defining and Assessing Benthic Recovery Following Dredging and Dredged Material Disposal." Proceedings XXVII World Dredging Congress, vol. 2007: 603-618.

Wilber, D.H., D.G. Clarke, G.L. Ray, and R. Van Dolah 2009 "Lessons Learned from Biological Monitoring of Beach Nourishment Projects." In Proceedings of the Western Dredging Association's Twenty-Ninth Technical Conference, vol. 2009: 262-274.

Wilcox, L. 1939. Notes on the life history of the piping plover. Birds of Long Island 1: 3-13.

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, K.L., M.G. Frick, and J.B. Pfaller. 2006. First report of green, *Chelonia mydas*, and Kemp's ridley, *Lepidochelys kempii*, turtle nesting on Wassaw Island, Georgia, USA. Marine Turtle Newsletter 113:8.

Williams, S.J., K. Dodd, and K.K. Gohn. 1995. Coasts in Crisis. U.S Geological Survey Circular 1075. 32 pp.

Williams, S.J., 2013. Sea-level rise implications for coastal regions. In: Brock, J.C.; Barras, J.A., and Williams, S.J. (eds.), Understanding and Predicting Change in the Coastal Ecosystems of the Northern Gulf of Mexico, Journal of Coastal Research, Special Issue No. 63, pp. 184–196, Coconut Creek (Florida), ISSN 0749-0208.

Williams, T. 2001. Out of control. Audubon Magazine October 2001.

Williams-Walls, N., J. O'Hara, R.M. Gallagher, D.F. Worth, B.D. Peery, and J.R. Wilcox. 1983. Spatial and temporal trends of sea turtle nesting on Hutchinson Island, Florida, 1971-1979. Bulletin of Marine Science 33(1):55-66.

Winn, B. 2006. Waterbird Use of Sandbars and Emergent Sand Spit Islands on the Georgia Coast. In Guilfoyle, M.P., R.A. Fischer, D.N. Pashley, and C.A. Lott (eds). 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>.

Witherington, B.E. 1986. Human and natural causes of marine turtle clutch and hatchling mortality and their relationship to hatching production on an important Florida nesting beach. Unpublished Master of Science thesis. University of Central Florida, Orlando, Florida.

Witherington, B.E. 1992. Behavioral responses of nesting sea turtles to artificial lighting. Herpetologica 48:31-39.

Witherington, B.E. 1997. The problem of photopollution for sea turtles and other nocturnal animals. Pages 303-328 in Clemmons, J.R. and R. Buchholz (editors). Behavioral approaches to conservation in the wild. Cambridge University Press, Cambridge, United Kingdom.

Witherington, B.E. 2006. Personal communication to Loggerhead Recovery Team on nest monitoring in Florida during 2005. Florida Fish and Wildlife Research Institute.

Witherington, B.E. and K.A. Bjorndal. 1991. Influences of artificial lighting on the seaward orientation of hatchling loggerhead turtles (*Caretta caretta*). Biological Conservation 55:139-149.
Witherington, B.E., K.A. Bjorndal, and C.M. McCabe. 1990. Temporal pattern of nocturnal emergence of loggerhead turtle hatchlings from natural nests. Copeia 1990(4):1165-1168.
Witherington, B.E. and R.E. Martin. 1996. Understanding, assessing, and resolving light pollution problems on sea turtle nesting beaches. Florida Marine Research Institute Technical Report TR-2.
Witherington, B., L. Lucas, and C. Koeppel. 2005. Nesting sea turtles respond to the effects of ocean inlets. Pages 355-356 in Coyne, M.S. and R.D. Clark (compilers). Proceedings of the Twenty-first Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-528.
Wood, D.W. and K.A. Bjorndal. 2000. Relation of temperature, moisture, salinity, and slope to nest site selection in loggerhead sea turtles. Copeia 2000(1):119-128.
Wooldridge, T, H . Henter, and JR Kohn. 2016. Effects of beach replenishment on intertidal invertebrates: A 15-month, eight beach study." Estuarine, Coastal and Shelf Science, vol. 175 (2016): 24-33.
Wyneken, J., L.B. Crowder, and S. Epperly. 2005. Final report: evaluating multiple stressors in loggerhead sea turtles: developing a two-sex spatially explicit model. Final Report to the U.S. Environmental Protection Agency National Center for Environmental Research, Washington, DC. EPA Grant Number: R829094.
Wyneken, J., L. DeCarlo, L. Glenn, M. Salmon, D. Davidson, S. Weege., and L. Fisher. 1998. On the consequences of timing, location and fish for hatchlings leaving open beach hatcheries. Pages 155-156 in Byles, R. and Y. Fernandez (compilers). Proceedings of the Sixteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-412.
Zajac, R. N. and R. B. Whitlatch. 2003. Community and population-level responses to disturbance in a sandflat community. Journal of Experimental Marine Biology and Ecology 294:101-125.
Zdravkovic, M. G. and M. M. Durkin. 2011. Abundance, distribution and habitat use of nonbreeding piping plovers and other imperiled coastal birds in the Lower Laguna Madre of Texas, submitted to U. S. Fish and Wildlife Service and National Fish and Wildlife Foundation by Coastal Bird Conservation/Conservian, Big Pine Key, Florida.
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>.
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. and M. Ryan. 1996. The ecology and conservation of piping plovers (*Charadrius melodus*) wintering along the Texas Gulf Coast. Dept. of Fisheries and Wildlife, University of Missouri, Columbia, Missouri 65211. 1995 Annual report. 49pp.