Final General Reevaluation Report
and
Final Environmental Impact Statement

on

Hurricane Protection and Beach Erosion Control

WEST ONSLOW BEACH AND NEW RIVER INLET (TOPSAIL BEACH), NORTH CAROLINA

Appendix L

Final
Fish & Wildlife Coordination Act Report

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Raleigh Fi ld Office
Post Office Box 33726
Raleigh, North Carolina 27636-3726

June 28,2007

Colonel John E. Pul1iam, Jr.
District Engineer
U.S. Army Corps of Engineers
P.O. Box 1890
Wilmington, North Carolina 28402-1890

Attention: Ms. Jennifer Owens, Environmental Resources Section

Dear Colonel Pulliam:

In accordance with our Transfer Funding Agreement and Scope of Work for FY 2007, the U. S. Fish and Wildlife Service (Service) has enclosed our Final Fish and Wildlife Coordination Act (FWCA) Report for the Shore Protection, West Onslow Beach and New River Inlet (Topsail Beach) Project in Pender County, North Carolina. This report identifies fish and wildlife resources in the project area; provides our assessment of project impacts on these resources; and lists the Service's recommendations for avoiding, minimizing, and compensating for impacts on these resources. This report constitutes the Service's report in accordance with Section 2(b) of the FWCA (48 Stat. 401, as amended; 16 U.S.c. 661 et seq.).

The Service appreciates the opportunity to provide this report. If you have any questions or comments, please contact Howard Hall at 919-856-4520, ext. 27 or bye-mail at Howard_Hall@fws.gov.

Sincerely,

Pete Benjamin
Field supervisor

Attachment

WEST ONSLOW BEACH AND NEW RIVER INLET PROJECT (TOPSAIL BEACH)

PENDER COUNTY, NORTH CAROLINA

FINAL FISH AND WILDLIFE COORDINATION ACT REPORT

Prepared by:

Howard F. Hall

Under the Supervision of:

Pete Benjamin
Field Supervisor

U.S. Fish and Wildlife Service
Ecological Services Raleigh Field Office
Raleigh, North Carolina

June 2007

SECTION 1 - INTRODUCTION

This report is provided under authority of Section 2(b) of the Fish and Wildlife Coordination Act (FWCA) of 1958 (48 Stat. 401, as amended; 16 U.S.C. 661-667d). The FWCA established two important federal policies which are: (1) fish and wildlife resources are valuable to the nation; and, (2) the development of water resources is potentially damaging to these resources. In light of these principles, the FWCA mandates that:

> ". .. wildlife conservation shall receive equal consideration and be coordinated with other factors of water-resource development programs through effectual and harmonious planning, development, maintenance, and coordination of wildlife conservation and rehabilitation."

The FWCA essentially established fish and wildlife conservation as a coequal purpose or objective of federally funded or permitted water resources development projects.

In order to fully incorporate the conservation of fish and wildlife resources in the planning of water resources development, the FWCA mandates that federal agencies consult with the U. S. Fish and Wildlife Service (Service) and the state agency with the responsibility for fish and wildlife resources in the project area. The state agency with this responsibility is the North Carolina Wildlife Resources Commission (NCWRC).

Consultation during project planning is intended to allow state and federal resource agencies to determine the potential adverse impacts on fish and wildlife resources and develop recommendations to avoid, minimize, and/or compensate for detrimental impacts. Therefore, this report will:

1. Describe the fish and wildlife resources at risk in the project area;

2. Evaluate the potential adverse impacts, both direct and indirect, on these resources;

3. Develop recommendations to avoid, minimize, or compensate for any unavoidable, adverse environmental impacts; and,

4. Present an overall summary of findings and the position of the Service on the project.

This final report constitutes the formal report of the Service under Section 2(b) of the FWCA.

Subject of This Report

Section 101 of the Water Resources Development Act (WRDA) of 1992 authorized the construction or implementation of the West Onslow Beach and New River Inlet (Topsail Beach) Shore Protection Project at Topsail Beach, Pender County, North Carolina. This authorization was based upon information presented in House Document Number 393, 102nd Congress, 2nd Session, dated September 23, 1992, entitled "Final Feasibility Report and Environmental Impact Statement on Hurricane Protection and Beach Erosion Control, West Onslow Beach and New River Inlet, North Carolina (Topsail Beach)." The authorized project consisted of a dune, beach fill, and transition sections to improve shoreline conditions within the Town of Topsail Beach (Town).

Authority to continue the preconstruction, engineering, and design (PED) investigations is contained in the Resolution adopted November 14, 1979, by the United States House of Representatives in accordance with Section 110 of the River and Harbor Act of 1962. The Design Memorandum prepared under PED was published in August 1992. However, the Project Cooperation Agreement was not executed and the project was then placed in an inactive status. The project was reactivated in 2000 at the request of the Town of Topsail Beach. The Energy and Water Development Appropriations Act for Fiscal Year 2001, Public Law 106-377, included funds for the Government to initiate a General Reevaluation Report (GRR) of the authorized project, and the remaining shoreline at Topsail Beach. The scope of the study includes the entire shoreline of the Town.

Scope

The geographic scope of this report includes all areas that would be directly or indirectly impacted by the proposed project. The project area includes not only the beaches seaward of the communities requiring storm damage protection, but those areas into which sand could be transported by natural forces, the offshore areas which are the most likely sand sources, and all areas likely to be impacted by the secondary development resulting from storm damage reduction measures. In all cases these areas represent habitat for fish and wildlife resources, and these resources will be considered. The temporal scope of this report extends from direct, immediate impacts of potential storm damage protective measures to long-term, indirect impacts that may occur as a result of these measures.

Prior Studies and Reports

During the feasibility phase, the Service provided a Draft FWCA Report to the Corps on September 12, 1986. The Final Feasibility Report for the project was issued in 1992 and recommended construction of a dune, beach fill, and transition sections to improve shoreline conditions within the Town.

After reactivation in 2000, an appropriation bill included funds for initiating a General Reevaluation Report for the project. The Service provided a Draft FWCA Report to the Corps by letter dated May 25,2005. The integrated Draft General Reevaluation Report and Environmental Impact Statement (Draft GRR/EIS) was released in June 2006 (O. S. Army Corps of Engineers [hereafter USACE] 2006). The Service provided comments on the Draft GRR/EIS by letter dated September 13, 2006.

Need for Federal Action

As with all man-made structures on dynamic barriers islands, the homes, businesses, and infrastructure within the Town are subject to a number of risks. Pilkey et al. (1998, p. 171) note that Topsail Island has a troublesome geologic setting along its entire length. The island is very narrow and flat with no significant area higher than the 500-year flood elevation. Most of the island lies on the 100-year floodplain. Hurricane Hazel which struck the southern North Carolina coast in 1954 generated a storm surge of 9.5 feet on the island which has an average elevation of nine feet (Pilkey et al. 1998, p. 171). A 1987 evaluation by the North Carolina Department of Emergence Management indicated that the island would be largely underwater in a category 1 or 2 hurricane and would be completely submerged in a category 3 hurricane (Pilkey et al. 1998, p. 173).

The island was severely impacted by two hurricanes (Bertha and Fran) within an eight week period during 1996. Prior to Hurricanes Bertha and Fran, a prominent artificial dune, 12 feet high and 50 feet wide, existed along much of southern Topsail Island (Pilkey et al. 1998, p. 180). Barnes notes (1998, p. 177-178) that large portions of the dunes between Figure Eight Island and Emerald Isle, an area including the Town, were washed away by Bertha which set the stage for extensive shoreline recession and ocean overwash during Fran. Hurricane Fran leveled the dune on southern Topsail Island and the entire area was overwashed by the storm surge which deposited up to three feet of overwash sand in some parts of Surf City, immediately north of the Town (Pilkey et al 1998, p. 180). The storm surge associated with Hurricane Fran, a minimal category 3 storm at landfall, created a storm surge of 8-12 feet along North Carolina's southeastern coast (Barnes, 1998, p. 177).

The Town's web page notes that many sections of the beach are now threatened by long-term erosion. With a long-term erosion rate of two feet per year, several properties on both the north and south ends of the Town may be lost within the next three to five years. Houses which are notched, or cut, into the landward side of the dune increase the hazardous conditions in the area (Pilkey et al. 1998, p. 178) and structures located in much of the southern part of the island are at high to extreme risk of damage (pilkey et al. 1998, p. 182).

The observed shoreline recession, or erosion, results from a number of natural processes influenced by global sea level rise. Leatherman (2001, pp. 188-189) states that shoreline position is determined by several factors such as sediment supply, wave energy, and sea level. He also states that sea level rise induces beach erosion, or accelerates ongoing shore retreat, in several ways. For example, deeper water decreases wave refraction and thus increases the capacity for longshore transport. He also notes that there are important differences between erosion and inundation. Erosion is the physical removal of material by waves and currents from the beach profile with the subsequent loss of this material offshore beyond the closure depth or to sediment sinks such as inlet and lagoons. In contrast, inundation is the permanent submergence of low lying land. Leatherman (2001, p. 189) writes that "total coastal retreat or recession equals the sum of erosion plus inundation. Along open ocean beaches, over 90% of the retreat is caused by erosion; the opposite is generally true for coastal marshes in sheltered bays, lagoons, and estuaries with limited wave action." If, as expected, global warming continues to accelerate in this century, the impacts of both erosion and inundation are likely to increase.

Structures near the ocean face the dual threat of damage from water (storm surge and hurricane waves) as well as damage from hurricane winds. Since a cubic yard of water weighs more that 1,500 pounds, a ten-foot wave can exert more than 1,000 pounds per square foot of pressure (Pilkey et al 1998, p. 219). However, by raising homes to avoid wave and surge attack, the risk of wind damage increase. Wind velocities increase with height above ground and tall structures are subject to greater wind force than lower structures (Pilkey et al 1998, p. 217, 254). At a height of 33 feet, wind of 100 miles per hour creates a force of 40 pounds per square foot, or a force of 13 tons on a wall 40 feet long by 16 high (Pilkey et al 1998, p. 217).

Purpose of Federal Action

The Draft GRRJEIS gives two, slightly different purposes for federal action. While these appear similar, the underlying meaning has important implications for the development of alternatives. Initially, the document states (USACOE 2006, p. 1) that the study has evaluated plans for "protecting the commercial and residential structures and infrastructure of Topsail Beach." This statement of purpose implies that all man-made structures would be maintained and protected in their present location and federal action would be directed toward ensuring the continued presence of current development.

Later the document states (USACE 2006, p. 4) that the purpose for the proposed shore protection project is to reduce both storm damages and beach erosion along the ocean shoreline of Topsail Beach. While shoreline recession is most pronounced during storms, it occurs continuously as sea level rises and will occur during both fair weather and foul. The dual goal of storm protection and filling inundated beaches, efforts directed at preserving ocean front structures, can only be achieved by importing sediment to construct a beach. This would be accomplished by the placement of beach fill to reestablish a functional berm and dune system that would reduce the impacts of erosion, flooding, and storm waves on commercial structures, homes, and infrastructure of the island. Enhanced public recreational opportunities would be provided by the proposed beach construction, and public parking facilities would be made available at locations reasonably near public access rights-of-way to the beach. These economic and recreational improvements would be achieved through measures designed to retain the aesthetic and ecological values of the beach and adjacent waters (USACE 2006, p. 4).

<u>Proposed Plan of Action</u>

The Draft GRRlEIS presents (USACE 2006, pp. 65-83) a proposed plan of action which represents the Locally Preferred Plan (LPP). The LLP consists of a 26,200-foot long dune and berm system to be constructed to a height of 12 feet NGVD fronted by a 7-foot NGVD (50-foot wide) beach berm with a main fill length of23,200 feet, from a point 400 feet southwest of Godwin Avenue to the northern limit of the Town, and having 2,000-foot transition length on the north end and a 1,000-foot transition on the south end.

Six borrow areas are located in the ocean between 1 mile and 5.5 miles from the shoreline. These are shown in the Draft GRR/EIS (USACE 2006, Appendix A, Figure A-2). These areas are between the 30-foot and 60-foot NGVD depth contour. The largest and closest site, borrow area A, has a sufficient sand layer thickness and volume to be designated as the borrow source for initial construction. The total volume of suitable material available from all six sites is approximately 21,100,000 CY. This volume is sufficient to meet the project requirements.

Initial construction would require approximately 3,223,000 cubic yards (CY) of sand from the borrow area with an overfill ratio of 1.35 (USACE 2006, p. 68). The material would be pumped to the beach by pipeline dredge and shaped on the beach by earth moving equipment. The initial construction profile would extend seaward of the final design berm profile a variable distance to cover anticipated sand movement during and immediately following construction. This variable distance would generally range from 100 to 200 feet along the project depending upon foreshore slopes established by the fill material. Once sand redistribution along the foreshore occurs, the adjusted profile should resemble the design berm profile. Initial beachfill construction would take five months to complete. The project will be constructed in FY2011 (November 2010 - April 2011), subject to availability of funds.

Periodic reconstruction would require approximately 866,000 CY of sand from the borrow areas with an overfill ratio of 1.25 at intervals of four years. The reconstruction material would be removed from the borrow areas by hopper dredge. Delivery of sand could occur by hauling filled scows to a pumping station buoy or by hopper dredge hauling sand to the pipeline buoy. In both initial construction and during reconstruction the delivery pipeline would be placed to avoid the piping plover habitat areas along the south end of the beach and material between the toe of dune and mean high water line would be tilled to prevent compaction. Over the 50 year life of the project 13,615,000 CY of sand would be placed on Topsail Beach. The volumes required are reported as borrow volumes including overfill ratios, not actual volume in place, which is less.

SECTION 2 - STUDY AREA DESCRIPTION

The study area consists of the beaches of the Town as well as the natural, barrier island uplands, estuarine ecosystems, and surrounding waters including offshore bottoms which would serve as beach fill for approximately 4.5 miles of ocean shoreline of the Town.

The project area located at the southern end of Topsail Island adjacent to New Topsail Inlet in Pender County on the southeastern coast of North Carolina. Topsail Island is a 22-mile long and 0.5-mile wide barrier island (USACE 2006, p. 3). Due to the northeast-southwest orientation of the coastline, the island faces the Atlantic Ocean on the southeast. Other water bodies in the vicinity include New Topsail Inlet immediately to the southwest, Banks Channel and the Atlantic Intracoastal Waterway (AIWW) to the northwest, and New River Inlet at the far northeastern end of the island.

The project proposed in the Draft GRRJEIS would directly impact a number of biological communities. Furthermore, the sense of security provided by the artificial berm and dune would facilitate addition development that would impact many estuarine and upland biological communities either directly or indirectly. This section will consider the basic physical characteristics, major plants, and important invertebrates of each community. These community attributes are important in supporting vertebrate populations that will be discussed later.

General Physical Environment

The offshore waters of the Town are part of Onslow Bay. Onslow Bay is a modern embayment of the Atlantic Ocean. It is bounded by Cape Lookout to the north and Cape Fear to the south. The geomorphology and stratigraphy of the region are discussed in the Draft GRR/EIS (USACE 2006, Appendix C). Topsail Island has beaches, dunes, marshes, and landforms typical of barrier island complexes.

On the nearshore floor of Onslow Bay are submarine scarps, shoals, and bars. The shoreface of Topsail Island consists of a thin, patchy veneer of modern sediments covering the low relief Oligocene limestone and siltstone hardbottoms (Cleary 2003). This thin veneer of sediment is ephemeral and easily reworked during storms; thus, exposing rock units in areas where the sediment cover is thin. Surficial Holocene sedimentary deposits are scarce offshore of Topsail Island in Onslow Bay (USACE 2006, p. C-3 and references therein). Much of the native beach sand is derived from the physical and biological erosion of Oligocene rock and strata submerged in Onslow Bay. These sediments are then reworked, redistributed and deposited within submarine valleys and ridges, or along the shoreface.

The geotechnical analysis of the project area (USACE 2006, p. C-l) states that the rivers and streams entering Onslow Bay are generally small with low gradients. Their continentally derived sediment loads are therefore not very large. In addition, much of this fluvial sediment becomes trapped within the river estuaries. This lack of significant sediment discharge into Onslow Bay limits the build-up of nearshore continental shelf sand deposits. This in turn contributes to the sand starved nature of the coast in this area (USACE 2006, p. 31). Modern sediment accumulation in the project area is negligible (Cleary 2002a, p. 149). In other areas along the Atlantic coast these nearshore deposits are an important source of sand. When deprived of this source of sand as at Topsail Island, seasonal storms and longshore currents can cause episodic severe shoreface erosion and migration (Cleary, 1968; Sarle, 1977; Riggs et al. 1996; Cleary 2002b).

Most of the sediments in Onslow Bay are created through bioerosion of offshore hardbottoms of limestone and siltstone (Riggs et al. 1998). Topsail Island and Onslow Beach are well-known for the extensive rock outcrops offshore, including rock ledges and rubble mounds that can be found in 30 feet of water with up to 15 feet in relief (e.g., Riggs 1994, Riggs et al. 1995). "New" sediment can be created by bioerosion of hardbottoms, contributing to the existing sediment supply found on the continental shelf. Boring infauna are the dominant bioeroders of hardbottom scarps (Riggs et al. 1996, Riggs et al. 1998). "Morphologically prominent hardbottoms are actively being degraded and retreating in response to intense bioerosion by endolithic bivalves, crustaceans, and worms" (Riggs et al. 1996, p. 844). This bioerosion may develop seafloor relief of millimeters to meters to tens of meters depending on the lithology and bioerosional processes involved (Riggs et al. 1998). The paucity of sand offshore and underneath the island controls the erosion and accretion patterns and storm response of these conununities by making them less flexible to movement and absorption of wave energy (e.g., Riggs 1994, Riggs et al. 1995, Cleary 2001).

Barrier island beaches depend on the interchange of sediment from both the shoreface and continental shelf on their seaward side and the dunes on their landward side (Pilkey et al. 2004, p. 37). Sand found on the Topsail Island beaches is classified as fine to medium-grained poorly-graded sands according to the Unified Soils Classification System. These sands are the result of a complex combination of factors. Part of the sand is accumulated from storm overwash and longshore drift. Another part results from the biological, chemical, and physical erosion of nearshore sedimentary rocks. Winnowing by wind and wave action results in the predominantly fine- to medium-grained, poorly graded sands on the beach today.

Dunes are an important component of the barrier island ecosystem. They deflect salt spray and allow the development of shrub thickets and maritime forests which increase barrier island resistance to wind erosion. Dunes are major storage centers for beach sediments, and they absorb and dissipate storm waves. The dunes are part of the sand sharing system which allows a barrier island to survive rising sea levels and the tremendous energies of the ocean (Godfrey and Godfrey 1976; Leatherman 1979). In this sand sharing system, an equilibrium is reached as sand grains move back and forth between offshore areas, such as sandy bars, and onshore areas, such as beaches and dunes, in response to wind, waves, currents, and tidal effects. However, Topsail Island is an example of low elevation barrier island with few, if any, natural dunes due to a poor sand supply from the adjacent shoreface (Pilkey et al. 1998, p. 47).

Important Coastal Processes

Sea Level Rise

Several recent reports have addressed the issue of global sea level rise. Rahmstorf (2007) states that since 1990, observed sea level has followed the uppermost uncertainty limit of the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (TAR) of 2002, which was constructed by assuming the highest emission scenario combined with the highest climate sensitivity and adding an ad hoc amount of sea level rise for "ice sheet uncertainty. Sea level is expected to rise as the ocean takes up heat and ice starts to melt, until a new equilibrium sea level is reached. The report presents a semi-empirical approach for predicting future sea level rise. Based on temperature increases projected by the IPCC, Rahmstorf (2007) projects that sea level in 2100 may be one-half meter (1.64 feet) to 1.4 meters (4.59 feet) above the 1990 level. A rise of over one meter (3.3 feet) by 2100 for strong warming scenarios cannot be ruled out, because all that such a rise would require is that the linear relation of the rate of sea level rise and temperature, which was found to be valid in the ZO" century, remains valid in the 21^{51} century (Rahmstorf 2007).

In February 2007, the IPCC released a Summary for Policymakers of the report entitled "Climate Change 2007: the Physical Science Basis" (Intergovernmental Panel on Climate Change [hereafter IPCe] 2007). Based on six scenarios, the rise in sea level between the 1980-1999 period and the 2090-2099 period ranges from a low of 0.18 of a meter (0.59 of a foot) to a high of 0.59 of a meter (1.94 feet). However, these projections consider the contributions due to increased ice flows from Greenland and Antarctica at the rates observed during the 1993-2003 period. These flow rates could increase or decrease in the future. If the inputs from these two areas were to grow linearly with projected global average temperature change, the upper ranges of sea level rise for each of the six scenarios would increase by 0.1 to 0.2 of a meter (0.33 to 0.66 of a foot). The addition of the maximum additional increase to the initial maximum increase yields a projected sea level increase of 0.79 of a meter (2.6 feet) [0.59m+0.20m].

The IPCC notes that dynamic processes related to ice flow which are not included in the current models, but suggested by recent observations, could increase the vulnerability of the ice sheets to warming. Such warming would increase future sea level rise. For planning purposes, a rise of two to four feet in global sea level during this century would seem appropriate.

Increases **in** Hurricane Frequency and Strength

In addition to sea level rise, there is observational evidence for an increase of intense tropical cyclone (hurricanes) activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures (IPCC 2007). There is no clear trend in the annual number of tropical cyclones. Based on a range of models, it is likely that future tropical cyclones will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperature (IPCC 2007).

Long-term sea level rise and more frequent hurricanes should be considered in light of the fact that the local sponsor seeks to create a structure which would become a permanent part of the Town's infrastructure. Once constructed and officially recognized by the FEMA as infrastructure, the engineered beach would be replaced in perpetuity with federal disaster assistance funding. Therefore, from the perspective of the Corps' planning process, the proposed construction should be considered as the first of many sediment placements, stemming directly from the initial construction and extending into the indefinite future.

Barrier Island Movement

Barrier islands are elongated bodies of sand bounded on either end by inlets that allow salt and fresh water to flow into and out of the estuary behind the island (Pilkey et al. 1998, p. 39). As soon as a barrier forms, it immediately begins to migrate and change its shape, vegetation, and landform (Pilkey et al 1998, p 40). The barrier islands of Onslow Bay are features that have steadily migrated landward over the past several thousand years (Cleary and Hosier 1990, p. 5). Some geologists believe that the coastal islands were born at the edge of continental shelf, where it drops off toward the oceanic abyss (Kaufman and Pilkey 1983, p. 98). As the sea gradually covered the gentle slope which is now the continental shelf, ridges of sand formed at the land-sea junction. These ridges were formed, as they are now, by wind blowing sand landward from the beach. As sea level continued to rise, the sandy ridges were breached and the area landward was flooded. This flooding created the large sounds that exist today. Storms washed sediment over the islands and built up their landward margins. As sea level continued to rise, it pushed the islands up the continental shelf. Topsail Island is now a low and narrow barrier island where few natural areas remain due to development (Frankenberg 1997, p. 170).

In the face of a rising sea over the past several thousand years, the low relief barrier islands would not exist today unless there were natural geologic mechanisms that allow them to move landward up the continental shelf. Kaufman and Pilkey (1983, p. 220) write that "as sea level rises, islands and beaches do not stand still and allow water to pass over them ... they move back through a series of complex maneuvers."

This movement, in a landward direction, is called island onshore migration or transgression. Island migration is a simple function of the slope of the mainland. The more gentle the slope of the coastal plain, the more rapid the island migrates. Accordingly, the horizontal island migration rate in North Carolina has been estimated to be 100 to 1,000 times the rate of sea level rise (Pilkey et al, 1980 p. 21; Leatherman 1988, p. 42). That is, for every foot of sea level rise, the islands retreat 100 to 1,000 feet. Based on estimates that sea level may be rising at 1-3 feet per century, the Topsail Island shoreline may move 100-3,000 feet landward over the next 100 years. Even during the official 50 year life of this storm damage reduction project, the beaches could be predicted to move 50 to 1,500 feet landward as a natural adjustment to an increase in sea level. A more recent estimate (Pilkey et al. 1998, p. 42) put the shoreline recession rate in North Carolina at 2,000 horizontal feet for every foot of sea level rise. At this greater rate, even a one foot per century rate of sea level rise would produce natural shoreline recession of 1,000 feet during the 50 year life of the project.

Island migration occurs as the island rolls over itself like the tread on a bulldozer (Pilkey and Dixon 1996, p. 16). For example, the red sand exposed on some of the small bluffs of Caswell Beach indicate old soils and are signs that a forested barrier island occupied the site about 1,000 years ago (Pilkey et al. 1998, p. 194). Tree stumps that may occur on Caswell Beach are the remains of a forest that grew well inland from the beach (Pilkey et al. 1998, p. 43). This forest was replaced by a salt marsh on the site that is now the beach. The shoreline adjustment to a rising sea pushed sand over the older communities which are now emerging on the ocean side of the island which has passed over them.

The major processes which produce island migration are: (l) island overwashes from the ocean; and, (2) the incorporation of flood tide shoals, primarily the flood tide delta. Wind blown sediment carried from the ocean beaches and dunes may also contribute to the process. Overwash and inlet deposits are the predominant material in all Mid-Atlantic barrier islands (Inman and Dolan 1989). Therefore, sediment in both inlet shoals and overwash deposits remain in the barrier island complex.

During storms, high energy waves can carry sand landward over the entire island. The ocean side retreats as sediment is removed from the beaches and primary dunes. Sediment is carried across the island to form sandy overwash fans. Overwash fans, which often extend into estuarine areas behind the island, may cause the island to widen in a landward direction. As the waves recede, large quantities of sand may be deposited in overwash fans. The sediment carried by overwashes help create new salt marshes and replaces sediment lost to wave erosion on the estuarine shoreline. Newly formed marshes are excellent buffers of sound side waves.

Shoreline Recession

The movement of sediment landward from the beaches during island migration appears as shoreline recession from stationary structures along the beach. This shoreline recession is usually referred to as "erosion" (USACE 2006, p. 31) even though some sediment is being pushed by winds and waves to a higher elevation rather than the common idea of sediment being carried to a lower elevation by water flowing to a lower elevation.

Over the last 40 years, the most serious long-term recession has been occurring in the southern half of the study area, where recession rates gradually increase from near zero in reach 13 to over 3 feet per year in reaches 5 to 7 (USACE 2006, p. 41). Long-term shoreline change rates along the northern half of the study area have remained relatively low, generally ranging from -1 to +1 foot per year. However, major storms in the late 1990s caused significant recession and decimated the island's natural dunes, resulting in major property damage.

Major Biological Communities

The project proposed in the Draft GRR/EIS would attempt to stop the natural response of Topsail Island to sea level rise. The artificial dune would block waves from carrying sediment inland and reduce cross island overwash which carries sediment into estuarine area and aids these areas in responding to sea level rise. Therefore, the 50-year effort to alter the fundamental geologic adaptations of this barrier island would directly or indirectly impact a number of biological communities. Furthermore, the perception of storm damage reduction provided by the proposed work would facilitate additional development that would impact many marine, estuarine, and upland biological communities. This section will consider the basic physical characteristics, major plants, and important invertebrates of each community. These community attributes are important in supporting vertebrate populations that will be discussed later. The habitats of a typical Atlantic coast barrier islands are shown in Figure 1. The discussion of these natural communities will start with the most seaward area and move landward.

Offshore Pelagic

Offshore pelagic areas have a role in primary production. Primary production may be defined as the rate at which radiant energy is converted by photosynthetic and chemosynthetic activity of producers organisms (chiefly green plants) to organic substances (Odum 1983, pp 98-99). Total primary production on the continental shelf of North Carolina is supported by three sources (Cahoon 1993). These are phytoplankton, benthic macro algae, and benthic microalgae. The pelagic community is composed of organisms which remain in the water column. This community is dominated by microscopic plants known as phytoplankton which are tiny unicellular or colonial marine algae. Phytoplankton in the waters of the southeastern United States continental shelf is dominated by centric diatoms, coccolithophores, and dinoflagellates (Marshall 1969, 1971). These small plants form the basis for the marine food chain. The species composition of the plankton community changes seasonally.

Herbaceous zooplankton, small animals of several phyla, feed on phytoplankton and are, in turn, eaten by larger organisms. The most important groups are copepod crustaceans, arrowworms, hydromedusae, krill, tunicates, and the larvae of many benthic species (Ruppert and Fox 1988, p. 344). Zooplankton is usually most abundant and varied during the summer.

Offshore Benthic - Soft Substrate

This community consists of the organisms that live on or within the unconsolidated sediments of the ocean floor. Offshore sandy bottoms are often considered to be relatively lifeless and unproductive. While there is limited specific information on the plants and invertebrates of this community, recent work points to an important role for such areas. The area of unconsolidated sediment may be designated as the pelecypod-annelid biome (Gosner 1978, p. 22). These terms refer to the bivalve mollusks (pelecypod) and polychaete worms (annelids) which may be found in offshore benthic sediment.

Onslow Bay has a distinct, productive benthic microflora (Cahoon et al. 1990). This conclusion is based on the finding of at least three times as much chlorophyll *a* in the sediment as in the entire overlying water column, data which suggest that Onslow Bay is not generally a depositional environment. The frequently observed near-bottom

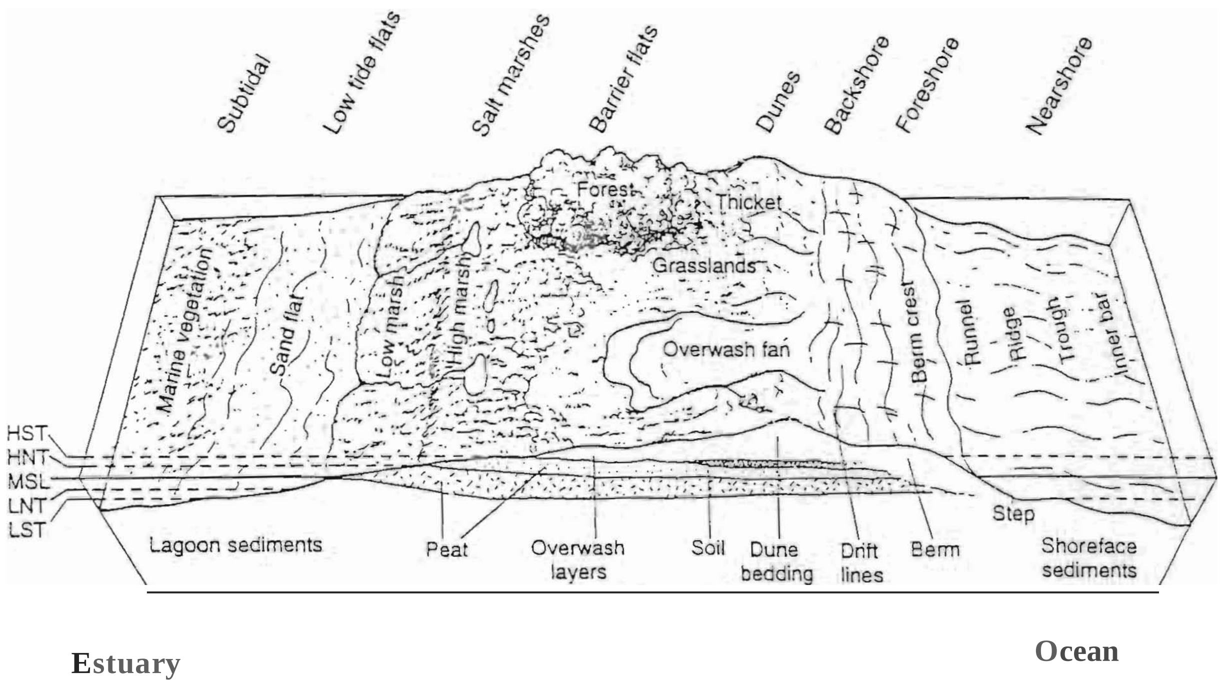

Figure 1. Diagram of the communities associated with a barrier island. HST = high spring tide; HNT = high neap tide; MSL = mean sea level; LNP = low neap tide; and LST = low spring tide. Source: Bellis (1995).

chlorophyll *a* maxima in Onslow Bay are likely to be created by suspension of benthic microalgae rather than the sinking of phytoplankton, i.e., organic detritus. The positive correlation of sediment chlorophyll *a* with sediment adenosine triphosphate (ATP), an energy-carrying molecule, was considered a good argument for the existence of a viable, productive benthic microflora.

The concentration of microalgal biomass at the top of sand ridges rather than the troughs, suggests that these microalgae are firmly attached to the sediment (Cahoon et al 1990). Observations of pennate diatoms in sediment samples indicate that benthic microalgae are distinct from the phytoplankton, which is dominated by centric diatoms, coccolithophores, and dinoflagellates.

Chlorophyll data strongly suggest that benthic microalgae are likely to be major primary producers across the continental shelf in Onslow Bay (Cahoon et al. 1990). Benthic microalgal biomass averaged 36.4 mg of chlorophyll *a* per square meter (Cahoon and Cooke 1992). This biomass consistently equals or exceeds that of the integrated phytoplankton which averaged 8.2 mg of chlorophyll *a* per square meter (Cahoon and Cooke 1992). Gross benthic microalgal production in Onslow Bay averaged 24.9 mg of carbon per square meter per hour (mg $C/m^{-2}/h^{-1}$) (Cahoon and Cooke 1992). This figure compares to an average primary production of 27.4 mg $C/m^{-2}/h^{-1}$ in the integrated water column.

Microalgae are a previously unmeasured source of primary production and may contribute significantly to continental shelf food webs, particularly the meiobenthos and macrobenthos. Microalgae at the sediment surface may also play an important role in nutrient cycling at the sediment-water interface.

Cahoon and Tronzo (1992) reported that the concentrations of holozooplankton (plankton that remain continuously in the water column) and demersal zooplankton (plankton living in or on the bottom) in Onslow Bay, North Carolina, are each in the general range of 1 to 6×10^4 per square meter. The high numbers of demersal zooplankton associated with soft substrates in Onslow Bay suggest that these organisms are an important component of the continental shelf ecosystem. Currents may carry these soft sediment organisms into hardbottom habitats, making them available to resident planktivores.

Offshore bottoms contain an entire category of animals known as the meiofauna (Thurman 1994, p. 434). These organisms live in the spaces between sediment particles and have lengths ranging from 0.004 to 0.08 inches (0.1 to 2 mm). The meiofauna feed primarily on bacteria removed from the surface of sediment particles. The group consists mostly of nematodes, arthropods (primarily copepods), mollusks, and polychaete worms.

Hardbottoms

Hardbottoms are also called "livebottoms" because they support a rich diversity of invertebrates such as corals, anemones, and sponges, which are refuges and food sources for fish and other marine life. Hardbottoms represent one of the most valuable biological communities in the project area. They provide very important habitat for fish and invertebrate species. Riggs et al. (1998) note that "Exposed hardbottom habitats free of sand are dominated by highly diverse communities of endolithic fauna and epilithic fauna and flora, those habitats with 2-6 cm of sand are generally dominated by scattered epilithic fauna with small growths of epilithic flora irregularly distributed on topographic highs, and those habitats with > 6 cm of sand are generally dominated by softbottom benthic communities." Burgess (1993) states that "some of these rocky hardbottoms are veritable oases covered with algal meadows, sponges, soft whip corals, tropical fishes and territorial and predatory animals. These habitats provide shelter and food to sustain valuable commercial and recreational fish such as groupers and snappers, worth millions of dollars to the state's economy. More than 300 species of fish and hundreds of thousands of invertebrates call these reefs home." Frankenberg (1997, pp. 191-192) states that these "hardground" habitats ". . . support a community of algae, soft and encrusted coral, sea anemones, sea whips, and recreational important finfish. These rocky outcrops are oases of sea floor life that support a northern extension of the snapper-grouper complex of fish as well as habitat for predators like mackerel and bluefish."

Riggs et al. (1998) identified storms as playing a major role in the distribution of hardbottom benthic communities as they remove sediments accumulated from bioerosion and redistribute the ephemeral bottom sediments, exposing or burying hardbottom surfaces. Riggs et al. (1996, p. 844) state that "the surficial sand sheet on the upper flat hardbottoms is generally very thin, has an irregular distribution, and is highly mobile."

Hardbottom communities in the vicinity of Topsail Beach are within state waters and are potentially vulnerable to shoreline alterations (Moser and Taylor, 1995). Shallow limestone and siltstone rock units offshore of Topsail Beach dominate and control the nearsurface geology and submarine landscape (Greenhorne & O'mara, Inc., 2004). According to Cleary (2003), the area offshore of Topsail Beach is characterized as a broad, shallow, high-energy shelf system with a thin and variable unconsolidated sediment cover as indicated by a large frequency of rock outcrops. The nearshore hardbottom features are generally low relief (McQuarrie, 1998) with isolated scarp formations. Though the best available data regarding hardbottom resources off of Topsail Island does not suggest the presence of high relief hardbottom, a nearshore hardbottom survey, utilizing side-scan sonar and multi-beam sonar, will be completed prior to finalization of the EIS.

Nearshore Pelagic and Benthic

In nearshore benthic habitats, deposit feeders are dominant with a few filter feeders and carnivores present. Invertebrates, such as crustaceans, polychaetes and molluscs, comprise the benthic community of the nearshore waters. Van Dolah and Knot (1984) conducted benthic surveys off of Myrtle Beach, South Carolina, and found that infaunal assemblages in nearshore subtidal areas were more complex than those in intertidal areas. They found 243 species representing 24 major taxa. The most dominant species were polychaetes such as *Spiophanes bombyx*, *Caulleriella killariensis*, *Clymenella torquata*, *Mediomastus californiensis*), amphipods (*Batea catherinensis*, *Erichthonius brasiliensis*, *Ampelisca vadorum*, and *Unicola serrata*.). Oligochaetes, pelecypods, and decapods were also highly represented. These invertebrates serve as food for fish and larger invertebrates and are an important part of the nearshore marine community.

Intertidal Beach

Sandy or silty sand beaches support many species of fat, soft-bodied, white, burrowing amphipods in many genera of the family Haustoriidae (Phylum Arthropoda) (Ruppert and Fox 1988, p. 346). High energy, intertidal beaches in the southeastern United States may have 20-30 invertebrate species (Ruppert and Fox 1988, p. 346). Invertebrates found here include the beach digger (*Haustorius canadensis*), a polychaete worm (*Scolelepis squamata*), and, in late summer, the mole crab (*Emerita talpoida*) and coquina clam (*Donax* sp.). The swash zone is dominated by the mole crab and coquina clam. The invertebrates of the intertidal zone provide an important food source for surf-feeding fish and shore birds (USACE 2006, p. 11).

Dry Beach

The dry, or subaerial, beach, is the sandy area which is literally under air. The dry beach extends from the high tide line to the line of primary dunes. This area appears to coincide with the backshore designated in Figure 1. Two of the four beach areas given by Reilly and Bellis (1978), the upper beach and high tide drift line, may be considered subaerial. The upper beach is the area between the high tide line and the primary dune. Vegetation consists primarily of a few annual, succulent species, including sea rocket (*Cakile edentula*), and seabeach amaranth (*Amaranthus pumilis*). Invertebrates inhabiting this zone include the ghost crab (*Ocypode quadrata*), beach flea (*Talorchestra megalophalma*), and various insects. The second subdivision is the high tide drift line, a small unvegetated area consisting of the line of detritus that marks the highest point to which the preceding high tide advanced. Ghost crabs and small invertebrates, such as amphipods and insects, use this area.

The subaerial beach may be called a berm. While the seaward part of the berm may slope down toward the ocean, there is usually a wider, flat part of the subaerial beach which is more characteristic of a berm. The berm is the active, unvegetated portion of the dry beach and is the direct product of waves and currents (National Research Council [hereafter NRC] 1995, p. 72). The berm is a primary factor in dissipating wave energy.

Dunes

Natural barrier island dunes are healthy ecosystems and the haunt of an intricate web of highly adapted life (Nickens 2006). The dominant dune plant on Topsail Island is the sea oat (*Uniola paniculata*). It is resistant to salt spray and drought conditions and, because of its ability to grow upward with the sand it collects, it is a major dune builder (Fussell, 1978). Other common dune plants are pennywort *(Hydrocotyle bonariensis),* camphorweed *(Heterotheca subaxillaris),* sea elder (*Iva imbricata),* seaside goldenrod

(Solidago sempervirens), spurge *(Euphorbia ammannioides),* evening primrose *(Oenothera humifusa),* and sandspur *(Cenchrus tribuloides*).

Low Shrub/Grasslands

The earlier Service report for the West Onslow Beach project discussed several natural, upland communities (U. S. Fish and Wildlife Service [hereafter USFWS] 1986). These were grasslands, maritime shrub thickets, and maritime forest. Pilkey et al. (1998, p. 178) state that there are significant areas of interior vegetation composed of shrub thickets and maritime forest from the Surf City area southward to just north of the Jolly Roger pier. However, a review of recent aerial photographs indicates that much of the uplands on the narrow barrier island have been developed. The Town has experienced a rapid rate of development (USACE 2006, p. 54), but small areas of barrier island interior upland communities may remain.

Coastal low shrub/grasslands occur within dune fields and on overwash terraces behind the primary dune. Sea oats, beach grass, and other dune plants create a prairie that covers the sand with low vegetation (Frankenberg 1997, p. 51, 56; grasslands in Figure 1). This community may occur in areas known as barrier flats (Leatherman 1988, p. 31), areas of low relief formed by island overwashes that destroy dune ridge topography. This community is often a transitional area between the diverse high marsh community and the more stable maritime shrub thicket. The plants are well adapted to direct sunlight, high soil temperatures, and the porous soil that occurs in the dunes. Low shrub/grasslands are commonly found behind the protection of taller shrub thickets and low dunes. Low, stable dunes and overwash fans behind or between low dunes support grasslands. These grasslands may occasionally be overwashed or buried by sand. Vegetation may be moderate or dense except in recently overwashed areas.

Grasslands may extend from the front or backslope of a dune to the sound. Vegetation consists primarily of grasses, sedges, and a few forbs, with sea oats being dominant. Common plants include pennywort (*Hydrocotyle ranunculoides*), seaside goldenrod, broomsedge (*Andropogon* spp.), salt meadow cordgrass, and panic grass.

Where human and natural disturbances are minimized, the grasslands and high marsh often support scattered wax myrtle (*Myrica cerifera*), groundsel tree (*Baccharis halimifolia*), and marsh elder (*Iva frutescens*). As plant succession continues, a maritime shrub thicket and/or a maritime forest may develop in well protected areas.

Maritime Shrub Thicket

Maritime shrub thickets typically occur landward of the low shrub/grassland community where they are protected from salt spray and harsh winds (Frankenberg 1997, pp. 57, 60). The construction of artificial dunes may have allowed this community to develop. The maritime shrub thicket community is located sporadically throughout Topsail Beach, occurring on the backside of the island, west of the highway, and is interspersed with marsh areas, which border the sound (USACE 2006, p. 100). Shrubs are strongly influenced by salt spray and they have a close-cut, hedge-like appearance due to the destruction of young branches on the windward side by wind-blown salt. Shrub thickets are often scattered and wind sheared in areas of intense salt spray, but become taller and denser in less exposed areas. The community is characterized by dense shrubs that are usually entangled with vines. Characteristic species include wax myrtle (*Myrica cerifera*), groundsel tree (*Baccharis halimifolia*), yaupon (*Ilex vomitoria*), red cedar (*Juniperus virginiana*), and stunted live oak (*Qucerus virginiana*) (Bellis 1995, p. 4). Other shrubs that dominate the higher elevations include bayberry (*Myrica pennsylvanica*), black cherry (*Prunus serotina*), and loblolly pine (*Pinus taeda*). Vegetation common in lower areas are marsh elder (*Iva frutescens*), wax myrtle, yaupon, and groundsel tree.

Maritime Forest

In areas where protection from salt spray and wind forces is substantial, the shrub thicket community gradually becomes maritime forest as one moves landward. Many of the shrubs found within the shrub thicket are full grown trees in the maritime forest. Maritime forests are considered the "climax communities" on stabilized dunes subject to predominantly maritime influences such as wind and salt stress (Nifong 1981, p. 10). The forests may be dominated by live oak (*Quercus virginiana*), laurel oak (*Q. laurifolia*), and loblolly pine (*Pinus taeda*). The Draft GRR/EIS does not mention this community and it is likely that any forests which may have existed on the island have been eliminated or reduced to only a few remnant trees.

High Marsh

The high marsh occupies a zone between the upland communities and the shore of estuarine water behind the island. These areas are generally flooded on an irregular basis as a result of storms and wind. High marsh is generally found on sandy flats of old overwash fans or old tidal deltas that are no longer in the intertidal zone. The water table is close to the surface, and irregular flooding from strong winds and/or seasonally high tides create conditions that allow the dominance of several plant species. The vegetation of the high marsh is usually diverse as it contains species from other grassland and dune communities, as well as some intertidal marsh species. Where flooding is more regular, co-dominant species include smooth cordgrass, black needlerush (*Juncus roemerianus*), salt grass, sea ox-eye (*Borrichia frutescens*) , and sea lavender.

High marsh is a transitional community between high ground areas and estuarine wetlands and, depending on location and frequency of flooding, may have characteristics of either. It is important in stabilizing the shifting sands of the barrier island. Given time and protection, it will eventually become vegetated with dominant shrub species such as marsh elder, wax myrtle, and yaupon.

Low Marsh

The waters of Stump Sound, immediately northeast of Topsail Sound in the project area, are surrounded by natural salt marshes and support dense populations of fish, shellfish, and wading birds (Frankenberg 1997, p. 171). Low marshes in the project area are regularly flooded and dominated by smooth cordgrass (*Spartina alterniflora*). This emergent wetland community is within the intertidal zone. Along the fringe of tidal creeks, the community receives regular tidal inundation and marsh plants provide stability for the shoreline margins. The low marsh community typically provides nursery areas for various species of shrimp, crabs, and marine and estuarine fish.

Tidal creek and sloughs divide the marshes of the project area into numerous islands and peninsulas. Tidal creeks support a large biomass of nekton (organisms capable of movement) which contributes to the value of these areas as nursery for immature fish and shellfish (Copeland and Birkhead 1972).

Estuarine Intertidal Flats

North Carolina estuaries are characterized by broad expanses of mud flats covered by intertidal oysters that are exposed at low tide and broad expanses of regularly flooded low salt marsh. This tidally influenced community is found on the landward side of the islands in the project area. Rooted aquatic plants are not characteristic of intertidal flats (Lippson and Lippson 1997, p. 51). However, other forms of plant life, such as microscopic algae, thrive on flats. Bacteria and algae are highly productive on flats and form thin sheets covering shells and sediment particles.

The mobile, epifaunal animals in this community are primarily crustaceans and snails that prey on the rich supply of buried infauna (Lippson and Lippson 1997, p. 53). Many foragers, such as blue crab, small fish, and shrimp, come in with the tide to feed on surface detritus or to prey on intertidal burrowers. However, these species leave the flats on the receding tide and are more properly at home in the shallow, estuarine waters.

Estuarine Water and Tidal Creeks

Tidal creeks and sloughs divide the marshes of the project area into numerous islands and peninsulas. Tidal creeks support a large biomass of nekton (organisms capable of movement) which contributes to the value of these areas as nursery for immature fish and shellfish (Copeland and Birkhead 1972). The shelter provided by the marsh and creek systems within the sound serves as nursery habitat where young fish undergo rapid growth before returning to the offshore environment. With the exception of navigation channels, most estuarine waters of the project vicinity have been designated as Primary Nursery Areas (PNA) by the North Carolina Division of Marine Fisheries (USACE 2006, p. 12). These area are bounded New River (to the north), Mason Inlet (to the south), the Atlantic Intracoastal Waterway (to the west), and the landward side of Topsail Island. The State of North Carolina defines Primary Nursery Areas (PNA) as tidal saltwaters, which provide essential habitat for the early development of commercially important fish and shellfish. It is in these estuarine areas that many fish species undergo initial postlarval development. These area provide valuable nursery habitat for many commercially valuable species of marine and estuarine organisms.

Development

Residential development of Topsail Island was initiated in the 1930s (Frankenberg 1997, p. 171). After World War II the island was used by the military as a test site for missiles. However, the missile test site was abandoned because hurricanes and storms repeatedly destroyed buildings and equipment during the late 1940s and early 1950s (Frankenberg 1997, p. 171). A major surge in development occurred after the island was returned to civilian ownership. However, over 90 percent of houses at New Topsail Beach (probably the community on the southern part of the island) were destroyed by Hurricane Hazel in 1954.

The Service noted that the island has been historically characterized by low density development consisting of vacation homes and cottages, but new and very dense development is occurring at a steady and rapid rate (USFWS 1986, p. 3). There are now few buildable, vacant lots in the project area (USACE 2006, p. 65). There are 30 suitable vacant first row lots and 127 second-row lots (USACE 2006, p. B-5). Based on established building patterns, the coastal North Carolina real estate market trends, and an analysis of building permits from January 2003 to October 2005, all suitable vacant lots are expected to be developed by the base year (the start of initial construction) in 2011 (USACE 2006, p. B-5). This analysis showed that 92 single family structures were built and one multi-family structure for an average of 32 new structures per year not counting the multi-family units. The value of these additional 157 structures is about $273,000 each, totaling approximately $42.8 million.

SECTION 3 - FISH AND WILDLIFE CONCERNS AND PLANNING OBJECTIVES

The involvement of the Service in this planning process is in response to a Congressional mandate through the FWCA which directs that the conservation of fish and wildlife resources shall receive full and equal consideration and be coordinated with other features of federal projects. Fish, wildlife, and their habitats are valuable public resources which are conserved and managed for the people by state and federal governments. If proposed land or water developments may reduce or eliminate the public benefits that are provided by such natural resources, then state and federal resources agencies have a responsibility to recommend means and measures to mitigate such losses. In the interest of serving the public, it is the policy of the Service to seek to mitigate losses of fish, wildlife, and their habitats and to provide information and recommendations that fully support the Nation's needs for fish and wildlife resource conservation as well as sound economic and social development through balanced, multiple use of the Nation's natural resources.

Fish and Wildlife Concerns

The proposed project seeks to reduce storm damage which is a worthwhile goal. The key issue is the alternatives that will be considered and the extent to which all short- and long-term adverse environmental impacts of each alternative will be weighed in the selection of the preferred alternative. Within the project area, well understood geologic processes driven by a rising sea level are creating hazardous conditions for man-made structures. As the distance between structures and the sea decreases over time, these structures are at greater risk of storm damage. Efforts to protect these structures by putting an artificial sand barrier in the path of the sea may provide some temporary protection, but when viewed from a perspective of several decades such measures have little chance of providing long-term protection.

The Service recognizes that estuarine waters, barrier island uplands, beaches, and the nearshore waters represent unique and valuable habitats for fish and wildlife resources. Our first concern is that these habitat values not be eliminated or degraded. Therefore, the selection of a method for reducing storm damage should look beyond the short-term advantages or disadvantage of any particular technology and fully evaluate and compare the long-term consequences of each alternative. Any manipulation of sensitive natural areas will be harmful, to some degree, to certain organisms within those habitats. In the past, these manipulations were smaller and impacted a smaller geographical area. Many organisms could simply move to other, less disturbed areas. At present, the efforts to delay the removal of structures built on shifting sand have come to encompass a larger portion of the North Carolina coast and a greater portion of sensitive coastal habitats have been affected. In some cases, the species that depend on the ocean-beach interface are running out of undisturbed options. Therefore, a complete consideration of the cumulative impacts of any construction alternative must be made.

Specific Fish and Wildlife Service Concerns for Direct Impacts

While the Service hopes that alternatives to beach construction will be thoroughly evaluated, such construction is now considered the most likely alternative in the short term. Therefore, our concerns will focus on that alternative. Direct impacts associated with creating an artificial beach-dune system are primarily related to the removal of offshore sand, its transportation to beach areas, and its placement on beaches. The Service is concerned that offshore borrow areas may be used at a time and dredged in a manner that would adversely affect fisheries resources and primary productivity in both soft- and hardbottom areas.

A major factor in the degree to which beach and dune habitat values will be maintained is the physical compatibility of the material used in construction. The construction material should be a close match to the physical characteristics of the historic beach.

The Service is concerned that sediment disposal may adversely affect fish and wildlife resources on the beach and nearshore zone. The scheduling of sediment disposal would influence the extent of impact on beach invertebrates, nesting sea turtles, foraging shorebirds, and nearshore fisheries.

Specific Fish and Wildlife Service Concerns for Indirect Impacts

Indirect impacts are likely to emerge slowly during the years and decades after initial offshore sand mining and periodic sand placements on the beach. The most significant indirect impact involves the development that would be fostered by the artificial beach-dune system. The initial construction of artificial beach-dune system and an assumption that the system would be maintained in perpetuity will create a sense of security that is likely to lead to larger structures built at a greater density. While most vacant lots will be developed in the near future, many current houses are relatively modest. With the perception that the federal government will permanently maintain an artificial beach and dune, existing houses may be torn down and larger, most expensive structures built in their place. Such increase in the size and density of development would put greater pressure on fragile and limited freshwater resources, increase the amount of wastewater requiring disposal, and foster the construction of more transportation infrastructure such as roads and bridges. The combined effects of these factors pose a significant threat to existing fish and wildlife habitat values in the project area, even while such values are greatly reduce by historical standards.

A significant concern of the Service is the long-term consequence of preventing Topsail Island from moving naturally in response to sea level rise. When overwash deposition is cut off by an artificial dune system, a primary source of sand for marsh expansion and elevation increase of estuarine bottoms is eliminated (Godfrey 1970, p. 30). While this is not a critical factor in areas where constant supplies of sand and sediment are being brought into the sounds by rivers, in most areas along the North Carolina coast, particularly from Cape Lookout northward, it can become critical. Therefore, in time the deeper water in the estuarine area could reduce the areas of marsh and intertidal flats which serve as important nursery areas for fisheries resources.

Planning Objectives

While one goal of federal action is to reduce the adverse economic and environmental effects of hurricanes and other storms at Topsail Beach, an additional goal is to address these problems with solutions that are protective of the environment through avoidance or minimization of impacts to natural resources, including beach invertebrates, shorebirds, marine fish, marine mammals, and their habitats, throughout the economic life of any proposed federal action (USACE 2006, p. 49). The Service supports these goals. Careful planning and a conscientious balancing of economic considerations with environmental concerns can produce a project with minimal, short- and long-term environmental impacts.

The planning process should consider the most recent information on global sea level rise and the implication for protecting existing structures within the project area. The increase in sea level which will occur throughout the project life could have profound implications for the potential destruction of structure near the shoreline.

In regard to both damage prevention and preserving important habitats, the Corps should consider Executive Order (EO) 11988 of 1977. This EO dealing with floodplain management was enacted to avoid, to the extent possible, the long and short term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative. The Corps should evaluate the role of the proposed work in creating a perception of permanency for nearshore lots. To the extent that a 50-year federal commitment to maintain a berm and dune contributes to the perception of permanency, the project represents support for floodplain development. This is development which would not be completely protected from storm damage. The question to be answered is whether repeated destruction and rebuilding represents unwise floodplain development which should not be supported by the federal government.

The Service proposes the following planning objectives:

1. Planning should include a thorough evaluation of all available technologies to reduce storm damage. While creation of an artificial beach-dune system may offer short-term advantages, the planning effort should consider that an artificial beach and dune is temporary, the system would encourage additional development, and that a continuing rise in sea level may render the system untenable;

2. If a program of beach and dune construction is selected as the preferred alternative, the complete long-term ramifications of initiating this alternative should be fully explored. Both the Corps and local sponsors should look beyond the standard 50-year life of the project. A project objective should be the full consideration of the environmental impacts associated with development that would be engendered by the sense of security provided, on a short-term basis, by the artificial beach and dune. Furthermore, project plans should consider whether the benefits of postponing the movement or destruction of fixed structures in the project area, by implementing the preferred alternative, outweigh the loss of natural aesthetics that will result from ever-increasing sand placements at greater frequencies;

3. If beach and dune construction is selected, offshore sand mining should be done in a manner and at a time of year so as to avoid negative impacts to primary productivity, hardbottoms, important offshore fish habitat, and other marine resources, including marine mammals. The utilization of offshore sand resources may be the most environmentally acceptable method of obtaining borrow material; however, prior to a commitment to offshore sand mining, a thorough study of the biological impacts associated with the offshore mining of sand must be conducted; and,

4. If beach and dune construction is selected, the transportation of sand to and placement on the beaches should be done in a manner and at a time of year so as to avoid significant adverse impacts to beach organisms, nearshore aquatic ecosystems, nesting sea turtles, and migratory shorebirds.

In accordance with the FWCA, as amended, these planning objectives should be given full and equal consideration with the economic benefits expected from the project.

SECTION 4 - EVALUATION METHODS

Descriptions of natural resources present within the study area and the preliminary assessment of the environmental impacts of the proposed project are based on previous studies for similar projects, published literature, and personal communications with knowledgeable individuals. Published reports and studies were examined to determine their relevance to the proposed project. This reports uses information contained in the Service's earlier draft FWCA report (USFWS 1986) and the extensive information in the Draft GRR/EIS (USACE 2006). Material which describes potential environmental impacts of similar projects and methods of reducing these impacts are incorporated by reference in this report.

The Service is familiar with the coastal processes in the project area and ongoing efforts to protect fixed structures in southeastern North Carolina. The Service has worked with the Corps on beach projects at Wrightsville Beach, Carolina Beach, Fort Fisher, Bald Head Island, Ocean Isle Beach, Dare County (Bodie Island Project) and the efforts to place sand from the Wilmington Harbor enlargement project on the beaches of New Hanover and Brunswick Counties.

SECTION 5 - EXISTING FISH AND WILDLIFE RESOURCES

There is a great deal of information on the fish and wildlife resources of North Carolina's barrier islands. The Service provided a general discussion of the important fish and wildlife resources of the area in an earlier FWCA report (USFWS 1986). The Draft GRR/EIS also contains information on these resources. This section will present a broad summary of the fish, reptiles, birds, and mammals occupying the diverse habitats of the project area. The species listed are representative of the fauna present and may not include all species that could be impacted by the project.

General Fish and Wildlife Resources

Fish

Marine waters in the vicinity of the beach nourishment area and offshore borrow sites provide habitat for a variety of ocean fish and are important commercial and recreational fishing grounds (USACE 2006, 11). Kingfish (*Menticirrhus* spp.), spot (*Leiostomus* *zanthurus*), bluefish (*Pomatomus saltatrix*), weakfish (*Cynoscion regalis*), spotted seatrout (*Cynoscion nebulosus*), flounder (*Paralichthys* spp.), red drum (*Sciaenops ocellatus*), king mackerel (*Scomberomorus cavalla*), Spanish mackerel (*S. maculatus*) are actively fished from boats, the beach, and local piers. Offshore marine waters serve as habitat for the spawning of many estuarine dependent species.

Hardbottoms are also attractive to pelagic species such as king mackerel, amberjack (*Seriola* spp.), and cobia (*Rachycentron canadum*) (USACE 2006, p. 11). Huntsman (1994) states that there are more than 300 species of reef fish along the South Atlantic. Some of these species may occur near the hardbottoms off North Carolina. Some species within this group are gray triggerfish (*Balistes capriscus*), scamp (*Mycteroperca phenax*), speckled hind (*Epinephelus drummondhayi*), vermilion snapper (*Rhomboplites aurorubens*), white grunt (*Haemulon plumieri*), snowy grouper (*Epinephelus niveatus*), red porgy (*Pagrus pagrus*), red snapper, and warsaw grouper (*Epinephelus nigritus*).

The surf zone typically exhibits a high diversity of fish fauna and provides important habitat on which some species are dependent. Surf zone fisheries are typically diverse, and 47 species have been identified from North Carolina; however, the actual species richness of fishes using the North Carolina surf area for at least part of their life history is much higher (Ross, 1996; Ross and Lancaster, 1996). According to Ross (1996), the most common species in the South Atlantic Bight surf zone are Atlantic menhaden (*Brevoortia tyrannus*), striped anchovy (*Anchoa hepsetus*), bay anchovy (*Anchoa mitchilli*), rough silverside (*Membras martinica*), Atlantic silverside (*Menidia menidia*), Florida pompano (*Trachinotus carolinus*), spot (*Leiostomus xanthurus*), Gulf kingfish (*Menticirrhus littoralis*), and striped mullet (*Mugil cephalus*). The Service earlier noted the use of the surf zone by Florida pompano, summer flounder (*Paralichtys dentalus*), Atlantic croaker (*Micropogonias undulatus*), spot, whiting (*Menticirrhus* spp.), Atlantic silverside, and crevalle jack (*Caranx hippos*) (USFWS 1986).

Two species in particular, the Florida pompano and gulf kingfish (*Menticirrhus littoralis*) seem to use the surf zone exclusively as a juvenile nursery area and are rarely found elsewhere. The major recruitment time for juvenile fishes to surf zone nurseries is late spring through early summer (Hackney el al., 1996). Recent studies by Ross and Lancaster (1996) indicate that the Florida pompano and gulf kingfish may have high site fidelity to small areas of the beach and extended residence time in the surf zone suggesting its function as a nursery area. Major surf zone species consume a variety of benthic and planktonic invertebrates, with most of the prey coming from the water column. The dominant benthic prey species are coquina clams; however, this is not the dominant food item throughout the South Atlantic Bight. Furthermore, many surf zone fishes exhibit prey switching in relation to prey availability, which could mitigate impacts from beach nourishment (Ross, 1996).

Juveniles of ocean spawning and estuarine dependent fish and invertebrates may congregate in nearshore ocean water in the late winter and early spring prior to their transport through New Topsail Inlet (Hackney et al., 1996). The Service stated that the creeks and sounds landward of Topsail Island are extremely productive nursery grounds for several fish species and are utilized by commercial and recreational fishermen. These areas support species of commercial and recreational importance, such as spot, Atlantic croaker, summer flounder, sea trout (*Cynoscion hebulosus*, *Cynoscion regalis*) and blue fish (*Pomatomus saltatrix*).

Amphibian and Terrestrial Reptiles

These animals are generally scarce in this dry, relatively unstable environment. Due to dryness, amphibians are absent (Fussell, 1978). The most common reptile is the Carolina anole (*Anolis carolinensis*). Reptiles such as the six-lined race runner (*Cnemidophorus sexlineatus*) and the eastern glass lizard (*Ophisaurus ventralis*) are common and some species of snakes, especially the black racer (*Coluber constrictor constructor*) and eastern coachwhip (*Masticophis flagellum*), probably occur. The rough green snake (*Opheodrys aestivus*) and rat snake (*Elaphe obsoleta*) are probably common based on observations by Fussell (1978) at Bogue Banks.

Birds

The Draft GRR/EIS provides good information on birds which may occur in the project area (USACE 2006, pp. 27-29, pp. 102-103). A detailed discussion of the birds that may be found in the project area, including shallow-probing and surface searching shorebirds is provided by Peterson and Peterson (1979, pp. 49-58).

In general, birds common to the nearshore ocean in the project area include loons, grebes, gannets, cormorants, scoters, red-breasted mergansers, gulls, and terns. The waters off of Topsail Island and Onslow Beach are very important to migrating and wintering northern gannets (*Morus bassanus*), loons and grebes because of the abundant hardbottom habitat (Sue Cameron, pers. comm. cited in USACE 2006, p. 27).

Beach use by feeding avifauna is principally limited to the high tide drift line and swash zone (USFWS 1986). The beaches of the project vicinity are heavily used by migrating shorebirds. More than 20 years ago, characteristic beach avifauna inhabitants include: willet (*Catoptrophorus semipalmatus*), sanderling (*Calidris alba*), black skimmer (*Rynchops niger*), semipalmated sandpiper (*Calidris pusilla*), boat-tailed grackle (*Quiscalus major*), laughing gull (*Larus atricilla*), herring gull (*Larus argentulus*), ring-billed gull (*Larus delawarensis*), royal tern (*Sterna maxima*), sandwich tern (*Sterna sandvicensis*), common tern (*Sterna hirundo*), and gull-billed tern (*Gelochelidon nilotica*) (USFWS 1986). However, dense development and high public use of project area beaches may reduce their value to shorebirds (USACE 2006, p. 27). Species noted by the Corps as occurring on ocean beaches include blackbellied plovers (*Pluvialis squatarola*), ruddy turnstones (*Arenaria interpres*), whimbrels (*Numenius americanus*), [red] knots (*Calidris canutus*), as well as willets, semipalmated sandpipers, and sanderlings (USACE 2006, p. 27).

While bird nesting on the beach is uncommon, records indicate that prior to extensive human intrusion and ocean front development, the upper beach was an important nesting site for the least tern (*Sterna albifrons*) (Parnell and Soots, 1978 cited in USFWS 1986). Nesting along the shoreline has been displaced by development pressures and heavy recreational use along the beach. Traditional nesting areas on the project beach have been lost (USACE 2006, p. 102).

In winter, the dunes are extensively visited by migratory birds. Flocks of red-winged blackbirds (*Agelaius phoeniceus*) feed on sea oats, and American kestrels (*Falco sparverius*) search for prey (Fussell, 1978). The savannah sparrow (*Passerculus sandwichensis*) is common in winter. The Ipswich race (*P. S. princeps*) of this species is thought to winter in the larger expanses of dunes on Bogue Banks (Fussell, 1978) and may occur on Topsail Island. American Goldfinches (*Carduelis tristis*) are less common but sometimes occur in small flocks that feed on sandspurs and other seeds. Palm warblers (*Dendorica palmarum*) may be common, especially along the dune-maritime shrub thicket border. In summer and fall, barn swallows (*Hirundo rustica*) and tree swallows (*Iridoprocne bicolor*) feed on insects above the dunes (Fussell, 1978). Raptors such as the American kestrel (*Falco sparverius*), merlin (*F. columbarius*), peregrine falcon (*F. peregrinus*), bald eagle (*Haliaeetus leucocephalus*), and northern harrier (*Circus cyaneus*) may also be common during migration (USACE 2006, p. 27).

Maritime shrub thickets offer excellent cover for neo-tropical migrating songbirds (USACE 2006, p. 26). Species that may be found in this community include the seaside sparrow (*Ammospiza maritima*), painted bunting (*Passerina ciris*), saltmarsh sharp-tailed sparrow (*Ammodramus caudacutus*), Nelson's sharp-tailed sparrow (*A. nelsoni*), and marsh (*Cistothorus palustris*) and sedge wrens (*C. platensis*).

The project area around New Topsail Inlet contains large intertidal shoals and mud flats, which are very important to migrating and wintering waterbirds, including the piping plover (USACE 2006, p. 12). A detailed discussion of birds occurring in the estuarine intertidal flats of North Carolina is given by Peterson and Peterson (1979. pp. 49-58).

Mammals

Mammals inhabiting these marshes can be divided into two groups: (1) species living there by necessity; and, (2) those which periodically venture into the area. The first group contains those species which are specially adapted to this wet environment and contains the muskrat (*Ondatra zibethicus*), nutria (*Myocastor coypus*), river otter (*Lutra canadensis*), mink (*Mustela vison*), marsh rabbit (*Sylvilagus palustris*), and marsh rice rat (*Oryzomys palustris*). The second group contains species which are adapted to a wide range of upland and wetland habitats and includes the raccoon (*Procyon lotor*), gray fox (*Urocyon cinereoargenteus*), and white-tailed deer (*Odocoileus virginianus*). The opossum (*Didelphis virginiana*) and raccoon are common in the barrier island shrub thicket, as is the marsh rabbit along the shrub thicket-marsh border (Fussell, 1978). Mammals associated with the beaches and dunes include the opossum, eastern cottontail (*Sylvilagus floridanus*), gray fox, raccoon, feral house cat (*Felis catus*), shrews, moles, voles (*Microtus* spp.), and house mouse (*Mus musculus*) (USACE 2006, p. J-5).

Federally Protected Species

The Draft GRR/EIS contains a Biological Assessment (BA) which discusses the federally protected species which are likely to occur in the project area (USACE 2006, Appendix I). The federally listed species which were considered in project planning are given in Table I-1 (USACE 2006, p. I-2). The BA presents information on the level of occurrence in the project area, the potential impacts of the proposed beach construction effort, and an effect determination for each species or closely related group of species. In general, the information in the BA is thorough and up to date. This section will briefly mention the species of concern

The shortnose sturgeon (*Acipenser brevirostrum*) is a federally endangered fish under the jurisdiction of the National Marine Fisheries Service (NMFS). There are no recent records of the species from the project area (F. Rhode 2004, pers. comm. cited in USACE 2006, p. I-15). Because of the lack of suitable freshwater spawning areas in the project area and the requirement of low salinity waters by juveniles, any shortnose sturgeons present would most likely be non-spawning adults.

Five species of sea turtles are known to occur in the ocean and estuarine waters of North Carolina and may nest on beaches in the state. These sea turtles are the loggerhead (*Caretta caretta*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*), and Kemp's ridley (*Lepidochelys kempii*). The leatherback, Kemp's ridley, and hawksbill are found in offshore waters of North Carolina throughout the year and Kemp's ridley can be present from April through December in inshore waters (Epperly et al. 1995). The BA states (USACE 2006, p. I-9) that there have been no documented nesting attempts by these three species in the area proposed for sediment disposal and concludes that the nesting habitat of these species would not be impacted.

The other two species, the loggerhead and green, are considered to be potential nesters in the area. These species are known from both estuarine and oceanic waters in the project area. Both of these species are considered to be residents of North Carolina waters primarily from the spring through the fall although occasional winter records exist. Of these two species, only the loggerhead is considered to be a regular nester in the state, while green sea turtle nesting is primarily limited to Florida's east coast, but has been observed as far north as North Carolina.

The BA provides data on recorded sea turtles nests in the project area from 1990 through 2004 (USACE 2006, p. I-11). During this period, 1,477 nests were reported. All nests were attributed to loggerheads except six nests by greens in 1999 and three nests by green in 2000. Since consistent turtle nesting surveys began on Topsail Island in 1990, there has been a gradual decline in the average numbers of nests laid per year.

The federally threatened piping plover (*Charadrius melodus*) is known to nest in low numbers in widely scattered localities on North Carolina's beaches. The species typically nests in sand depressions on unvegetated portions of the beach above the high tide line on sand flats at the ends of sand spits and barrier islands, gently sloping foredunes, blowout areas behind primary dunes, sparsely vegetated dunes, and washover areas cut into or between dunes. Piping plovers arrive on their breeding grounds in late March or early April and nesting usually begins in late April; however, nests have been found as late as July (USACE 2006, p. I-19 and references therein).

The piping plover is a fairly common winter resident along the beaches of North Carolina (Potter et al., 1980). Most piping plovers at Topsail Beach have been observed predominantly as migratory and winter residents utilizing intertidal flats exposed at low tide for feeding and roosting. On 10 July 2001, the USFWS designated 137 areas along the coasts of North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas as critical habitat for the wintering population of the piping plover where they spend up to ten months of each year on the wintering grounds. Constituent elements for the piping plover wintering habitat are those habitat components that are essential for the primary biological needs of foraging, sheltering, and roosting, and only those areas containing these primary constituent elements within the designated boundaries are considered critical habitat. Unit NC-11 of designated wintering habitat encompasses approximately 1,114 acres in Pender and New Hanover counties extending southwest from 1.0 km northeast of mean lower low water (MLLW) of New Topsail Inlet on Topsail Island to 0.53 km southwest of MLLW of Rich Inlet on Figure Eight Island. This unit includes New Topsail Inlet and associated lands including emergent sandbars, from MLLW on Atlantic Ocean and sound side to where densely vegetated habitat, not used by the piping plover, begins and where the constituent elements no longer occur. In Topsail Sound, the unit stops as the entrance to tidal creeks become narrow and channelized.

Most piping plovers at Topsail Beach have been observed as predominantly migratory and winter residents utilizing intertidal flats exposed at low tide for feeding and roosting. However, breeding pairs have been observed on Topsail Beach from which seven nests have been documented since 1999 (USACE 2006, Table I-4, p. I-20). All nests were located in the critical habitat area and were laid on the inlet spit in front of the main dune system. Of the nests laid on Topsail Beach only one was successful with one documented fledgling in 1999 (Sue Cameron, personal communication cited in USACE, 2006, p. I-20).

The federally endangered West Indian manatee (*Trichechus manatus*) is considered a seasonal inhabitant of North Carolina with most occurrences reported from June through October. Manatees are rare visitors to the Topsail Beach Region. According to Schwartz (1995), a total of 68 manatee sightings have been recorded in 11 coastal counties of North Carolina during the years 1919-1994. Though none of these sightings occurred within the project vicinity, since sightings occurred north and south of Topsail Beach, it is likely that manatees transit through the Topsail Beach region. Manatees are known to infrequently occur within nearly all North Carolina ocean and inland waters (Schwartz, 1995) with four North Carolina records from inlet-ocean sites and six from the open ocean (Rathbun 1982).

The BA considers six species of whales (USACE 2006, pp. I-4 to I-6). These are the right whale (*Eubaleana glacialis*), sei whale (*Balaenoptera borealis*), sperm whale *Physeter macrocephalus* E), finback whale (*Balaenoptera physalus*), humpback whale *Megaptera novaeangliae*), and blue whale (*Balaenoptera musculus*). All are designed as endangered. Of these, only the right whale and the humpback whale routinely come close enough inshore to encounter the project area. Humpbacks are often found in protected waters over shallow banks and shelf waters for breeding and feeding. They migrate toward the poles in summer and toward the tropics in winter and are in the vicinity of the North Carolina coast during seasonal migrations, especially between December and April. Sighting data provided by the Right Whale Program of the New England Aquarium indicates that 93 percent of all North Carolina sightings between 1976 and 1992 occurred between mid-October and mid-April (Slay 1993). The occurrence of right whales in North Carolina waters is usually associated with spring or fall migrations. Due to their restriction to oceanic environments, the only aspects of the proposed action, which might result in an encounter with these species, will be the operation of the hopper dredge in the offshore borrow areas.

SECTION 6 - FUTURE FISH AND WILDLIFE RESOURCES WITHOUT PROJECT

This section presents the opinion of the Service on the condition of fish and wildlife resources in the project area which could be reasonably anticipated in the absence of the federally funded creation of the artificial beach-dune system. While these opinions reflect a course of no action on the part of the federal government, they do not represent the total lack of action by non-federal entities.

Topsail Island will continue to be developed with limitations imposed by the availability of suitable land, soil constraints, water supplies, and local land use regulations, zoning regulations, and ordinances. Frankenberg (1997, pp. 219-235) discusses trends in human population, land, use, and economic development along the southern North Carolina coast. While local governments seek orderly development, development will continue for the foreseeable future as long as favorable economic conditions exist. More and better roads will bring more people to the project area. All suitable vacant lots are expected to be developed by 2011 (USACE 2006, p. B-16).

With or without federal action the important coastal processes discussed in Section 2 will continue. Over the course of the proposed 50 years of periodic beach replacements, sea level will likely continue to rise and the artificial beach can to be expected to wash away over shorter spans of time. Without beach replacement or shoreline armoring (the placement of hard structures), the natural process of island migration would continue to move sand from the beaches to estuarine area during episodes of island overwash. The shoreline would continue to move landward and structures in their present location would be threatened or destroyed. An array of stop-gap measures, such as beach bulldozing and sand bagging, would be employed by the local government and/or individual property owners.

From one perspective, the five miles of currently eroding beach and dune complex would continue to deteriorate, thus endangering public infrastructure, public and private property, human lives, and important habitat for a variety of plants and animals (USACE 2006, p. 48). The floodplain in the Topsail Beach area is currently being adversely affected by shoreline recession and the continued deterioration of the beach and dune complex. These effects will become more pronounced as the shoreline continues to recede and future storms encroach upon the area. This viewpoint envisions that continued recession would result in a narrowing of the area between the surf, especially at high tide, and the landward limits of recreational use (USACE 2006, p. 41). As the available width of the dry beach decreases, some recreational activities would be hindered and eventually prevented.

Overall, the absence of the 50-year federal project would have little impact on the interior upland communities on Topsail Island. These communities, such as maritime grassland, maritime shrub thickets, and maritime forest, have already been largely eliminated and remnants of these natural communities would continue to be developed.

No Action by Public or Private Entities

No action by any party is not considered likely, as such inaction would probably lead to the loss of most structures on the island and the demise of the Town of Topsail Island. However, this course would be ultimately beneficial to fish and wildlife resources. Topsail Island would adjust to sea level rise as sand is washed from the beaches to the sound side during major storms. Wide natural beaches would develop for use by fish and wildlife resources as well as tourists and mainland homeowners. Complete no action would not result in the continued erosion of the beach, as suggested in the Draft GRR/EIS (USACE 2006, p. 61), and would not result in losses of sea turtle nesting habitat and possible poor nest site selection by females. Existing development would be gradually relocated or demolished resulting in considerable social upheaval. If other communities on Topsail Island adopted similar policies, the island would come to come to resemble the national seashores in the state and could become a tourist destination in the southern part of the state.

Non-Federal Protection of Existing Structures at Current Location

One action scenario in the absence of the 50-year federal beach construction effort would be non-federal measures to protect current oceanfront structures. This scenario is already occurring through the planning for a non-federal beach construction project. This non-federally funded measure would construct a beach along approximately the same length of shoreline. Furthermore, the Wilmington Corps also started planning in May 2007 for a dredging project of New Topsail Inlet, Topsail Creek, and/or Banks Channel with any dredged sand to be placed on the beaches of the Town in order to protect imminently threatened structures. These large-scale measures would be in addition to small scale measures such as beach bulldozing and sandbagging which could be expected to occur at more frequent intervals as sea level rises.

This effort may adversely affect fish and wildlife resources if standards for sand compatibility are reduced. The implementation of summer dredging and disposal, as currently under consideration, would adversely affect sea turtle nesting, growth of sea beach amaranth, and shorebird feeding. The combination of sandbag placement and beach bulldozing could ultimately result in the permanent loss of the dry beach when the high tide line reaches the toe of the constructed dune or the line of sandbags. Rising estuarine water could produce conditions detrimental to salt marsh and estuarine flats.

Overall, piecemeal efforts to stabilize Topsail Island and preserve existing structures, would threaten a number of important fish and wildlife habitats. In a report on his research on the Outer Bank, Paul Godfrey (1970) stated that "by attempting to hold everything in one place, man is actually creating a much more unstable situation that will lead to greater problems of erosion in the future. Erosion is a man-conceived evil that only man worries about, especially when it threatens his structures . . . In the long run, he will make the situation worse because such interruption will put the islands in greater jeopardy of destruction as long as the sea continues to rise."

Summary of Future Fish and Wildlife Resources Without the Project

A likely course of events over the next 50 years without the federal project would be periodic, non-federal efforts to preserve beach front structures in their current location. As sea level continued to rise and hurricanes of greater force became more common, non-federal attempts to prevent barrier island mitigation could be perceived as too costly and ineffective. These factors would lead to a decision to either armor the island with rock revetments or gradually retreat from the barrier islands to the mainland.

This report will not attempt to predict the future of current development in the project area beyond 50 years. However, within the life of the proposed work, fish and wildlife resources are likely to be impacted by periodic sand placements and small scale beach stabilization efforts. In general, the adverse impacts of these non-federal stabilizations effort would be similar, but perhaps on a somewhat smaller scale than those which would occur with the proposed federal beach construction program.

Perhaps the most significant without project impact would be psychological. Without the 50-year federal commitment for beach construction, the risk associated with permanent structures on the island would be perceived as higher. Prior to federal intervention to protect ocean front development, such development was considered too dangerous. In the earliest European settlement in North America, there was practically no building on the coastline (Dean 1999, p. 186). The early settlers kept their homes on high ground away from the heavy weather and thin soils of the shoreline. Some east coast communities near the ocean were eventually abandoned when the area was determined to be unfit for settlement. In the late 19th century the community of Diamond City on Shackleford Banks was relocated to the mainland after repeated damage by major storms (Dean 1999, pp. 185-186). All that remains of this community of 500 people are a few tombstones in the tiny cemetery.

Ultimately, the consequence of not undertaking a federal beach construction effort is to hasten the decision on whether the island will be held in place and surrounded by a rising sea or allowed to move naturally and continue to provide important habitat for sea turtle, shorebirds, nearshore fisheries resources. Since this cannot be predicted at this time, the long-term outlook for the habitat values in the project area is uncertain.

SECTION 7 - ALTERNATIVES CONSIDERED

The Draft GRR/EIS identifies three goals for the federal project (USACE 2006, p. 49). These are: (1) reduce the adverse economic and environmental effects of hurricanes and other storms at Topsail Beach; (2) find problem solutions that are protective of the environment through avoidance or minimization of impacts to natural resources, including beach invertebrates, shorebirds, marine fish, marine mammals, and their habitats, throughout the economic life of any proposed federal action; and, (3) protect endangered and threatened species and their habitats within the project area. These goals do not specifically mention measures to minimize the undercutting of ocean front structures as sea level rises and the shoreline is inundated, an occurrence unrelated to storm conditions. While the inland reach of flooding and damaging waves is most dramatic during storms, the fundamental threat to ocean front structures is not the occasional storm, but the slow and continuous rise of sea level which brings the ocean closer to the structures.

The goal of reducing structural damage is worthwhile. The key issue with regard to fish and wildlife resources is the alternatives that will be considered and the extent to which all short-term, long-term, and cumulative adverse environmental impacts of each alternative will be weighed in the selection of the preferred alternative.

The fundamental question in the development of alternatives is whether the selected alternative needs to protect existing structures at their present location or simply seek to reduce the overall damage to man-made structures within the project area. Within the project area, geologic processes driven by a rising sea level are creating hazardous conditions for man-made structures. As the distance between structures and the sea decreases over time, these structures are at greater risk of storm damage. Efforts to protect these structures by constructing an artificial sand barrier in the path of the sea may provide protection against some forms of storm damage. However, some risks and uncertainties are associated with beach construction (NRC 1995, pp. 40-41).

On the other hand, there is no permanent storm damage on undeveloped barrier islands. While some plant communities may appear to be harmed by major storms, hurricanes are natural phenomena and fish and wildlife species of the coast are adapted to these periodic disturbances. Di Silvestro (2006) states that barrier islands erode and rebuild naturally and many species that use them, particularly birds, adapt to their destruction by moving to undamaged habitat. Alexander and Lazell (2000, p. 38) write that "violent weather is an integral part of life" on the Outer Banks where plants and animal are well-adapted to foul weather. However, when viewed in the short-term, coastal storms can produce a loss of habitat at a particular location, but identical habitat can be created elsewhere in very dynamic coastal areas. In their natural state barrier islands can be considered as disturbed habitats and the species using these areas adapt and recovery from even the strongest storms.

The National Environmental Policy Act (NEPA) requires a consideration of a no action alternative. This alternative requires the consideration of whether the need and purpose actually necessitates action and the consequences of such inaction. The no action alternative also provides a "baseline" against which the impacts of various action alternatives can be compared. The Draft GRR/EIS appears to consider this approach as the absence of any major action at any level of government. However, the no action plan does not preclude emergency measures for dealing with shoreline recession, such as beach scraping (bulldozing) to push up a small sand ridge and sandbagging, but, in the long run, these emergency measures are assumed to be ineffective (USACE 2006, p. B-32).

The current project is different from many water resources development efforts. Certain development efforts, such as damming a free-flowing river, seek to alter a stable, natural ecosystem for economic development. Without action there is less new economic development, but no harm to existing economic conditions. In the current situation, there is current economic development (structures on a barrier island) on an unstable ecosystem. The situation at Topsail Beach represents a case where economic assets are being damaged. These assets face the threat of greater damage and even widespread destruction. Since the Town is almost fully developed, additional economic gains would come as modest structures are replaced by larger structures. However, the major economic threat is elimination of current economic conditions. Action is needed primarily to prevent economic losses rather than produce major economic gains. Therefore, from an economic perspective, a no action alternative does not meet the economic standards of the federal effort which is to prevent certain damage to existing structures. The environmental setting represents an unstable, altered ecosystem which natural forces are directing to a new location in order to return it to a natural equilibrium with sea level.

With regard to potential actions, the Draft GRR/EIS discusses the formulation of plans based on general criteria and four categories of technical criteria (USACE 2006, pp. 50-51). The document notes that there are an extremely large variety of potential measures that might be considered in the formulation of plans. Actions to address recurring storm damage and the threat of shoreline recession can be divided into two broad categories: structural or nonstructural.

The Draft GRR/EIS states (USACE 2006, p. 51) that "nonstructural measures are those taken to reduce damages without directly affecting those conditions." While this is not entirely clear, the statement seems to refer to measures to reduce structural damage while allowing natural barrier island processes, such as island overwash and island migration, to continue. While ocean front homes could persist by implementing some nonstructural measures, such as stronger home construction, these measures do not protect structures from coastal inundation as sea level continues to rise. The Draft GRR/EIS states (USACE 2006, p. 52) that changes in regulations and physical modifications to reduce damages were considered. Some regulatory measures are coastal building codes, building construction setbacks, and floodplain regulations. Most regulatory measures are no longer considered in the alternative plans because these measures have already been implemented. Such measures do not affect older structures, and there are few buildable, vacant lots remaining that would benefit. These measures are considered as part of the existing conditions. They have reduced damages from past events, and as older structures are replaced, will help to reduce future damages.

Another category of nonstructural measures is reduction of the damage threat by removing beachfront structures from the threat. The three removal measures are retreat, relocation, and demolition. Retreat is moving an existing structure away from the shoreline a short distance within the same property parcel. Relocation is moving an existing structure away from the shoreline a longer distance to a vacant property. Acquisition of the property and demolition of the structure is a third measure where retreat or relocation is not feasible. These removal measures were retained for consideration in the nonstructural alternative.

The Draft GRR/EIS states (USACE 2006, p. 51) that structural measures are those that directly affect conditions that cause storm damage and erosion. This statement is vague and does not provide a clear indication of this broad approach. This approach actually involves constructing a barrier between ocean front structures and the ocean. These alternatives may also involve additional construction to protect the artificial barrier.

The Draft GRR/EIS (USACE 2006, p. 51) states that a wide variety of structural measures are possible. They are beach construction, breakwaters, seawalls, and groins. Beach construction measures consist of berms, dunes, and terminal sections. The beachfill measures are considered some of the most appropriate, since they mimic the natural environment and can be shaped to maximize net storm damage reduction benefits. Groins can be a terminal groin near an inlet, or can be installed as a repetitive groin field throughout the project length. A terminal groin at New Topsail Inlet was identified as a measure in the National Economic Development (NED) plan in the original report. This measure was retained for consideration. Groin fields were rejected as a measure because of the possibility of causing increased beach losses outside of the project area. Seawalls, bulkheads, and revetments are appropriate for reducing structural damage. However they would not meet the goal of preserving recreational and environmental value of the beach profile and were rejected as measures. Breakwaters can be used in erosional hotspots to maintain a beachfill, however, no such condition appropriate for breakwaters was found in the project area. Moreover, while offshore breakwaters may reduce erosion in their lee, these benefits may be offset by accelerated erosion of the downdrift shoreline due to interruption of the littoral drift. Vegetation and sand fencing help retain windblown sand, but do not provide adequate storm protection for moderate to severe storms.

SECTION 8 - SELECTION OF PREFERRED ALTERNATIVE

The alternatives are considered in three broad categories consisting of: (1) no action; (2) nonstructural measures; and, (3) structural measures. The Draft GRR/EIS does not contain a detailed discussion of the no action approach, but the basic premise of no federal action is that the oceanfront structures would maintain their current location in the face of ongoing sea level rise and major storm events. Based on this premise, the existing beach would continue to narrow as it is squeezed between the rising ocean and the fixed line of structures. Man-made structures and natural resources dependent on the beach would continue to be harmed.

The evaluation of the no action approach can only be made indirectly from the comparison of impacts (USACE 2006, Table 5.3, pp. 59-62). The discussion notes that no action would produce: (1) continued deterioration of the beach; (2) continued threat to ocean front land, road/utilities, structures, and personal property; (3) expanded overwash areas and formation of new overwash areas; and, (4) detrimental effects on community cohesion and public facilities. This discussion does not specially address the non-federal measures which would be attempted to halt shoreline recession and preserve oceanfront homes.

A discussion of no action by any government entity is relevant to the decision making process even if such a course is unlikely. This discussion should separate the impacts on natural barrier island features from man-made structures. As noted above, storms would periodically move sand from the beach into the island's interior and ultimately into the marshes on the sound side. This the natural process of island migration by which barrier islands adapt to rising sea level. This course would not lead to the loss of the recreational beach over time. This is evident by the fact that Ocracoke Island within the Cape Hatteras National Seashore was selected as the best swimming beach in America in 2007 (Martha Waggoner, Associated Press, published in the Wilmington StarNews, June 8, 2007). The beaches would continue to exist, the island interior would be built up, and the estuarine saltmarsh would gradually move landward. While established building lots would be lost on the ocean front, new, buildable lots would be created on the sound side.

On the other hand, no governmental action would eventually lead to loss of ocean front structures and infrastructure. This would create a significant adverse economic impact. However, the damage that would occur during storms even with a structural alternative is not fully considered in the context of the no action alternative. That is, major hurricanes will continue to produce major economic losses with or without a structural barrier along the shoreline. A no action approach would produce the greatest harm by not addressing the encroachment of the ocean on existing ocean front structures. This is a process that will continue for many decades and can be expected to increase in the future. While mitigating this non-storm threat is not a stated goal of the federal effort (USACE 2006, p. 49), the economic damage resulting from global sea level rise appears to be the justification for rejecting the no action alternative.

The evaluation of nonstructural alternatives is brief in the main text of the Draft GRR/EIS (USACE 2006, p. 54). There is some additional analysis in Appendix P. The overall discussion does not consider changes in building codes, setbacks, and floodplain regulations, but focuses on retreat and relocation aspects. The evaluation of removing structures is best revealed in the Table 5.3 (USACE 2006, pp. 59-62). The table notes that removing structures would: (1) reduce the tax base; (2) have greater costs than benefits; (3) not stop beach erosion or the expansion of new overwash areas; (4) increase noise during demolition and removal; and (5) be detrimental to community cohesion and public facilities. However, for a fish and wildlife perspective, the removal of structures would: (1) allow a remote and undisturbed beach; (2) eliminate recurring losses of beach invertebrates due to beach bulldozing and sediment placements; (3) maintain the status quo of marine resources; (4) improve conditions for nesting sea turtles by removing disorienting beach lighting; and, (5) offer an opportunity for better habitat for piping plovers, other shorebirds, and sea beach amaranth.

There is conflicting information regarding public recreation in the evaluation of the nonstructural approach. As noted, at some places in the evaluation this approach would allow beach erosion to continue and no recreational benefits would be derived (USACE 2006, p. 54, 60). On the other hand, Table 5.3 notes that this approach would create a more natural appearance along the beach, maintain existing recreational capacity of the beach, and increase adjacent public land. The latter position is more accurate because a retreat and relocation strategy would allow natural island migration to continue. A wide beach similar to some remote areas of the national seashores in the state would be created for both the benefit of tourists, sea turtles, shorebirds, and marine fisheries. Access could be maintained along the entire length of the project area by pervious, gravel roads which could be replaced and/or relocated relatively easily after storms.

While two of the three project goals directly relate to protecting environmental values, the final decision on the nonstructural approach was based entirely on costs and a narrow view of the economic benefits to be gained. With an overall benefit-cost-ratio (BCR) of 0.92, the nonstructural approach was not found to be "economically feasible," and there was not further evaluation for technical feasibility or for acceptability" (USACE 2006, p. 54). A BCR of 0.92 is quite good considering that no recreational benefits were assigned and no dollar value was assigned for basically maintaining the status quo for marine resources.

As with all beach projects to date, after evaluating the range of alternatives, there is only a single viable alternative as a course of action. In a very narrow sense, the absence of any government action – either removing existing structures or protecting them – would lead to small piecemeal protective measure which would fail and dunes and beaches covered by debris for many years. Evaluating the nonstructural approach from the narrow perspective of relocation costs without any consideration of the broader benefits of allowing natural island adjustment to rising sea level does not seem consistent with the stated goals of the federal effort.

However, with the rejection of the nonstructural approach, the Draft GRR/EIS states (USACE 2006, p. 55) that the "evaluation of plans at this point has narrowed the alternatives to beachfill in reaches 4 through 26 with tapered transition sections at each end." From the perspective given in the Draft GRR/EIS, there was no decision to use the structural approach, it was the only available option.

SECTION 9 - DESCRIPTION OF PREFERRED ALTERNATIVE

The Draft GRR/EIS discusses construction plans for the artificial beach and dune system (USACE 2006, pp. 65-83). The plan has a main fill length of 23,200 feet (4.39 miles), from approximately 400 feet southwest of Godwin Avenue, in reach 3, to the Topsail Beach town limit in reach 26. The two essential features of the selected plan are the dune and the berm. The plan has a dune at a height of 12 feet above the National Geodetic Vertical Datum (NGVD) and with a crest width of 25 feet. The side slopes of the dune are 5H:1V on the landward side and 10H:1V on the seaward side to the berm. The plan includes a berm seaward of the dune. The berm has a flat, level section with an elevation of 7-feet NGVD and an optimum width of 50 feet. The seaward slope of the berm extends the beach fill approximately another 100 feet at a slope of 15H:1V down to Mean Low Water (MLW) elevation (-1.9 feet-NGVD), below which the with-project profile parallels the existing profile out to a closure depth of -23 feet NGVD.

There would be transition sections at both ends of the main fill to improve project stability and reduce end losses. The 2,000-foot northern transition consists of a tapered berm only, with the dune not extending beyond the limits of the main fill section, resulting in a starting transition berm width of 155 feet that uniformly tapers to zero. The southern transition section is similar to the northern transition, except for the length of 1,000 feet.

Six borrow areas are located in the ocean between 1 mile and 5.5 miles from the shoreline, (USACE 2006, p. A-3). These areas are between the 30-foot and 60-foot NGVD depth contour. The largest and closest site, borrow area A, has a sufficient sand layer thickness and volume to be designated as the borrow source for initial construction. The total volume of suitable material available from all six sites is approximately 21,100,000 CY. This volume is sufficient to meet the project requirements.

Initial construction would require approximately 3,223,000 cubic yards (CY) of sand from the borrow area with an overfill ratio of 1.35. The material would be pumped to the beach by pipeline dredge and shaped on the beach by earth moving equipment. The initial construction profile would extend seaward of the final design berm profile a variable distance to cover anticipated sand movement during and immediately following construction. This variable distance would generally range from 100 to 200 feet along the project depending upon foreshore slopes established by the fill material. Once sand redistribution along the foreshore occurs, the adjusted profile should resemble the design berm profile. Initial beachfill construction would take 5 months to complete. The project would be constructed in FY2011 (November 2010 – April 2011), subject to availability of funds.

Periodic reconstruction would require approximately 866,000 CY of sand from the borrow areas with an overfill ratio of 1.25 at intervals of 4 years. The reconstruction material would be removed from the borrow areas by hopper dredge. Delivery of sand could occur by hauling filled scows to a pumping station buoy or by hopper dredge hauling sand to the pipeline buoy.

In both initial construction and during reconstruction the delivery pipeline would be placed to avoid the piping plover habitat areas along the south end of the beach and material between the toe of dune and mean high water line would be tilled to prevent compaction. Over the 50 year life of the project 13,615,000 CY of sand would be placed on Topsail Beach. The volumes required are reported as borrow volumes including overfill ratios, not actual volume in place, which is less.

Initial construction would begin November 16 of year 0 for the project. The initial construction would consist of pipeline dredging from Borrow Area A and proceed until completion before April 30 of the following year. The four-year cycle of reconstruction would begin in year 4 and consist of hopper dredging due to limited thickness of available material in the borrow areas and long haul distances. Each reconstruction of the beach and dune would use a combination of offshore borrow areas. Because the potential for sea turtle interactions using hopper dredges is higher during the warmer months, periodic reconstruction would adhere to the hopper-dredging window which opens on December 1 and proceed until completion before March 31 of the following year. In summary, one hopper dredge would be expected to complete the reconstruction every four years within the designated hopper-dredging window.

SECTION 10 - IMPACTS OF THE PREFERRED ALTERNATIVE

The preferred alternative involves offshore sediment extraction, transport to the beaches, and beach placement over 50 years would impact many important biological communities. These impacts would be both direct and indirect. After discussing these environmental impacts, this report will present conservation measures and recommendations for avoiding and minimizing the consequences of the preferred course of federal action.

Direct Impacts on General Fish and Wildlife Resources

Direct impacts refer to those consequences of a given action which occur at generally same time as the action and in the immediate vicinity of the action. Direct impacts are generally easier to observe and quantify, but they are not necessarily the most serious and long-lasting consequences. In fact, even dramatic, direct impacts to organisms and habitats may soon dissipate and resilient ecosystems can return to pre-project levels in relatively short spans of time.

Sand removal may produce direct adverse impacts within offshore soft bottom communities. Benthic infauna are killing during dredging (Greene 2002, p. 12). While re-colonization may occur, significant alteration of the substrate may prevent the area from regaining pre-dredging productivity. Some changes in species composition and population may occur (Johnson and Nelson 1985, Van Dolah et al. 1984). Differences in community structure may occur that may last two to three years after initial density and diversity levels recover (Wilber and Stern, 1992). Specifically, species of large, deeper-burrowing infauna can require as much as three years to return to pre-disturbance abundance.

Dredging in offshore areas would adversely affect organisms in the water column. Free-floating, planktonic larvae that lack efficient swimming abilities are susceptible to entrainment by an operating hydraulic or hopper dredge (USACE 2006, p. 86). Some adult fish may also be entrained by the dredge, but such mortality is expected to be low since adult fish have the ability to leave the dredge site (USACE 2006, p. 87).

While project plans seek to avoid dredging near offshore hardbottoms, some adverse impacts could occur. Sediment suspended during dredging could be carried to hardbottom areas resulting in both harmful turbidity and burial of exposed rock. This would occur if relatively small areas of fine grained material exist within larger area of sand. Currents could carry sediment with high silt and clay content over a considerable distance and cover hardbottom areas with a damaging layer of sediment.

Nearshore hardbottoms may also be adversely impacted by turbidity and sedimentation by material carried seaward from the constructed beach. Burial of nearby hardbottoms by dredge and fill activities has been shown to reduce the abundance of fish species and individuals in Florida (Lindeman and Snyder 1999). Lindeman and Snyder (1999) state that "because of behavioral and morphological constraints on flight responses, high mortalities are probably unavoidable for many cryptic [fish] species, newly settled life stages, or other site-associated taxa subjected to direct habitat burial." Nearshore, shallow hardbottoms were found to carry a large number of newly settled stages, and therefore Lindeman and Snyder (1999) conclude that burial as a result of dredge and fill activities may have amplified impacts if conducted just prior to peak larval recruitment, which is in spring and summer in their study area. Therefore, the Service is concerned that the timing of open ocean sediment extraction and beach placement of sediments from this project may be a critical factor in the magnitude and frequency of impacts to nearshore hardbottoms.

The biological community of nearshore soft bottoms may also be adversely impacted by either direct burial during construction or later burial by material carried off the constructed beach. Fish and invertebrates may smother when gills are clogged due to high levels of suspended solids. Reduced light penetration decreases primary productivity. Planktonic larvae of both vertebrates and invertebrates found in the surf zone may be adversely affected by high turbidity levels (NRC 1995, p. 114). Van Dolah et al. (1992) found that macrofaunal communities in the lower intertidal zone and subtidal areas of the beach declined after nourishment. However, recovery was rapid and this was attributed to the similarity of beach fill material to the natural sediments and to the placement of fill material high on the beach.

Rakocinski et al. (1996) found that macrobenthic assemblages in nearshore, sandy-beach environments are less resilient to the impacts of beach construction projects than more diverse offshore assemblages. These nearshore assemblages respond to such projects with "decreased species richness and total density, enhanced fluctuations in those indices, variation in abundances of key indicator taxa, and shifts in macrobenthic assemblage structure" (Rakocinski et al. 1996, p. 326).

Beach construction can affect fishery resources through increased turbidity and sedimentation that, in turn, may create localized stressful habitat conditions, and may result in temporary displacement of fish and other biota (USACE 2006, p. 99). During and immediately after construction, short term turbidity and sedimentation can reduces prey availability and hindering foraging success. Street et al. (2005, p. 398) state that fish may be impacted by beach construction due to reduction in food availability, alteration of preferred topographic features, disturbance prior to or during spawning, or reduced visibility. Current plans state (USACE 2006, p. 85) that during periods of low prey availability, as a result of short-term impacts to the benthic invertebrate population during beach disposal activities, surf zone fishes may temporarily utilize alternative food sources. Considering the dynamic nature of the surf zone, this opportunistic behavior of avoidance and prey switching may enable some surf zone fishes to adapt to disturbances like beach construction. A combination of short-term prey switching and temporary relocation capabilities may help mitigate short-term prey reductions during beach disposal operations. However, this prediction of minimal adverse impacts may not fully reflect conditions that could occur with the placement of limited amounts of silt and clay sediment.

Beach construction may have negative impacts on intertidal macrofauna through direct burial, increased turbidity in the surf zone, or changes in the sand grain size or beach profile (USACE 2006, p. 88). Placement of sediment on the beach will kill the existing infauna through suffocation or loss of access to food. The burial of organisms, such as coquina clams, mole crabs, amphipods, polychaetes and other invertebrates in both the surf zone and beach will usually result in temporary elimination of these organisms with the exception of highly mobile species or species able to withstand prolonged periods of burial. Since ghost crabs are present in the project area all year, construction would bury any of these organisms present (USACE 2006, p. 102). Sand placement disturbs the indigenous biota inhabiting subaerial beach habitats, which in turn affects the foraging patterns of the species that feed on those organisms (NRC 1995, p. 108).

Peterson et al. (2000) documented invertebrate populations following disposal of dredge spoil from Bogue Sound on the beaches of Bogue Banks. Populations were reduced by 86-99% (compared to control beaches) five to ten weeks following fill placement. The authors conclude that "failure of *Emerita* [mole crabs] and *Donax* [coquina clams] to recover from nourishment by mid summer when they serve as a primary prey base for important surf fishes, ghost crabs, and some shorebirds may be a consequence of the poor match in grain size and high shell content of source sediments and/or extension of the project too far into the warm season" (Peterson et al. 2000, p. 2).

Turbid waters could be carried through New Topsail Inlet on the flood tide and harm oyster producing areas in estuarine waters. Current planning notes that primary nursery areas (PNAs) will not be directly impacted by this project (USACE 2006, p. 100). However, PNAs located near New Topsail Inlet may experience indirect and short-term elevated turbidity levels from the nourishment operation on the shoreface. These turbidity effects are dependent on the location of the outflow pipe and the direction of longshore and tidal currents. These elevated turbidity levels are expected to be short-term and within the range of elevated turbidity from natural storm events and are considered to be insignificant (USACE 2006, p. 100).

Beach construction would impact shorebird nesting and feeding during disposal operations. Shorebird species which feed in the intertidal zone may be adversely affected by beach constructions (NRC 1995, p. 110). Shorebirds may be displaced by dredges, pipelines, and other equipment along the beach or may avoid foraging along the shore if affected by construction noise (Peterson et al. 2001). While initial construction would extend into the 1 April bird nesting timeframe, the Corps plans to work, to the maximum extent practicable, with the North Carolina Wildlife Resources Commission, to plan construction around designated nesting areas (USACE 2006, p. 103). Based on conservation measures included in current plans, the proposed construction activities are not expected to significantly impact breeding and nesting by shorebirds or colonial waterbirds within the project area (USACE 2006, p. 103).

Indirect Impacts on General Fish and Wildlife Resources

Indirect impacts are those consequences caused by the action, but occur at a later time and at a location away from the actual work site. Consequences which permanently alter a given habitat gradually over time can be more detrimental to fish and wildlife resources than the more dramatic and highly visible direct impacts.

Such permanent alterations in habitat values could occur in the offshore sediment extraction areas. The areas mined for beach construction can refill with decomposed organic matter that is silty and anaerobic, hydrogen sulfide level may increase, and eventually, the area may become anoxic (Greene 2002, p. 12). Project plans acknowledge (USACE 2006, p. 91) that a change in bottom contour may be evident throughout the project life and post-construction populations may differ from pre-construction conditions. A change in the hydrologic regime as a consequence of altered bathymetry may result in the deposition or scour of fine sediments, which may result in a layer of sediment that differs from the existing substrate. Also, once material in the extraction site is removed, it is possible that different type of sediment layer will be exposed. The new type of sediment may not support the same biological community as the original surface layer. Some infilling from sedimentation and sloughing of bottom substrate from surrounding areas is expected. Some areas may never recover from these dredging events (Greene 2002, p. 12). However, plans state that recolonization of affected areas is expected within one to three years (USACE 2006, p. 104).

Offshore sediment removal may reduce primary productivity and impact the food chain. Cahoon and Cooke (1992) state that primary production data from Onslow Bay indicate that the sediment-water interface must be viewed as a dynamic part of continental shelf habitat. There is significant microalgal biomass and production concentrated in the surface layer of bottom sediment. Benthic microalgae may provide a dependable food source for both benthic deposit feeders and suspension feeders.

There may be a deterioration of nearshore habitat quality due to long-term turbidity from the artificial beach-dune system. Bush et al. (1996, p. 83) state that "streams of turbid water from the surf zone of Miami Beach are still responsible for killing coral heads 14 years after the beach was emplaced." Goldberg (1985) gives an example of a Florida beach construction project which resulted in damage to a nearby rocky environment 50 to 60 meters offshore. Material placed on the beach during a nourishment project quickly eroded off the beach and covered nearshore rocks. Seven years after the project, the rocks were still covered in fine sand and silt, and turbidity of the nearshore area remained high. Hurme and Pullen (1988) conclude that increased turbidity levels from winnowing of fine sediments in the fill can extend from a few months to seven years.

Long-term indirect impacts to beach invertebrates would occur if the proposed four-year reconstruction cycle was reduced over the 50 years of the project. While ghost crab populations might recover within one year of sand placement (USACE 2006, p. 102), a series of storms could necessitate more frequent sand placements, either by private funding or through FEMA disaster relief. After 50 years, beach reconstruction may need to be undertaken on almost an annual basis and this frequency of work would severely impact populations of ghost crabs and other beach invertebrates. Peterson et al. (2000, p. 376) state that long-term impacts on large beach invertebrates could arise from "persistent modifications of the physical environment, either of the topography or the sedimentology." Holding the beach at a fixed location as sea level rises can potentially produce higher wave heights onshore and the modified wave energy could have a lasting impact on beach biology (Peterson et al. 2000, p. 376)/

One indirect impact of an artificial berm and levee project is sediment starvation of the sound-side shoreline resulting from the inhibited overwash of the island during storms. Croft and Leonard (2001) state "coastal development, inlet stabilization, and post-storm bulldozing, disrupt the natural processes of marsh accretion by limiting sediment inputs." All three of these processes already occur on Topsail Island, where both New River and New Topsail Inlets are maintained with navigational dredging and beach bulldozing occurs regularly. Large-scale nourishment projects that construct and maintain an artificial beach and dune inhibit this natural process. This could result in the progressive narrowing of Topsail Island as water advances from both the ocean and sound sides.

A major indirect impact of maintaining the island at its present location as sea level rises is the gradual reduction in freshwater supplies available to plants and animals. In coastal areas, fresh groundwater is found as a lens, or perched water table, overlying salt water.

Freshwater in a perched water table generally extends 40 feet in depth for every one foot that the water table extends above sea level (Frankenberg 1995, p. 128). As sea level rises the capacity of the freshwater lens is reduced. While the human population could import water from the mainland as sea level rises, plants and animal would be adversely impacted as freshwater resources declined.

Furthermore, additional growth and population increases will put pressure on existing freshwater supplies. Rain is the only source for recharging island groundwater which flows downward and laterally under its own weight. This one-way flow of water prevents salt water from intruding into surface layers where high chlorine concentrations would kill terrestrial plants. Over pumping of groundwater in excess of recharge by precipitation can significantly lower the water table and eventually draw salt water inland. Changes in this groundwater level will be reflected in the extent and health of the freshwater communities. To the extent that new development leads to a lowering of the water table, freshwater wetlands would be adversely affected.

Overall, the most significant, long-term environmental impacts of beach construction will result from preventing Topsail Island from responding to sea level rise. Holding the island in place to protect existing structures is likely to threaten many biological communities which exist today in a natural relationship to sea level, but may not survive in deeper water.

Impacts to Federally Protected Species

Shortnose Sturgeon

Since this species has not been documented in the project area, the Corps determined that the proposed action is not likely to affect any of this species or its habitat (USACE 2006, p. I-16). We encourage the Corps to continue to coordinate with the National Marine Fisheries Service regarding potential project-related effects to this species.

Seabeach Amaranth

With regard to seabeach amaranth, the Service is primarily concerned about sediment placement on growing plants. The growing season of this annual plant can extend from April through September. The proposed civil works project would place sediment outside the growing season except for possible work during April of one year for initial construction. Furthermore, the Corps has surveyed Topsail Beach for the plant since 1992 (USACE 2006, p. I-16). Considering that the current project seeks to move a maximum of 1.5 million cubic yards of material, it is likely that the entire project can be completed outside the growing season of this species. Work outside the growing season and the ongoing survey are likely to result in a project which is not likely to adversely affect seabeach amaranth.

Sea Turtles

Since hawksbill, Kemp's ridley, and leatherback sea turtles do not regularly nest in North Carolina, the project should not significantly affect their nesting habitat. However, dredging activities may impact these species during periods of offshore and inshore migration (Epperly et al., 1995) depending on the time of year. Pipeline and hopper dredges will be used to dredge material from the designated borrow sites and transport it to the shore. Cutterhead pipeline dredges have not been known to take sea turtles; however, hopper dredges potentially pose the greatest risk to sea turtles through physical injury or death by entrainment. Hopper dredges move rapidly over the bottom sediments and can injure or kill juvenile turtles lying on the sea bottom. In order to minimize potential impacts, hopper dredges would be used only from 1 December to 31 March of any year when water temperatures are cooler, generally <14°C (57.2°F). However, because some sea turtle species may be found year-round in the offshore area, hopper dredging activities may occur during low levels of sea turtle migration. To reduce these impacts, the Corps plans to take certain precautions as prescribed by NMFS and USACE under standard hopper dredging protocol.

Most of the Topsail Beach has experienced severe shoreline recession due to inundation and exacerbated by frequent hurricanes passing over or near the area since 1996. In many locations the dune and beach berm have been washed away, and no sufficient nesting habitat is available. Since consistent turtle nesting surveys began on Topsail Island in 1990, there has been a gradual decline in the average numbers of nests laid per year (USACE 2006, Table I-2). Coupled with this decline, there has been an increase in nest relocations for those that are laid. For those nests that are relocated, they are moved higher up on the berm to different incubating environments; since it is not possible to move the eggs to a similar position between the high tide line and the toe of the dune.

While the proposed dredging schedule would occur outside the recognized sea turtle nesting and incubation period, the BA acknowledges that the imported sediment may alter the nesting environment on the beach. The BA concludes that the project may affect the all five marine sea turtles known to occur in the project area (USACE 2006, p. I-10, I-15).

Piping Plover

The direct impacts on piping plover nesting may be minor over the 50-year project life. Initial construction would occur November 16 through April 30. The 12 reconstruction events (from 2014 to 2058) would follow the accepted hopper dredging window of December 1 through March 31 (USACE 2006, p. 73). Since piping plovers head to their breeding grounds in late March and nesting occurs in late April, it is possible that both initial construction and reconstruction could impact breeding and nesting piping plovers. This potential impact will only be during the start of the breeding and nesting season and for a short period. However, all of the piping plover breeding and nesting activity documented since 1999 has occurred on the inlet spit and within the designated critical habitat area, areas which would not received sediment placements.

Wintering habitat of piping plovers for roosting and foraging may also be impacted (USACE 2006, p. I-20). Direct, short-term foraging habitat losses will occur during construction of the project fill. Since only a small portion of the foraging habitat is directly affected at any point in time during sediment placement and adjacent habitat is still available, the Corps concludes (USACE 2006, p. I-21) that the overall direct loss of foraging habitat will be minimal and short-term.

The BA notes (USACE 2006, p. I-20) that the current commercial, residential, and recreational development has decreased the amount of coastal habitat available for piping plovers to nest, roost, and feed. Furthermore, shoreline recession and the abundance of predators, such as feral cats, have further diminished the potential for successful nesting of this species. Since project beaches are wintering area for the piping plover, the major threat to its occupation of the area during the winter months would be continued degradation of beach foraging habitat. Similar degradation of beaches elsewhere could be a contributing element to declines in the state's nesting population.

However, the BA does not fully consider potential adverse impacts on piping plover foraging habitat over the 50 year project life. If the proposed reconstruction interval of four years becomes shorter over time, there would less recovery of beach invertebrates, a food source for piping plovers and other shorebirds. If the reconstruction interval after 40 years is reduced to only two years, beach invertebrate populations could decline dramatically and greatly diminish the habitat value for piping plovers and other migratory shorebirds.

West Indian Manatee

Manatees are only seasonal transients in North Carolina waters. However, dredges and pipelines used in beach construction have the potential to harm this species if work is done during the warmer months of the year, primarily June through October. The Draft GRR/EIS considers (USACE 2006, p. I-7) impacts to estuarine and nearshore ocean habitats to be minor. The effect of these impacts on the value of the area to the manatee is unknown. With the current state of knowledge on the habitat requirements for the manatee in North Carolina, it is difficult to determine the magnitude of such impacts.

SECTION 11 - COMPARISON OF IMPACTS

The Draft GRR/EIS compares the impacts of three, broad courses of action (Section 5.02, pp. 51-52). These are no action, non-structural measures, and structural measures (beachfill, seawalls, bulkheads, breakwaters, and groins). A comparison of these broad categories is given in Table 5.3 (pp. 59-62). From the perspective of fish and wildlife resources, the most relevant categories are marine resources, natural communities, threatened and endangered species, and water quality.

In general the no action alternative would maintain the status quo of these major resource areas. There is one major exception in that a course of no action is expected to result in the continued deterioration of the existing beach (USACE 2006, p. 59). This is not entirely certain since the extent to which the beach would continue to recede is dependent on the non-federal attempts to control shoreline recession. In the near future these efforts are likely to involve beach construction, but as costs rise and the interval for reconstruction decrease, hard structures (groins, jetties, and rock revetments) may be employed in an attempt to reduce costs. In this scenario, the beach would deteriorate and fish and wildlife resources would be harmed. The existing beach would continue to be squeezed between the structures and rising ocean waters. The beach would eventually cease to exist. On the other hand, these efforts may prove ineffective. The economic value of the recreational beach could be recognized as greater than that of ocean front structures. In this case, a program of gradually withdrawal could be coordinated by state and local governments. The island would be allowed to gradually move inland. The natural beach would be maintained and habitats would be preserved for fish and wildlife resources.

While the ultimate fate of project area beaches will be decided in the coming decades, existing structures near the ocean are clearly in danger and some action is required to prevent their periodic destruction. Table 1 presents a simplified comparison of the direct environmental impacts of beach construction and the non-structural approaches. The Service acknowledges that these yes-no dichotomies simplify very complex impacts and do not address the socioeconomic issues such as maintaining ocean front structures at their present location. This table indicates that all of the ten environmental impacts considered would occur with beach construction, but none with the non-structural approaches.

The Draft GRR/EIS contains some of the same information as Table 1. Table 5.3 notes (USACE 2006, p. 59-62) that beach construction "temporarily" impacts beach invertebrates while the non-structural approaches eliminates periodic losses of these organisms along the beach. Beach construction creates "temporary" impacts to adult, larval, and juvenile fish due to turbidity and reduced benthic food in dredging and disposal areas while the non-structural alternative maintains the status quo. Beach construction may reduce sea turtle nesting success by increasing beach hardness and altering other beach physical characteristics while the non-structural approach would maintain the status quo.

Table 2 compares the indirect impacts of the two options. Among the ten, potential long-term impacts considered, all are possible with the 50-year beach construction alternative, but none are considered likely with the non-structural approach. Again, the GRR/EIS contains some of the same information as Table 2. Beach construction would modify bottom substrate and bathymetry along 4,210 acres (6.58 square miles) of nearshore ocean while the non-structural approach would maintain the status quo.

Table 5.3 of the Draft GRR/EIS contains conflicting information on the future condition of the beach with the beach construction and non-structural alternatives. In the consideration of socioeconomic and recreational/aesthetic resources, the table notes that a non-structural approach would create a more remote, undisturbed beach and the existing

Table 1. Comparison of direct project impacts for the West Onslow Beach and New River Inlet (Topsail Beach) Project, Pender County, North Carolina, among the preferred alternative (an artificial beach-dune system) and a combination of building restrictions, zoning regulations, selective removal, and improved construction standards.

	Major options for storm damage reduction	
Direct Impact	Construction of Artificial Beach-Dune System	Combination of Building Restrictions, Zoning, Selective Relocation, and Improved Construction Standards
Eliminate offshore benthic community	yes	no
Create offshore turbidity	yes	no
Create offshore sedimentation	yes	no
Disrupt fish in offshore wintering areas	yes	no
Create nearshore turbidity from beach	yes	no
Create sedimentation as beach material washes off	yes	no
Kill beach invertebrates	yes	no
Reduce sea turtle nesting success	yes	no
Disturb piping plovers and other shorebirds on beach	yes	no
Disturb marine mammals offshore	yes	no

Table 2. Comparison of indirect project impacts for the West Onslow Beach and New River Inlet (Topsail Beach) Project, Pender County, North Carolina, among the preferred alternative (an artificial beach-dune system) and a combination of building restrictions, zoning regulations, selective removal, and improved construction standards.

	Major options for storm damage reduction	
Indirect Impact	Construction of Artificial Beach-Dune System	Combination of Building Restrictions, Zoning, Selective Relocation, and Improved Construction Standards
Alter ocean bottom characteristics at offshore sediment extraction sites	yes	no
Reduce productivity of offshore hardbottoms through turbidity and sedimentation	yes	no
Reduce productivity of nearshore hardbottoms through turbidity and sedimentation from the beach	yes	no
Reduce invertebrate populations on beach by periodic sediment placements	yes	no
Create greater demand for more shoreline recession control by producing a steeper beach profile that influences erosion	yes	no
Increase development that threatens upland, estuarine habitats, and water quality	yes	no
Create long-term reduction in sea turtles reproduction by altering beach characteristics and beach lighting	yes	no

recreational capacity of the beach would be maintained (USACE 2006, p. 59). However, in considering natural communities, the comparison states that the beach would continue to erode with a non-structural alternative (USACE 2006, p. 60). A non-structural approach is considered to be an alternative that "does not prevent beach erosion" (USACE 2006, p. 54). However, as noted for the no action alternative, most discussion of alternative to beach construction fail to consider that the recreational beach is not lost, but simply pushed landward by a combination of rising sea level and periodic storms. Ultimately this issue would depend on the extent of non-federal measures to armor the receding shoreline. However, the application of non-structural measures, primarily a phased withdrawal of fixed structures, at all level of government would maintain a wide, natural recreational beach by allowing the island to adapt to sea level rise by moving inland.

Overall, the non-structural approach produces fewer adverse environmental impacts than a program to maintain the beach at its present location by massive placement of offshore sediment. While the environmental benefits of allowing natural island movement produce economic benefits, such benefits are hard to quantify. On the other hand, the costs associated with retreat, relocation, and demolition can be estimated precisely (USACE 2006, Appendix P). Project planning has also not considered the broad economic benefits to southeastern North Carolina of creating a natural recreational area on Topsail Island. A full consideration of such economic benefits might not support the current finding that the non-structural plan is "not economically feasible" USACE 2006, p. 54).

There are advantages to the strategy of relocating buildings away from the shoreline. Bush et al. (1996, p. 101) summarized these as:

1. Removes threats to buildings
2. Allows natural shoreline processes to continue;
3. Preserves the beach; and,
4. Good possibility of one-time-only cost.

These authors also note that relocation is a viable coastal management tool and does not need to be considered only for single-family houses. In the final analysis, if any structure is moved back from the shoreline, the potential for storm damage reduction has been achieved.

Perhaps the greatest issues in comparing beach construction and the various non-structural approaches are the broad ramifications of holding the barrier island in place as sea level rises. Attempting to prevent the natural adjustment of Topsail Island will adversely impact all natural communities on and around the island.

SECTION 12 - FISH AND WILDLIFE CONSERVATION MEASURES

Fish and wildlife conservation measures, as specified in the FWCA, consist of "...means and measures that should be adopted to prevent the loss of or damage to such wildlife resources (mitigation), as well as to provide concurrently for the development and improvement of such resources (enhancement)." Mitigation, as defined by the Council on Environmental Quality and adopted by the Service in its Mitigation Policy, includes:

1. Avoiding the impact altogether by not taking a certain action or parts of an action;
2. Minimizing impacts by limiting the degree or magnitude of the action and its implementation;
3. Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
4. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and,
5. Compensating for the impact by replacing or providing substitute resources or environments.

These five actions should be viewed as the proper sequence for formulating conservation measures.

Enhancement measures are those which result in a net increase in resource values under the with-project condition compared to the without-project condition. For any given type, kind, or category of resource being evaluated, there must be compensation (i.e., full replacement) for all project-associated losses before any enhancement of that given resource can occur.

General Conservation Measures for Planning Federal Action

Clarification of Federal Objective

The first goal of the federal project is to reduce the adverse economic and environmental effects of hurricanes and other storms at Topsail Beach (USACE 2006, p. 49). The Service supports the goal of reducing damage to man-made structures on the barrier island. Barrier islands, the offshore ocean, and the estuarine sounds are valuable fish and wildlife habitat. These habitats have been heavily impacted in recent decades and the trend of greater human impacts appears likely to continue. Therefore, it is imperative that careful planning seek to achieve the stated project goals with minimal environmental impacts.

However, a non-structural approach does not appear consistent with the goals of the Town. The main public concerns of the Town are economic losses resulting from: (1)

damages to structures and their contents due to hurricane and storm activity, and (2) the loss of beachfront land due to progressive shoreline erosion (USACE 2006, p. 41). The Locally Preferred Plan (LPP) for federal action would preserve the tax base and property values (USACE 2006, p. B-47). The needs of the Town indicate a desire to maintain existing beachfront structures at their current location.

The need for federal action should clearly demonstrate that the goals of the non-federal sponsor are consistent with federal authorities, policies, and guidelines. Federal objectives may center on reducing the need to periodically rebuilt structures and infrastructure destroyed by storms. After a declared disaster, some rebuilding costs may be paid by the Federal Emergency Management Agency (FEMA). Since the Town is eligible for Federal Flood Insurance, funds from this program would be available to policy holders. However, these federal expenditures would not be required if the island was undeveloped, a condition which would meet federal objectives of reducing federal expenditures resulting from damage to man-made structures.

The federal role for preventing damage due to gradual shoreline inundation is less clear. While the encroachment of the ocean on existing structures is most dramatic during storms, shoreline recession is totally independent of storms and occurs continuously without any major storm activity. Any federal objective to replace private land loss to long-term shoreline recession should be clarified. An objective limited to reducing, direct storm damage could be addressed by the non-structural alternatives (retreat, relocation, and demolition) outlined in Appendix P of the Draft GRR/EIS. The twin objectives of the Town could not be met by a non-structural approach. A need to replace portions of platted lots due to the offshore movement of sand and simple inundation by the rising ocean could not be met by the non-structural alternatives. For the Town, a federally maintained berm and dune would be both a means to an end (block storm waves) and an end in itself (replace private land). A clear statement of the federal need for action would indicate whether any non-structural alternatives should be considered.

Greater Consideration of Most Recent Data on Projected Sea Level Rise

In light of the danger posed by rising sea level which will increase throughout the life of the 50-year project, an assessment of global sea level rise based on the best scientific data available would serve as a conservation measure. Such an assessment is likely to indicate that an artificial beach will become more difficult to maintain over time. The high cost of maintaining the artificial beach may provide support for reconsidering the economics of non-structural approaches to reducing damage to existing structures.

A thorough consideration of future sea level rise is one of the most important conservation measures associated with project planning. If Topsail Island is held in place as the sea rises, many important natural communities will become imperiled. Without island overwash to nourish salt marshes in the sound, the area occupied by this community would diminish as the water rises. Upland communities may become imperiled as natural sources of freshwater are lost to salt water intrusion. The habitat value of the beaches is likely to diminish as the reconstruction period is reduced over the decades. The Draft GRR/EIS states (USACE 2006, p. I-20) that the loss and degradation of habitat due to development and shoreline stabilization have been major contributors to the decline of piping plovers. If the proposed four-year reconstruction cycle is maintained, the continuation of forces pushing the island landward would result in greater use of beach bulldozing. The use of sandbags, which is actually a form of hard seawall, would increase.

Clarification of Compliance Requirements with Executive Order 11988

An additional factor in the consideration of non-structural alternatives should be Executive Order 11988 (Floodplain Management). The Draft GRR/EIS states (USACE 2006, p. 119) that the selected plan is in compliance with EO 11988 which was enacted to avoid, to the extent possible, the long and short term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative. Draft GRR/EIS acknowledges that the placement of beachfill would occur in the floodplain of area beaches (USACE 2006, p. 118). Pilkey et al. (1998, p. 171-172) state that most of Topsail Island lies on the 100-year floodplain and that the island would be almost completely submerged in a Category 3 hurricane. The area is subject to high velocity waters (including, but not limited to, hurricane wave wash) in a storm having a one percent chance of being equaled or exceeded in any given year (USACE 2006, p. 122).

In addition to sea level rise, there is observational evidence for an increase of intense tropical cyclone (hurricanes) activity in the North Atlantic since about 1970 (IPCC 2007). This increase is correlated with increases of tropical sea surface temperatures. However, there is no clear trend in the annual number of tropical cyclones. Based on a range of models, it is likely that future tropical cyclones will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperature (IPCC 2007).

The Economic Analysis states (USACE 2006, p. B-46) that "implementation of effective damage reduction measures will ensure that current growth trends in population and recreational visitation will continue." The beach construction program "may induce additional development within the floodplain" (USACE 2006, p. 119). However, a non-structural alternative is expected to result in a reduction in tax base (USACE 2006, p. 59). The preferred alternative is expected to reduce, but not entirely eliminate, damages due to short-term erosion, inundation, and wave overwash during storms (USACE 2006, p. 76). The preferred alternative does not provide protection from storm tide flooding coming from the sound side of Topsail Island (USACE 2006, p. 77). Considered together, the Draft GRR/EIS indicates that the selected plan, a 50-year program of beach construction, contributes to the growth potential of the community. This growth would occur within the 100-year floodplain and remain unprotected from flood waters pushed from the sound. The issue with regard to EO 11988 is whether such growth poses a significant threat to human life, health, and property.

Even with a constructed beach, the threat to existing development would be significant if two or more hurricanes occur over a short time period, such as occurred in 1996. During a two-moth period in 1996, the first storm (Bertha, July 12-13, 1996) washed away the dune, left the island completely unprotected, and allowed the 115-mile per hours winds of the second hurricane, Fran (September 5-6, 1996), to produce "complete devastation" (Pilkey et al. 1998, p. 171). Barnes (1998, pp. 177-178) states that a "large portion of the dunes between Figure Eight Island [south of Topsail Island] and Emerald Isle [north of Topsail Island] had been washed away by Bertha, setting the stage for extensive beach erosion and ocean overwash during Fran." There should be additional justification of determination that the selected plan is not supporting floodplain development which would continue to be at risk from a number of factors. By the time Fran moved inland, two-thirds of the ocean front houses on Topsail Island were either dumped in surf, floating in the inland waterway, lying in ruin in the road, or simply gone (Dean 1999, p. 194). The island's water, sewer, and electric power infrastructure had been wrecked. Federal and other aid flowed in for more than a year as homeowners rebuilt and workers removed ton after ton of debris from the fragile marsh behind the island (Dean 1999, p. 194). Over the 50 years of the proposed project, years with back-to-back hurricanes are likely to occur.

With regard to the wisdom of development within the floodplain, there should also be a consideration of wind damage. News reports in the aftermath of Hurricane Karina indicate that many homeowners believed that their homes were destroyed by hurricane force winds before they were inundated by the large storm surge. The potential for wind damage could be assessed by considering private insurance rates within the project area. Stable rates for wind insurance would indicate a perception by private insurers that the area is relatively safe and that development does not represent unwise development.

With regard to EO 11988, the Draft GRR/EIS states (USACE 2006, p. 119) that while the preferred alternative may induce additional development within the floodplain, the project "is not expected to significantly increase the effect on the floodplain." It is not exactly clear what effects are being considered. The statement may refer to adverse impacts on the natural communities on the island. While EO 11988 seeks to restore and preserve the natural values of floodplains, the avoidance of adverse impacts to the natural communities within a floodplain is only one of several goals of the EO and should not form the sole basis for establishing compliance with EO 11988.

Planning documents should clearly state the extent to which the Corps, part of the executive branch of the federal government, can choose the alternative for damage reduction. As noted, a previous House [of Representatives] Document has authorized a plan consisting of a dune and beach fill over a total of 18,900 feet (USACE 2006, p. 7). The EO does not apply to actions of the federal legislative branch such as the U. S. House of Representatives. If the structural approach represents federal law or a lawful mandate from the legislative branch, then the Corps' obligations under EO 11988 have been nullified since the course of action was dictated by Congress.

If, however, the Corps has a broad mandate to reduce storm damage and protect human lives in the project area, then there should be a consideration of whether development on the low lying and flood-prone barrier island represents wise use of this floodplain. As noted by Frankenberg (1997, p. 171) the military abandoned its missile testing operations on Topsail Island because storms and hurricanes repeatedly destroyed buildings and equipment. It is only a matter of time before a storm similar to Hurricane Hazel (1954) strikes. That storm destroyed 210 of the 230 houses at what was then the community of New Topsail Beach (Barnes 1998, p. 100). Past history and the likelihood of more intense storms should be considered in the Corps' compliance with EO 11988.

In determining whether a given course of federal action would comply with EO 11988 there should be a consideration of conditions at the northern end of the island which is within the Coastal Barrier Resource System (CBRS). The CBRS was established by the Coastal Barrier Resources Act (CBRA) of 1982. In the legislation Congress declared (16 U.S.C. § 3501(a)(3)) that "coastal barriers serve as natural storm protective barriers and are generally unsuitable for development because they are vulnerable to hurricanes and other storm damage and because natural shoreline recession and the movement of unstable sediments undermine manmade structures." Furthermore, "certain actions and programs of the Federal government have subsidized and permitted development on coastal barriers and the result has been the loss of barrier resources, threats to human life, health, and property, and the expenditure of millions of tax dollars each year" (16 U.S.C. § 3501(a)(4)).

The CBRA seeks to minimize the loss of human life, wasteful federal expenditures, and damage to fish, wildlife, and other natural resources associated with coastal barriers. The areas placed within the CBRS included "undeveloped coastal barriers." More than seven miles at the northern end of Topsail Island are included within the CBRS. Therefore, Congress has determined that development within certain areas at the northern end of the island pose a risk to human life, the potential for requiring wasteful federal expenditures. The project area for this federal action was excluded from the CBRS due to the level of existing development at the time the CBRS was enacted. It was correctly determined that it would be unfair to retroactively deny federal assistance, including federal flood insurance, to property owners at the southern end of the island. The exclusion of the southern part of Topsail Island was based on the level of existing development, not on any determination that there was less risk to human life or the potential for wasteful federal expenditures.

Compliance with EO 11988 requires a consideration of whether the Topsail Beach project area shares the same characteristics as the CBRS area at the north end of the island. If the project area does have the same level of risk as the northern part of the island, does the proposed 50 years of beach construction which seeks to preserve development comply with the intent of EO 11988? The Service is not suggesting in any way that the restrictions on federal funding applicable to areas within the CBRS be applied to areas outside the system. We are suggesting that the conditions which led to the inclusion of northern Topsail Island in the CBRS be considered for the southern end of the island in the context of EO 11988. That is to say, since Congress has declared that federal expenditures for development on the northern part of the island (within the designated CBRA Unit) could contribute to the loss of human life, wasteful federal expenditures, and damage to fish, wildlife, and other natural resources, then contributing to additional development at the southern end of the same island (roughly 15 miles from the CBRS Unit) may represent support for the "unwise use" of a floodplain.

Unless a storm damage structure is created to provide protection against storms such as Hazel and Fran, the area will continue to repeat the cycle of destruction and rebuilding. The question to be answered in regard to EO 11988 is whether such repeated destruction and rebuilding represents unwise floodplain development which should not be supported by actions of the executive branch. Whether state and local funds would be periodically provided to construct the beach is not the issue, the issue is whether action by the Corps, as part of the executive branch of the federal government, maintain existing development and support additional development in an inherently dangerous location.

Greater Consideration of the Economic Value of Natural Resources on an Undisturbed Barrier Island

As noted in Section 11 (Comparison of Impacts) a combination of non-structural approaches would produce less adverse impacts on fish and wildlife resources. These approaches would also reduce damage to structures in the project area. Over the long term, these approaches would remove or relocate the structures to areas not subject to direct storm damage or inundation. Therefore, the implementation of non-structural measures would be a significant conservation measure.

A major conservation measure regarding the evaluation of alternatives is a greater consideration of the economic values associated with the more natural setting that would occur as structures are relocated. The non-structural measure would produce a more remote, undisturbed beach (USACE 2006, p. 59). As this report has discussed, the adoption of non-structural measures at all levels of government would not lead to continued loss of land, but would allow the island to gradually move landward while preserving a wide, natural beach.

Specific Conservation Measures for 50 Years of Beach and Dune Construction

The Draft GRR/EIS has selected a 50-year program of beach and dune construction. There are several design features and construction techniques that would reduce the adverse environmental impacts of this program.

Use of Sediment Compatibility with the Native Beach

The physical characteristics of the fill material used for beach construction have a significant influence on the impacts of the work. The fill should closely match the characteristics of the native beach. The summary data presented in Table E-15 (USACE 2006, p. E-29) indicates that the grain size and shell content of the offshore borrow areas are similar to those of the native beach. However, these data are based on selective samples and large area of silt and mud could be interspersed within otherwise compatible sand.

A major change in sediment characteristics could adversely impact migratory shorebirds. Many shorebird species actively feed in the intertidal zone and may be adversely affected by nourishment operations (NRC 1995, p. 110). A large number of avian species use ocean beaches and dunes for feeding, overwintering, and/or breeding (Greene 2002, p. 31). If the constructed beach is too coarse or high in shell content, birds may not be able to extract food particle from the substrate (Greene 2002, p. 35).

Beach construction should require the highest degree of sediment compatibility. The North Carolina Sediment Criteria Rule, contained in the Technical Standards for Beach Fill Projects (15A NCAC 07H .0312), provides beneficial guidelines for both grain size and percent weigh of calcium carbonate. However, other important characteristics such as organic content, heavy mineral content, and color are not addressed.

The color of material imported for beach construction should be evaluated by an objective criterion, such as the Munsell Soil Color Chart, and compared with sediment outside recent placement areas or a nearby beach which represents the historic beach color. Hutaff Island, south of the project area, may be appropriate as a baseline for beach sediment color. There should be a quantifiable measure of sediment color and an objective criterion for rejecting mined material which deviates from historic beach sand coloration. The standard for existing beach sediment should not include areas which have received recent sand placements. Color evaluations on the beach should extend beyond the upper few inches which may be bleached by sunlight or covered by lighter, windblown sand. If post placement data indicate that material from a given extraction site produces a detectable change in the color of the constructed beach, the extraction site should be eliminated as a source of construction material.

Monitor Material Used for Beach Construction

Since the nature of the borrow material can not be described with any defined level of confidence or certainty, contingency plans must be made in the event the dredging operation encounters mud, silt or shell hash to avoid the placement of these materials on the beach. The Draft GRR/EIS states (USACE 2006, p. 74) that while though borrow area characterization and utilization will be refined during the plans and specifications stage, a degree of uncertainty and interpolation may still exist between boring locations during construction. As the dredge excavates the borrow area during beach nourishment operations, there may be some instances where the material discharged onto the beach from the dredge pipeline may appear to be incompatible for beachfill. Grain size characterization and distribution measurements of material sampled directly from the discharge pipe or from material placed a day earlier are biased and do not yield an accurate prediction of the final outcome of beach grain size distribution. The dredge will have proceeded to new locations by the time the unbiased measurements of the stabilized beachfill material can be made. Therefore, a precise correlation between dredging location within a borrow area and site-specific beachfill material coming out of the pipe cannot be made with any accuracy. Considering the difficulties of assessing real time grain size distributions and compatibility, grain size analyses of the dredged material will not be conducted during construction of the project.

Service comments of May 2005 recommended (USACE 2006, p. 129) the development of contingency plans to quickly halt the dredging operation if incompatible material is encountered. While sediment disposal does not lend itself to real time grain size distribution measurements, some quantitative and qualitative assessments of the operation can still be made. Qualitative visual characterizations of the in-place material will be made by representatives of the Corps' construction and environmental offices throughout the project construction (USACE 2006, p. 74). A qualitative and quantitative assessment can be made to determine whether the volume of potentially inconsistent material is significant relative to the overall project. Results from these calculations will be used by appropriate Corps personnel to determine whether dredging should continue at the dredge's present location.

The response to the Service's recommendation notes (USACE, p. 129) that the Corps is currently developing a contingency plan in the event that incompatible material is encountered during nourishment events. Federal and state environmental agencies would be notified if potentially incompatible is encountered. If incompatible material is encountered, the Corps would determine a suitable contingency measure which may include moving the dredge to another site within the borrow area or to another borrow area. A contingency borrow area (borrow area C) containing approximately 2.5 million cy of material has been identified to function as a secondary source of sediment throughout the 50 years of the project if unsuitable material is encountered and relocation of the dredge to more suitable borrow areas is required. If rigorously applied these measures provide some level of protection against large quantities of mud, silt, or large shell fragments being placed on the beach.

If large areas of incompatible material are placed on the beach, there should be a plan for removing such material. There should be a specified procedure for inspecting the placement site to evaluate whether the material meets the compatibility requirements. If the material does not meet the minimum standards, it should be removed prior to the start of the next sea turtle nesting season.

Schedule Work during Period of Least Biological Activity

The schedule of work is a significant conservation measure that can greatly reduce adverse impacts to species by avoiding sensitive periods in the annual life cycle of a species. The major beach invertebrates, *Donax* spp. and *Emerita talpoida*, reach larval abundance in the summer and are presumed to migrate offshore with the movement of sand during the winter (Greene 2002, p. 25). If these species can avoid direct mortality during sand placement during the winter by migrating to nearshore waters, they can initiate recovery through migration and reproduction at the end of the project. Therefore, sediment placement when these organisms are not on the beach would benefit the viability of these populations. If beach construction occurs during the winter, the work should end before April or May when *Donax* and *Emerita* return to the intertidal beach (Peterson et al. 2000, p. 376). In another report, Peterson and Wells (2000, p. 11) stated that the ecological damage of beach construction on Bogue Banks could be minimized by sediment placement during the winter (December-March) when "these invertebrates are largely absent."

Shorebirds may be displaced by dredges, pipelines and other equipment along the beach and may avoid foraging along the shore if disturbed by construction noise (Greene 2002 and references therein, p. 31). The duration of work should be reduced to the greatest extent possible to avoid adverse impacts during the spring nesting season.

The Service recommends that in order to minimize adverse impacts to the important resource represented by the intertidal-to-shallow-subtidal invertebrate community, every effort should be made to complete all beach work, both actual placement and shaping, by the end of March. The 50-year, federal project for Topsail Beach plans work in April only during initial construction and all subsequent beach replacements by hopper dredge are planned for the period of December 1 through March 31 (USACE 2006, p. 72). A single occurrence of disposal during April over a 50-year period would not be expected to produce long-term adverse impacts.

Protect Offshore Hardbottoms

To protect offshore hardbottoms a sufficient buffer should be required between the dredging operation and hardbottoms. State law specifies (15A NCAC 07H. 0208(b)(12)(A)(iv)) that mining of submerged land should not be conducted on or within 500 meters (1,640 feet) of significant biological communities, such as high relief hardbottom areas. High relief is defined in the statute as vertical relief greater than one-half meter (approximately 20 inches) per five meters (approximately 16.4 feet) of horizontal distance. While high relief may enhance the habitat of hardbottom, similar areas without such pronounced relief provide valuable habitat.

The Draft GRR/EIS presents a good description of hardbottoms and their ecological value (USACE, 2006, pp. 19-21). Project plans now indicate that dredging would not occur at offshore hardbottom sites (USACE, 2006, p. 95), but there is an acknowledgement that sediment plumes from the overflow of hopper dredges have the potential to adversely affect nearby hardbottoms (USACE, 2006, pp. 95-97). There are, however, three mitigating factors (USACE, 2006, p. 97) including information that the proposed dredge sites are at least 2,000 feet from the nearest known offshore hardbottom area.

Project plans should include adequate measures to protect the valuable habitat of offshore hardbottoms which may be adversely impact by turbidity and sedimentation produced by dredging for sediment extraction. Such measures would include strict adherence to the buffer requirement required by state law.

Protect Nearshore Hardbottoms

All feasible measures should be employed to prevent adverse impacts to nearshore hardbottoms. While the use of material with low silt and clay content would benefit these communities, some sources of material may contain pockets of silt and clay in an area determined to be primarily sand. Thus long-term beach construction along Topsail Island has the potential to affect sensitive hardbottoms and introduce a different sediment composition (quartz sand as opposed to carbonate, silty or rock fragmented material) to the nearshore system.

Project planning should establish a program to monitor the location, areal extent, and major organisms of nearshore hardbottoms prior to initial construction. These areas should be survey after initial construction to determine an adverse sedimentation and change in the biological community. The program should include recent data from side-scan and/or multi-beam surveys and a discussion of closure depth. If it appear likely that nearshore hardbottoms could be covered by sediment moving off the constructed beach, it may be necessary to have a monitoring program to detect an overall loss of exposed hardbottoms and a consideration of mitigation measures. Mitigation measures could include a reduction in the amount of beach fill near vulnerable hardbottoms.

Avoid Adverse Impacts in Pipeline Placement

The pipeline used to move the sediment-water slurry has the potential to adversely affect migratory shorebirds and beach invertebrates. Material for initial project construction and beach nourishment will be dredged by pipeline dredge and hopper dredge from the offshore borrow areas, then moved by pipeline to the beach. The pipeline will be routed along the ocean shoreline, where it will be placed either below Mean High Water or within the acquired Perpetual Beach Storm Damage Reduction Easements (USACE, 2006, p. 75). During both initial construction and reconstruction events, the delivery pipeline will be placed to avoid the piping plover habitat areas along the south end of the beach (USACE 2006, p. 68). Pipelines placed on the ocean floor would have adverse impacts on any benthic organisms covered by the pipeline (USACE 2006, p. 90). During both hopper and pipeline dredging, identified live hardbottom communities will be avoided (offshore pipeline routes will be developed to avoid live hardbottom) and no direct impacts are anticipated (USACE 2006, p. 95). The Service supports these conservation measures. However, there should be a plan to monitor pipelines for leaks and an established plan of action in the case a joint in the dredge pipe should break. This plan should describe measures to contain and clean the spill.

Protect Beach Invertebrates

There may be some adverse impacts to the intertidal-to-shallow subtidal invertebrate community which can not be mitigated by compatible sediment and work season restrictions. Peterson et al. (2006, p. 215) notes that every case of significantly lower mean abundance of a macroinfaunal taxon on filled beaches was comprised of contributions from: (1) reductions in both habitat area; and, (2) organism density per unit area. While the density reduction was the greater contributor, the loss of occupied habitat area average 14-29% less at filled locations than at control beaches. This reduction in foraging habitat is one of three plausible explanations for the "greatly depressed use of filled beaches" by shorebirds (Peterson et al. 2006, p. 219). If a constructed beach does have a steeper profile, the new intertidal zone may be reduced compared to the more gentle slope of a beach allowed to adjust naturally to a higher sea level.

In May 2005 the Service recommended that funding be directed toward developing procedures to better understand mole crab and coquina clam life history requirements and developing effective measures to mitigate adverse impacts to these important resources. The NCWRC, NC Audubon Society, the North Carolina Coast Federation, NOAA Fisheries, and the Service should be actively engaged in the planning process.

The Corps responded (USACE 2006, p. 130) that several Corps contracts addressing beach nourishment impacts to benthic invertebrate populations have recently been completed or are ongoing throughout the North Carolina beaches including Bogue Banks, Brunswick Beaches, and Dare County. The data that has come back from these studies continue to support the large historical database, which indicates an initial impact to the benthic invertebrate resource with recovery occurring immediately after nourishment when the sediment is compatible with the native beach. Furthermore, the Dare County Beaches shore protection project has a significant monitoring plan, which includes a pre- and post-construction benthic invertebrate assessment. In light of the past and ongoing work, the Corps does not plan to collect additional monitoring data for Topsail Beach. However, the Corps is encouraged by the Services recommendation to develop procedures to better understand benthic invertebrate life history requirements and the relationship these requirements have to beach activities, instead of additional monitoring studies.

As a conservation measure for this important community, the Corps should continue to monitor the recovery of intertidal and near shore invertebrate populations. Data from these studies will be especially important if the reconstruction interval is reduced as sea level continues to rise. While the Corps notes (USACE 2006, p. 130) that benthic populations may recovery within one to four years after large-scale sediment placement, a gradual reduction of the reconstruction interval could preclude adequate recovery and threaten these organisms which form an important base to the coastal food chain.

Conservation Measures for Federally Protected Species

All federally listed species would benefit, to varying degrees, by constructing the beach and dune with material that is highly compatible with the physical characteristics of the historic beach. These physical characteristics include sand grain size, density, shear resistance, color, heavy mineral content, and moisture content.

Seabeach amaranth

With regard to seabeach amaranth, the Service is primarily concerned about sediment placement on growing plants. The growing season of this annual plant can extend from April through September. The proposed project would place sediment outside the growing season except for possible work during April of one year for initial construction.

In May 2005 the Service recommended continued monitoring of seabeach amaranth and beach vitex (*Vitex rotundifolia).* Beach vitex is a deciduous, woody vine from Japan and Korea that was introduced to the southeastern U.S. in the mid-1980s as an ornamental landscape plant as well as for sand dune stabilization. Along the coast of North and South Carolina, beach vitex has escaped cultivation and covered oceanfront dunes. Beach vitex crowds out native dune plants such as sea oats, American beach grass and seaside panicum. In addition, beach vitex threatens endangered loggerhead sea turtle nesting habitat as well as habitat for a federally threatened plant, seabeach amaranth and other rare species

The Service normally recommends surveys for seabeach amaranth both before and for three years after sediment placement in order to avoid direct burial and to monitor recovery of the plant. With the proposed four-year reconstruction cycle, survey for this endangered plant would be made every year. Overall, with actual disposal outside the growing season and the ongoing survey, the proposed project is not likely to adversely affect seabeach amaranth.

The Corps responded (USACE 2006, p. 131) that surveys for seabeach amaranth have been made at Topsail Beach since 1992 (USACE 2006, p. I-16). The Corps will consider providing funds to continue monitoring for seabeach amaranth and add to this existing database. The Corps has worked with the Service in the past to build this database and will continue to work together to derive management guidelines from this data that help minimize impacts to seabeach amaranth during beach nourishment projects. The Service reiterates our recommendation that survey for this threatened plant be continued throughout the life of this beach construction effort.

The Corps also expressed an understanding that beach vitex is a growing threat to the native species of the dune community. The Corps will work with the Service and the other agencies participating on the beach vitex project delivery team to gather and share information on beach vitex density and location throughout the survey area of our study sites.

Sea Turtles

Since project area beaches represent reproductive habitat for at least two species of sea turtles, every effort should be made to ensure that the constructed beach continue to support such reproduction. Greene states (2002, p. 30) that beach construction poses a "serious threat to sea turtles if proper conditions are not met." The BA states (USACE 2006, p. I-14) that the Corps plan includes measures to protect sea turtle nesting that "are now common practices or commonly listed conditions on permits . . . such as contingency plans, sediment quality monitoring, compaction tests, tilling, leveling scarps, and monitoring for nests." The Service strongly supports these measures.

With regard to sediment quality, the color and organic content of beach sediments can modify nest temperatures and the nutrient environment, which can result in an altered sex ratio of the sea turtle hatchlings. In addition, sediments that differ from those of the native beach can result in beach compaction which may increase false crawls, increase nest digging time, hinder gas exchange within incubating nests, alter the hydric environment of the nest, and result in broken eggs from clutches deposited in an egg chamber which is too shallow.

Certain conditions may adversely affect sea turtle nesting and incubation for several seasons after the actual work. Therefore, in addition to a general evaluation of compatibility, three specific aspects of the post-placement area should be evaluated. These factors are: (1) sediment compaction; (2) escarpment formation; and, (3) altered sand temperature which may occur as a result of a change in sediment color.

Incompatible material may also lead to harder, or compacted, beaches which cause females to abandon nest construction. Greene (2002, p. 30) cites studies which indicate that constructed beaches may not become suitable for sea turtle nesting until several years after project completion.

As a conservation measure for this potential impact, the Service recommends that compaction monitoring should occur after each construction event and for three subsequent years. Considering that reconstruction is scheduled for every four years between 2010 and 2058, a sediment compaction survey should be made each year of the project. However, compaction monitoring would not be required if the sediment used to construct the beach is completely washed away.

After each construction event monitoring should not begin until the material has been graded and dressed to the final slope. A period of time should be allowed for finer particles to be washed away and final settling of the material to occur prior to compaction monitoring. Normally compaction data should be collected prior to April 1 in order to allow any required remedial action to be completed prior to May 1, the start of the sea turtle nesting season. This schedule can be used for all the periodic reconstruction events which are scheduled to end by March 31. For initial construction, which will extent to April 30, it will be necessary to conduct compaction monitoring in stages. The overall beach can be divided into sections and monitored separately. If the earlier sections require remedial action, it is likely that the later sections will also require the same measures.

If harmful compaction occurs in the disposal area, beach tilling may be required to restore sea turtle nesting habitat. Beach tilling should only be performed as a result of an identified compaction problem and not performed routinely in place of compaction monitoring. An annual summary of compaction surveys and the actions taken should be submitted to the Service. This summary will be evaluated to determine whether any corrective actions, such as a more compatible sand source, are needed to maintain sea turtle nesting habitat.

The use of incompatible material can lead to the formation of steep berms or escarpments which block females from reaching suitable nesting sites (Greene 2002, p. 30). As a conservation measure for this possibility, visual surveys for escarpments should be made along the project immediately after completion of the sediment placement and prior to May 1. Additional surveys should be made for three years following initial construction. As with compaction monitoring, escarpment survey should be made each year of the project. Survey results should be submitted to the Service prior to any action being taken. After discussion with the Service, escarpments that interfere with sea turtle nesting or exceed 18 inches in height for a distance of 100 feet should be leveled to the natural beach contour by May 1. The Service should be contacted immediately if new escarpments that interfere with sea turtle nesting or exceed 18 inches in height for a distance of 100 feet form 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 will provide a brief written authorization that describes methods to be used to reduce the likelihood of impacting existing nests. An annual summary of escarpment surveys and actions should to be submitted to the Service.

Corps should monitor the color of the material placed on the beach. Sediment color can have an important influence on sea turtle reproduction. Sediment color controls sand temperature. Significant deviations in sand temperature can alter the incubation time and the sex ratios of the hatchlings. A conservation measure to guard against such adverse effect would be a program to monitor any color changes along the beach throughout the course of the project. The program could use a Munsell Color Chart to tract any change in the color of the beach.

A program for detecting stranded sea turtles and securing appropriate care should be part of the project. It is the understanding of the Service that measures to rescue stranded sea turtles are becoming standard provisions of federal beach construction projects. This conservation should be coordinated with the North Carolina Wildlife Resources Commission.

Piping Plover

Since piping plovers use the project area for nesting, migration, and overwintering, conservation measures are needed for every phase of the species' lifecycle. Plans to exclude the southern part of the Town from sediment placement will benefit the species. All recorded piping plover nests in the project area were located in the inlet spit area which is included in designated critical habitat for the species (USACE 2006, p. I-19).

Plans to avoid work during the nesting season of April 1 through July 31 (except for one year during initial construction when work would end on April 30) would be beneficial.

However, piping plovers are especially susceptible to human disturbance during territory establishment and early nesting attempts and after the chicks have hatched. The birds exhibit high sensitivity to human disturbance during territory establishment and often will abandon a potential nesting site if human disturbance is high. Therefore planning should be directed at reducing construction activities near potential breeding areas. Since each construction event would start in mid-November and continue until April 30 (initial construction) or March 31 (reconstruction events), it would be beneficial to have the final phases of construction in the more developed beach areas north of the undeveloped area adjacent to New Topsail Inlet. The highly developed areas in the northern part of the project area provide less suitable habitat for both breeding and overwintering plovers. Therefore, an important conservation measure would be to start all construction events at the southern end of the project area (near the inlet) and move north. This construction feature would place actual construction away from the important inlet area at the end of each construction period. Current plans to place the delivery pipeline during all construction events along the south end of the beach in a manner to avoid piping plover habitat areas (USACE 2006, p. 68) would benefit the species. The Service expects that the inclusion of this feature, along with the other conservation measures proposed for the federal project, would result in a project that may effect, but is not likely to adversely affect the piping plover.

West Indian Manatees

To minimize potential impacts to the West Indian manatee the federal project would implement guidelines developed by the Service (USACE 2006, p. I-8). These guidelines, entitled "Precautions for General Construction in Areas Which May Be Used by the West Indian Manatee in North Carolina", address all types of in-water construction, except blasting, and should produce little, if any, additional expense. The guidelines are intended mainly to ensure that: (1) construction personnel are informed that manatees may occur in the work area; (2) work should cease if a manatee approaches the work area; and (3) work should not resume until the manatee leaves the work area. They also include procedures for reporting the death or injury of a manatee. These guidelines are available on our web site at < http://nc-es.fws.gov/mammal/manatee_guidelines.pdf>. The risk to manatees could be reduced to an acceptable level by the implementation of the Service's guidelines. The risk would be further reduced by performing the work during the period of November through May.

Project Impacts for Which Conservation Measures Cannot be Developed

The preferred alternative of a 50-year program of beach and dune construction represents an effort to stabilize Topsail Island which could be expected to gradually move landward as sea level continues to rise. This effort will produce significant adverse impacts on a variety of natural communities throughout the course of the project.

In discussing the barrier islands of the Outer Banks, Frankenberg (1995, p. 40) states that sound side erosion has increasingly become a concern as dune construction and stabilization have reduced sand movement across the islands. A sediment supply of sand

and mud is just as critical to the back side of a barrier islands as to the beaches and interior dunes (Bush et al. 1996, p. 25). Prior to such construction, sand was carried by wind and island overwash to the sound side beaches. Today much of that sand has been trapped by artificial dunes and residential development. As a result, sound side beaches are being eroded by waves created by wind blowing across the sound. The situation where shoreline recession occurs on both sides of an island is referred to by geologist as "narrowing in place" (Frankenberg 1995, p. 40).

Perhaps the most apparent impact of "narrowing in place" will be harm to the estuarine salt marshes which will not receive sediment from island overwash events. Without periodic infusion of new sediment, the estuarine intertidal areas will gradually disappear if held in their current location. The area of salt marsh will also decline as estuarine water rise.

SECTION 13 - RECOMMENDATIONS

In accordance with the FWCA, the Service offers the recommendations in this section in order to avoid, minimize, and mitigate adverse impacts on fish and wildlife resources. These brief recommendations are the culmination of all the information presented and analyzed in the preceding sections of this report. These recommendations should not be considered without a thorough understanding of the entire report, specifically the conservation measures presented in Section 12.

1. There should be a clear presentation of the federal interest in the project area. The discussion should distinguish between efforts to reduce damage during storms and efforts to replace land lost as rising sea level pressures the island to move landward. There should be an acknowledgement that the ocean does not create permanent damage on the natural communities of barrier islands. What appears to be recession of the beach and dune results from movement of sand across the island to nourish the natural communities on the sound side, part of the natural, adaptive process of island movement. The reduction in beach width is actually the result of the area being squeezed between the rising ocean and a fixed line of man-made structures. A clear presentation of the nature of the problem will provide the foundation for determining the federal interest and the development of alternatives.

2. The efficacy of any program for replacing inundated beaches with imported fill material over 50 years will depend on global sea level rise during the period. Sea level rise along with more intense hurricanes will contribute to the destruction of a beach constructed, at least partially, in shallow ocean waters. Information from the Intergovernmental Panel on Climate Change (IPCC 2007) and analysis such as Rahmstorf (2007) should be used in project planning.

3. The Corps is within the executive branch and is therefore required to comply with Executive Order (EO) 11988. This EO was enacted to avoid, to the extent possible, the long and short term adverse impacts associated with the occupancy and modification of

floodplains and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative (USACE 206, p. 118). Most of Topsail Island is in the 100-year floodplain (Pilkey et al. 1998, p. 171) and most of the island would be largely underwater in a category one or two hurricane and nearly completely submerged in a category three hurricane (Pilkey et al. 1998, p. 173). These dangers are reflected in the fact that the northern portion of Topsail Island is included in the Coastal Barrier Resource System (CBRS). Areas included the CBRS were generally considered unsuitable for development because they are vulnerable to hurricanes and other storm damage and because natural shoreline recession and the movement of unstable sediments undermine manmade structures. The current project area was excluded from the CBRS because it was developed at the time of the legislation and not because the development was at less risk. Since the 50-year program of beach construction is intended, in part, to "ensure that current growth trends in population and recreational visitation will continue," any action under the control of an executive branch agency must determine whether the action contributes to unwise development within a hazardous floodplain. The Corps should present a comprehensive discussion of the justification for the conclusion that "the proposed action is in compliance with the requirements of Executive Order 11988" (USACE 2006, p. 119). Compliance with this EO should not be based on the high cost of removing the structures, but rather whether the presence of existing structures and the additional growth that would be supported by the federal action represents unwise development in a hazardous floodplain.

4. The goal of reducing storm damage could be achieved with less environmental harm by using non-structural measures. However, the Draft GRR/EIS determined (USACE 2006, p. 54) that the non-structural plan was not economically feasible and was not fully evaluated for technical feasibility or acceptability. This decision was based on consideration of the costs of removing or relocating structures, but without any economic consideration of the economic benefits to the natural resources of the area. There was an assumption that a non-structural approach would continue to result in land losses (USACE 2006, p. 59). Information presented in this report indicates that the non-structural approach, if implemented at all levels of government, would allow the formation of a wide, natural beach as Topsail Island is pushed landward. The remote, undisturbed beach which is recognized by the Corps (USACE 2006, p. 59) would support tourism and provide significant economic benefits for the region. The Service recommends that the economic benefits of the non-structural alternative receive greater consideration in the selection of the preferred course for federal action.

5. If beach construction is ultimately undertaken, the fill material should have a high degree of compatibility with the native beach. The North Carolina Sediment Criteria Rule, contained in the Technical Standards for Beach Fill Projects (15A NCAC 07H .0312), should be used in regard to grain size and percent weigh of calcium carbonate. In addition, compatibility should be established for other important characteristics such as organic content, heavy mineral content, and color.

6. If beach construction is ultimately undertaken, there should be a plan to monitor the quality of the fill material as it placed on the beach. There should be an effective

procedure for stopping operations if inappropriate material is being pumped onto the beach. Since such real time protective measures may not be completely effective, there should also be a plan for inspecting the constructed beach for areas of incompatible material and removing such material before the start of the nest sea turtle nesting season.

7. Offshore sediment extraction and sediment disposal should be scheduled during the least sensitive period of the year for the organisms dependent on the habitats to be affected. Every effort should be made to complete all beach work, both actual placement and shaping, by the end of March for the benefit of important beach invertebrates and migratory shorebirds.

8. The Corps should ensure that no offshore hardbottom habitats are affected by sedimentation produced by the project, either as a result of offshore dredging or sediment washing off the beach. This goal may be accomplished by actual surveys of the offshore sediment extraction sites. A sufficient buffer should be required between the dredging operation and hardbottoms. At a minimum, sediment extraction should comply with the North Carolina law (15A NCAC 07H. 0208(b)(12)(A)(iv)) requiring that mining of submerged land should not be conducted on or within 500 meters (1,640 feet) of significant biological communities, such as high relief hardbottom areas. If offshore hardbottoms are adversely affected, the project should include specific measures to mitigate any adverse impacts.

9. While the use of highly compatible fill material would minimize turbidity and sedimentation due to runoff from the constructed beach, small inclusion of mud and silt pose a risk to nearshore hardbottoms. Project planning should establish a program to monitor the location, areal extent, and major organisms of nearshore hardbottoms prior to initial construction. These areas should be surveyed after initial construction to determine an adverse sedimentation and change in the biological community. If it appears likely that nearshore hardbottoms could be covered by sediment moving off the constructed beach, it may be necessary to have a monitoring program to detect any overall loss of exposed hardbottoms and to develop and implement appropriate mitigation measures. Mitigation measures could include a reduction in the amount of beach fill near vulnerable hardbottoms.

10. Project plans should include measures to avoid adverse impacts associated with placement of the sediment pipeline and measures to monitor and mitigate any spills from the pipeline. During both initial construction and reconstruction events, the delivery pipeline should be placed to avoid the piping plover habitat areas around New Topsail Inlet. Pipeline placement should avoid all hardbottom areas. There should be a plan to monitor pipelines for leaks and an established plan of action in the case a joint in the dredge pipe should break. This plan should describe measures to contain and clean the spill.

11. The project should include an annual monitoring program on beach and subtidal invertebrates that form an important food resource for shorebirds and surf fishes. While other monitoring programs have been implemented in North Carolina, each project has

unique features such as the sediment source and the responses of invertebrates at one location may not be application to each beach construction effort. The project should include a requirement for a pre-project assessment of beach invertebrate biomass and community composition, i.e., the number of species present. The program should have adequate control areas such as Hutaff Island, south of the project area. After construction, the Corps should monitor the recovery of intertidal and near shore invertebrate populations. If any assessment indicates a significant decline in either biomass or the number of species present when compared to control areas, there should be definite procedures in place to develop mitigation for this community. Data from these studies will be especially important if the reconstruction interval is reduced as sea level continues to rise. While the Corps notes (USACE 2006, p. 130) that benthic populations may recovery within one to four years after large-scale sediment placement, a gradual reduction of the reconstruction interval could preclude adequate recovery and threaten these organisms which form an important base to the coastal food chain. The overall project plan should include funding for developing procedures to better understand mole crab and coquina clam life history requirements and developing effective measures to mitigate adverse impacts to these important resources.

12. A program for beach construction should include surveys for seabeach amaranth both before and for three years after sediment placement in order to avoid direct burial and to monitor recovery of the plant. With the proposed four-year reconstruction cycle, surveys for this endangered plant would be made every year. If data indicate a declining trend in the presence of this federally threatened species, the development of mitigation measures may be required. The project should also monitor beach vitex in the project as part of an effort to eradication this harmful invasive foreign plant.

13. Nesting by sea turtles will benefit from strict sediment compatibility standards and work schedules that avoid the nesting season. Current plans for beach construction avoid the recognized nesting and incubation season of May 1 through November 15. However, artificial beaches pose a risk to sea turtle nesting due to: (1) sediment compaction; (2) escarpment formation; and, (3) altered sand temperature which may occur as a result of a change in sediment color. To mitigate sediment compaction, the Service recommends that compaction monitoring should occur after each construction event and for three subsequent years. Considering that reconstruction is scheduled for every four years between 2010 and 2058, a sediment compaction survey should be made each year of the project. However, compaction monitoring would not be required if the sediment used to construct the beach is completely washed away. Beach tilling should only be performed as a result of an identified compaction problem and not performed routinely in place of compaction monitoring. Similarly, visual surveys for escarpments should be made along the constructed beach immediately after completion of the sediment placement and prior to May 1. Additional surveys should be made for three years following initial construction. As with compaction monitoring, escarpment survey should be made each year of the project. Survey results should be submitted to the Service prior to any action being taken. After discussion with the Service, escarpments that interfere with sea turtle nesting or exceed 18 inches in height for a distance of 100 feet should be leveled to the natural beach contour by May 1. The Service should be contacted immediately if new

escarpments that interfere with sea turtle nesting or exceed 18 inches in height for a distance of 100 feet form 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 will provide a brief written authorization that describes methods to be used to reduce the likelihood of impacting existing nests. A program for detecting and securing appropriate care for stranded sea turtles should be part of the project.

14. Plans to exclude the southern part of the Town from sediment placement will benefit federal trust resources such as migratory shorebirds. However, piping plovers are especially susceptible to human disturbance during territory establishment and early nesting attempts and after the chicks have hatched. Therefore, the work on each construction event should start at the south end of the project area, near New Topsail Inlet, and move north during construction. This construction method would place the final phase of each construction event in the more developed, northern areas of the project area, habitat less likely to be used for nesting by the piping plover. Current plans to place the delivery pipeline away from areas that might be used by piping plovers would also reduce adverse impacts on the species.

15. While the West Indian manatee is not likely to be in the project area during the proposed construction period, protective measures should be in place to safeguard this endangered species. Corps plans call for the implementation of the Service's "Precautions for General Construction in Areas Which May Be Used by the West Indian Manatee in North Carolina." These guidelines should provide adequate protection for this species.

SECTION 14 - SUMMARY OF FINDINGS AND SERVICE POSITION

Summary of Findings

Barrier islands and spits are inherently dangerous places for any man-made structures such as roads, houses, or utility infrastructure. The islands are subject to the full force of both tropical hurricanes and, to a lesser extent, winter storms. Early residents recognized this fact of life and built their homes as far from the ocean as possible. On the Outer Banks, development was limited to the sound side of the islands until the mid-1880s (Frankenberg 1995, p. 118). Current beach front development occupies an extremely hazardous location as shown by the devastation of the Mississippi coastline by Hurricane Katrina in August 2005.

The threat to all development on barrier island is increased by the rise in global sea level. While the causes of sea level rise may be debated, the increase has been well documented and is likely to continue for many decades, perhaps at an increasing rate of rise. The intensity of hurricanes may also increase as ocean waters become warmer. Therefore, both the threat of damage during storms and the gradual inundation of the coastline can be expected to continue throughout the 50 years of the beach construction effort and beyond.

While it may appear that rising ocean waters are destroying the beaches, this is not entirely correct. Barrier islands are not fixed, stationary landforms. These islands are unconsolidated masses of gravel, sand, and mud surrounded by ocean and sound waters and characterized by low elevation, narrow width, and fragile vegetation cover (Bush et al. 1996, p. 11). When global sea level is rising, natural processes push the islands landward and allow them to survive. One of these natural processes is the movement of sand from the beaches across the island to the sound side. From the perspective of a beachfront structure, this process of island overwash appears to represent the destruction of the beach. If artificial dunes block the island overwash process, the sand may be lost to deeper offshore waters rather than contributing to the survival of the island. Pilkey et al. (1998, p. 4) state that "when sea level is rising, as it is today, barrier islands do not stay in one place; they migrate in order to survive." Therefore, it should be understood that hurricanes do not damage barrier islands. In fact, the forces that occur during major storms and are so destructive to man-made structures are necessary for barrier islands to respond to sea level rise and ultimately continue to exist. The wide natural beaches that are so important to the tourist economy are not destroyed as the islands move landward. They merely change location. The current loss of the beach in the project area results from the area being squeezed between a rise ocean and a fixed line of structures.

All man-made structures near the rising ocean are unquestionably in danger. No action at all levels of government will probably lead to short-term efforts to save structures near the ocean. These efforts would continue squeezing the beach, but are likely to be ineffective in the long term (USACE 2006, p. B-32). The two major categories of action can be characterized as either non-structural or structural.

A non-structural approach involves a number of actions to remove or relocate structures threatened by storms and coastal inundation. These measures would require consideration of suitable relocation sites and compensation for property owners. The approach would also restore valuable barrier island habitats, such as overwash areas, that have been lost by effort to stabilize the island.

The structural approach consists primarily of a program to periodically place sediment extracted from offshore in a structure designed to resemble a beach and dune. This approach would produce numerous short-term adverse impacts on fish and wildlife resources. There are design features and construction techniques to minimize the some of the adverse impact of actual beach construction at the present sea level. The use of highly compatible beach fill, a restricted work schedule, and a reconstruction interval of four years would retain most of the habitat functions of the beach and dune communities.

The most significant question with regard to the long-term conservation of fish and wildlife resources is whether the beach construction effort which provides some security in the short run can be maintained over 50 years as sea level continues to rise. Over many decades, a greater portion of the beach fill used to reconstruct the beach at its present location will actually be below what would be the natural low tide level. This structure, partially build in the ocean, will wash away in ever shorter time intervals over the life of the project. There is a concern that over many decades the escalating costs of more frequent beach replacement along with diminishing supplies of available beach fill will lead to requests for rock seawalls to protect the ever increasing value of shoreline property. Where seawalls are built, the beach is eventually lost (Pilkey et al. 1980, p. 10).

Position of the Service

In light of the findings discussed above, the Service believes that action must be taken to reduce the periodic destruction of man-made structures in the project area. The Service also supports two of the goals for the current effort which seek solutions that are protective of the environment and federally listed species (USACE 2006, p. 49).

Implementation of a long-term program of beach construction is not likely to remain effective as sea level continue to rise. The environmental issues surrounding a long-term program of beach and dune construction involve much more than just offshore sediment extraction and beach construction. The most significant issues are the consequences of attempting to hold the island in place as sea level rises around it. When beach fill no longer provides cost effective protection, rock seawalls would be required to hold back the rising water. Eventually the beaches and salt marshes of the sound would be lost. Pilkey et al. (1998, p. 102) have summarized the issue by stating that "in the long run, North Carolinians must make a decision. They can have beaches or they can have beachfront buildings; they can't have both. If we opt in favor of buildings, the beaches will be lost – and so, ultimately will the buildings."

The Service recognizes that decisions regarding the Nation's response to rising sea level rest with the Congress. However, our review of the available information in this case leads us to believe that the long-term success of the proposed approach is questionable and it is likely that other structural or non-structural measures will need to be implemented during the life of the project. Furthermore, we note that non-structural measures would be more successful at conserving the natural resources of the project area.

Planning for the current project should give greater consideration to Executive Order (EO) 11988 which seeks to avoid federal support for unwise development within floodplains which can result in both high costs for reconstruction and danger to human life and safety. The area at the northern end of Topsail Island is part of the Coastal Barrier Resource System (CBRS), an area which is currently barred from federal support for development due to inherent risks of damage. Since the project area at the southern end of Topsail Island shares the same risks as the CBRS unit, compliance with EO 11988 for the proposed 50-year beach construction effort to maintain and expand existing development within the project area should be thoroughly evaluated.

SECTION 15 - LITERATURE CITED

Alexander, J. and J. Lazell. 2000. Ribbons of Sand: the Amazing Convergence of the Ocean and the Outer Banks. The University pf North Carolina Press. Chapel Hill, NC. 238 pp.

Barnes, J. 1998. North Carolina's Hurricane History – Revised and Updated Edition. The University of North Carolina Press. Chapel Hill. 256 pp.

Bellis, V. J. 1995. Ecology of Maritime Forests of the Southern Atlantic Coast: A Community Profile. National Biological Service. U. S. Department of the Interior. Biological Report 30. 95 pp.

Burgess, C.B. 1993. A hard rock oasis - under the sea. Coastwatch. The University of North Carolina Sea Grant College Program. March/April 1993:2-7.

Bush, D. M., O. H. Pilkey, Jr., and W. J. Neal. 1996. Living by the Rules of the Sea. Duke University Press. Durham, North Carolina. 179 pp.

Cahoon, L. B. 1993. Stable isotope analyses differentiate between different tropic pathways supporting rocky-reef fishes. Marine Ecol. Progress Series. 95:19-24

________ and J. E. Cooke. 1992. Benthic microalgal production in Onslow Bay, North Carolina, USA. Marine Ecology Progress Series. 84:185-196.

________ and C. R. Tronzo. 1992. Quantitative estimates of demersal zooplankton abundance in Onslow Bay, North Carolina, USA. Marine Ecol. Progress Series. 87:197-200.

________ R. S. Redman, and C. R. Tronzo. 1990. Benthic microalgal biomass in sediments of Onslow Bay, North Carolina. Estuarine, Coastal and Shelf Science. 31:805-816.

Cleary, W.J. 1968. Marine Geology of Onslow Bay. Department of Geology. Duke University, Durham, NC. M.S. Thesis, 73p.

________ W. J., 2001. Availability of offshore sand resources for shoreline restoration in southeastern North Carolina. Geological Society of America Southeastern Section. Annual Meeting, 2001 Abstracts with Program.

________ 2002a. Variation in inlet behavior and shoreface sand resources: factors controlling management decisions, Figure Eight Island, NC, USA. J. Coastal Research. Special Issue 36:148-163.

________ June 10, 2002b. An Assessment of the Availability of Beachfill Quality of Sand Offshore Topsail Beach, Pender County, NC.

________ March 2003. An Assessment of the Availability of Beach Fill Quality Sand Offshore North Topsail Beach and Surf City North Carolina. HDR Engineering, Inc. of the Carolinas.

_________ and P. E. Hosier. 1990 (May). A long range plan for channel maintenance and beach restoration. Figure Eight Island, North Carolina. Report submitted to the Figure "8" Beach Homeowners Association, Inc. 72 pp.

Copeland, B. J. and W. S. Birkhead. 1972. Some ecological studies of the lower Cape Fear River Estuary, Ocean Outfall, and Dutchman Creek. Contribution 27, Pamlico Marine Lab. North Carolina State University, Raleigh, NC. 105 pp.

Croft, A., and L. A. Leonard, 2001. Effects of dredged material disposal on tidal marsh processes. Geological Society of America Southeastern Section Annual Meeting, 2001 Abstracts with Program.

Dean, C. 1999. Against the Tide: The Battle for America's Beaches. Columbia University Press. New York, NY. 279 pp.

Di Silvestro, R. 2006 [August/September]. When hurricanes hit habitat. National Wildlife. 44:20-23.

Epperly, S. P., J. Braun, and V. Veishlow. 1995. Sea turtles in North Carolina waters. Conservation Biology. 9:384-394.

Frankenberg, D. 1995. The Nature of the Outer Banks: Environmental Processes, Field Sites, and Development Issues, Corolla to Ocracoke. The University of North Carolina Press. Chapel Hill. 157pp.

_________ 1997. The Nature of North Carolina's Southern Coast: Barrier Islands, Coastal Waters, and Wetlands. The University of North Carolina Press. Chapel Hill. 250 pp.

Fussell, J. 0., III. 1978. Bogue Banks study: a description of vegetative communities and annotated lists of amphibians, reptiles, birds, mammals, and endangered and threatened species. Report to U.S. Fish and Wildlife Service. Raleigh Field Office. Raleigh, North Carolina. 115 pp.

Godfrey, P. J. 1970. Oceanic Overwash and its Ecological Implications on the Outer Banks of North Carolina. Office of Natural Science Studies. National Park Service. U. S. Department of the Interior. Washington, DC. 44 pp.

_________ and M.M. Godfrey. 1976. Barrier island ecology of Cape Lookout National Seashore and vicinity, North Carolina. U.S. Department of the Interior, National Park Service, Scientific Monographic Series, 9. 160pp.

Goldberg, W.M. 1985. Long term effects of beach restoration in Brevard County, Florida, a three year overview. Unpublished Report to Broward County Environmental Quality Control Board and Erosion Preservation District. (As reported in Goldberg 1988).

Gosner, K. L. 1978. A Field Guide to the Atlantic Seashore - from the Bay of Fundy to Cape Hatteras. The Peterson Field Guide Series. Houghton Mifflin Company. Boston, MA. 329pp.

Greene, K. 2002 [November]. Beach Nourishment: A Review of the Biological and Physical Impacts. ASMFC Habitat Management Series #7. Atlantic States Marine Fisheries Commission. Washington, DC. 69 pp. + Appendices. [available at < http://www.asmfc.org > under Publications; Habitat Documents; Habitat Management Series].

Greenhorne & O'Mara, Inc. September 29, 2004. Final Report Marine Geophysical Investigation for The Evaluation of Sand Resource Areas Offshore Topsail Island North Carolina. Prepared for: USAED, Wilmington 69 Darlington Avenue Wilmington, North Carolina 28403.

Hackney, C. T., M. R. Posey, S. W. Ross, and A. R. Norris. (eds.). 1996. A Review and Synthesis of Data on Surf Zone Fishes and Invertebrates in the South Atlantic Bight and the Potential Impact from Beach Renourishment. Report to the Wilmington District, U. S. Army Corps of Engineer. Wilmington, North Carolina. 109 pp.

Huntsman, G. 1994. Living resources: fisheries. pp. 5-9. in Hart, K. (ed.) Managing the Coastal Ocean for the 21th Century: North Carolina's Role. A proceedings from a conference held May 20-21, 1993, University of North Carolina at Wilmington. N.C. Sea Grant Publication UNC-SG-94-02. 54 pp.

Hurme, A. K. and E. J. Pullen. 1988. Biological Effects of Marine Sand Mining and Fill Placement for Beach Replenishment: Lessons for Other Uses. Marine Mining 7:123-136.

Inman, D. and R. Dolan. 1989. The Outer Banks of North Carolina: budget of sediment and inlet dynamics along a migrating barrier system. Journal of Coastal Research 5(2):192-237.

Intergovernmental Panel on Climate Change. 2007. Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth assessment Report of the Intergovernmental Panel on Climate Change (Summary for Policymakers). World Meteorological Organization. Geneva, Switzerland. Available at < http://www.ipcc.ch/SPM2feb07.pdf >. 18pp.

Johnson, R. O. and W. G. Nelson. 1985. Biological effects of dredging in an offshore borrow area. Florida Scientist. 48:166-188.

Kaufman, W. and O. H. Pilkey, Jr. 1983. The Beaches are Moving. Duke University Press. Durham, North Carolina. 336pp.

Leatherman, S.P. 1979. Barrier Islands from the Gulf of St. Lawrence to the Gulf of Mexico. Academic Press. New York, NY. 325pp.

________ 1988. Barrier Island Handbook. 3rd edition. Coastal Publication Series. Laboratory for Coastal Research. The University of Maryland. College Park, MD. 92pp.

________ 2001. Social and economic costs of sea level rise. pp. 181-223. in Douglas, B. C., M. S. Kearney, and S. P. Leatherman (eds.). Sea Level Rise - History and consequences. Academic Press. San Diego, CA. 232 pp.

Lindeman, K.C., and D.B. Snyder. 1999. Nearshore Hardbottom Fishes of Southeast Florida and Effects of Habitat Burial Caused by Dredging. Fishery Bulletin. 97:508-525.

Lippson, A. J. and R. L. Lippson. 1997. Life in the Chesapeake Bay. 2nd edition. The John Hopkins University Press. Baltimore. 294pp.

Marshall, H. G. 1969. Phytoplankton distribution off the North Carolina coast. American Midland Naturalist. 82:241-257.

________. 1971. Composition of phytoplankton off the southeastern coast of the United States. Bull. of Marine Science. 21:806-825.

McCrain, J. 1988. Environmental parameters on north Hatteras Island (South Point), Dare County, NC. North Carolina Department of Transportation. Raleigh, North Carolina. 10 pp.

McQuarrie, M.E. 1998. Geologic framework and short-term, storm-induced changes in shoreface morphology: Topsail Beach, NC. Unpub. M.S. Thesis, Dept. of the Environment, Duke Univ., Durham. 105p.

Moser, M.L. and T.B. Taylor. 1995. Hard Bottom Habitat in North Carolina State Waters: A Survey of Available Data. Final Report to North Carolina Division of Coastal Management Ocean Resources Taskforce.

National Research Council. 1995. Beach Nourishment and Protection. National Academy Press. Washington, D.C. 334 pp.

Nickens, T. E. 2006. Beach blanket. Audubon. 108:24-28.

Nifong, T. D. 1981. Natural Areas Inventory of Brunswick County, North Carolina. North Carolina Coastal Energy Impact Program. CEIP Report No. 10. Office of Coastal Management. North Carolina Department of Natural Resources and Community Development. Raleigh, NC. 252 pp.

Odum, E. P. 1983. Basic Ecology. Saunders College Publishing. New York, NY. 613pp.

Parnell, J. F. and R. F. Soots, Jr. 1978. The use of dredge islands by wading birds. pp. 105-111 in Wading Birds. National Audubon Society Res. Report 7.

Peterson, C. H. and N. M. Peterson. 1979. The ecology of intertidal flats of North Carolina: a community profile. U. S. Fish and Wildlife Service, Office of biological Services. FWS/OBS-79/39. 73pp.

_________. and J. T. Wells. 2000. Bogue Banks beach renourishment project: late fall 1999 assessment of benthic invertebrates and demersal fish resources in the offshore mining sites prior to sand mining. Final Report prepared for Carteret County and CSE Baird, Inc. 13 pp + Figures and Tables.

Peterson, C. H., R. W. Laney, and T. M. Rice, 2001. Biological impacts of beach nourishment. Workshop on the Science of Beach Renourishment. May 7-8, 2001. Pine Knoll Shores, North Carolina.

_________, D. H. M. Hickerson, and G. G. Johnson. 2000. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy beach. Journal of Coastal Research. 16:368-378.

_________, 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 upward to shorebirds. J. of Experimental Marine Biology and Ecology. 338:205-221.

Pilkey, O. H. and K. L. Dixon. 1996. The Corps and the Shore. Island Press. Washington, D.C. 272pp.

___________, W. J. Neal, O. R. Pilkey, Sr., and S. R. Riggs. 1980. From Currituck to Calabash: Living with the North Carolina's Barrier islands. Duke University Press. Durham, NC. 244 pp.

___________., W. J. Neal, S. R. Riggs, C. A. Webb, D. M. Bush, D. F. Pilkey, J. Bullock, and B. A. Cowan. 1998. The North Carolina Shore and Its Barrier Islands - Restless Ribbons of Sand. Duke University Press. Durham, North Carolina. 318 pp.

_________, T. M. Rice, and W. J. Neal. 2004. How to Read a North Carolina Beach. The University of North Carolina Press. Chapel Hill, NC. 162 pp.

Potter, E.F., J.F. Parnell, and R.P. Teulings. 1980. Birds of the Carolinas. The University of North Carolina Press

Rahmstorf, S. 2007 (January). A semi-empirical approach to projecting future sea level rise. Science 315:368-370.

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.

Rathbun, G.B., RK. Bonde, and D. Clay. 1982. The status of the West Indian manatee on the Atlantic coast north of Florida. Pages 152-165. *in* RR Odum and J.W. Guthrie (eds.). Proceedings ofthe Symposium for Nongame and Endangered Wildlife. Technical Bulletin WL 5. Georgia Department of Natural Resources. Social Circle, Georgia.

Riggs, S. R. 1994. Nonliving resources. pp. 13-19. in Hart, K. (ed.) Managing the Coastal Ocean for the 21th Century: North Carolina's Role. A proceedings from a conference held May 20-21, 1993, University of North Carolina at Wilmington. N.C. Sea Grant Publication UNC-SG-94-02. 54 pp.

_________ W. J. Cleary and S. W. Snyder. 1995. Influence of inherited geologic framework on barrier shoreface morphology and dynamics. Marine Geology. 126:213-234.

_________ S. W. Snyder, A. C. Hine and D.L. Mearns. 1996. Hardbottom morphology and relationship to the geologic framework: Mid-Atlantic continental shelf. Journal of Sedimentary Research. 66(4):830-846.

_________ W. G. Ambrose Jr., J. W. Cook, S. W. Snyder, and S. W. Snyder. 1998. Sediment production on sediment-starved continental margins: The interrelationship between hardbottoms, sedimentological and benthic community processes, and storm dynamics. Journal of Sedimentary Research. 68(1):155-168.

Reilly, F.J. Jr., and V.J. Bellis. 1978. A study of the ecological impact of beach nourishment with dredged materials on the intertidal zone. East Carolina University Institute for Coastal and Marine Resources, Technical Report No. 4., Greenville, North Carolina. 107 pp.

Ross, S. W. 1996. Surf zone fishes of the south Atlantic Bight. Section III, pp. 42-107. In: Hackney, C. T., M. H. Posey, S. W. Ross and A. R. Norris (Eds.). A review and synthesis of data on surf zone fishes and invertebrates in the South Atlantic Bight and the potential impacts from beach nourishment. Report to the U.S. Army Corps of Engineers. Wilmington, N.C. 111 pp.

Ross, S.W., and J.E. Lancaster. 1996. Movements of Juvenile Fishes Using Surf Zone Nursery Habitats and the Relationship of Movements to Beach Nourishment Along a North Carolina Beach: Pilot Project. Final Report submitted to NOAA Office of Coastal Resource Management and the U.S. Army Corps of Engineers, November 22, 1996. 31 pp.

Ruppert, E. E. and R. S. Fox. 1988. Seashore Animals of the Southeast. University of South Carolina Press. Columbia, South Carolina. 429pp.

Sarle, L. L., 1977, Processes and Resulting Morphology of Sand Deposits within Beaufort Inlet, Carteret County, North Carolina, Duke University, MS, 150 p;

Schwartz, F. J. 1995. Florida manatees, *Trichechus manatus* (Sirenia: Trichechidae), in North Carolina 1919-1994. Brimleyana 22: 53-60.

Slay, C. 1993. Right Whale Research Project, New England Aquarium. Personal communication regarding seasonal occurrence of right whales of the Cape Fear region; p.5, In: Biological Assessment: Channel Realignment Masonboro Inlet, New Hanover County, NC. August 1995. USACOE.

Street, M.W., A.S. Deaton, W.S. Chappell, and P.D. Mooreside. 2005. North Carolina Coastal Habitat Protection Plan. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, Morehead City, NC. 656 pp.

Thurman, H. V. 1994. Introduction to Oceanography. Macmillian Publishing Company. New, NY. 550 pp.

U. S. Army Corps of Engineers. 2006 (June). Draft General Reevaluation Report and Environmental Impact Statement – Shore Protection – West Onslow Beach and New River Inlet (Topsail Beach), North Carolina. Wilmington District, U. S. Army Corps of Engineers, Wilmington, North Carolina. Various pagination.

U. S. Fish and Wildlife Service. 1986. West Onslow Beach and New River Inlet Study. Draft Fish and Wildlife Coordination Report. Raleigh Field Office, Raleigh, NC. 44 pp.

Van Dolah, R.F. and D.M. Knott. 1984. A biological assessment of beach and nearshore areas along the South Carolina Grand Strand. Final Report to U.S. Department of the Interior, Fish and Wildlife Service. Marine Resources Division, South Carolina Wildlife and Marine Resources Department, Charleston, South Carolina. 58 pp.

_________ D. R. Calder, D. M. Knott. 1984. Effects of Dredging and Open-Water Disposal on Benthic Macroinvertebrates in South Carolina Estuary. Estuaries. 7(1): 28-97.

_________ P. H. Wendt, R. M. Martore, M. V. Levisen, W. A. Roumillat. 1992. A physical and biological monitoring study of the Hilton Head beach nourishment project. Marine Resources Research Institute, South Carolina Marine Resources Division, Charleston, S.C. 159 pp.

Wilbur, P. and M. Stern. 1992. A re-examination of infaunal studies that accompany beach nourishment projects. pp. 242-257 in New Directions in Beach Management: Proceedings of the 5th Annual National Conference on Beach Preservation Technology. Florida Shore and Beach Preservation Association. Tallahassee, Florida.