Appendix B
Draft Fish and Wildlife Coordination Act Report

NORTHERN DARE COUNTY STORM DAMAGE REDUCTION PROJECT, DARE COUNTY, NORTH CAROLINA

DRAFT FISH AND WILDLIFE COORDINATION ACT REPORT

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EXECUTIVE SUMMARY

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 fish and wildlife conservation as a coequal objective of federally funded or permitted water resources development projects. 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.

In 1990 the U. S. Congress authorized funds for a reconnaissance study of problems associated with erosion on the beaches of Dare County. On July 23, 1997, the U. S. Army Corps of Engineers (Corps) published a Notice of Intent (NOI) that stated the shoreline protection project would involve the placement of a berm and, where necessary, the establishment of a dune line on approximately 10 miles of beach within Dare County north of Oregon Inlet. The most likely sand sources at that time were various offshore borrow sites. Routine renourishment would be required at 3-5 year intervals, but portions of the project area could require more frequent renourishment. The Service provided both a preliminary and revised Planning Aid Report on the project during 1992. During the life of the planning process, the project has evolved from one emphasizing beach stabilization to one with the stated purpose of storm damage reduction.

Study Area Description - The barrier island system is part of the Outer Banks of North Carolina, a series of long, narrow barriers extending south to Bogue Sound. The study area includes the beaches of Dare County from the Currituck County line to the boundary with Cape Hatteras National Seashore (CHNS), as well as potential sand borrow areas. Beaches experiencing the most severe erosion problems have been identified, and erosion control measures will focus on these areas. The project area would also include the uplands and wetlands of the barrier islands that could experience secondary impacts.

The barrier islands were created approximately 5,000-8,000 years ago (Inman and Dolan 1989). Sea level has risen approximately 3.9-7.8 inches during the past century (Michener et al. 1997). The rate of sea level change during the recent past may not be the same that will occur in the future. The rate of sea level rise is likely to increase in the future.

The project area is subject to hurricanes and northeasters. Northeasters occur primarily from October through April, with the most storms during February (Davis and Dolan 1993). These storms commonly produce waves 5-33 feet high (Davis and Dolan 1993) and the destructive impact of these waves is much greater when accompanied by a high storm surge. Hurricanes form over tropical water and move northward. The official hurricane season begins on June 1 and lasts for five or six months.

The major factor in worldwide shoreline recession, or beach erosion, is rising sea level (Pilkey et al. 1998, p. 45). Inman and Dolan (1989) state that the Outer Banks have migrated landward with rising sea level. A one foot sea level rise could produce a 1,000 foot retreat of the shoreline during the 50 year life of the storm damage reduction project. The Atlantic shoreline in the project area has an average recession rate of about 5.2 feet per year, or 520 feet per century (Inman and Dolan 1989) and the annual rate in the project area range from 2 to 11 feet. Island transgression is directly related to shoreline recession/erosion which has resulted in some structures being at risk during coastal storms. The natural movement of sediment from the ocean side to the sound side of barrier islands is critical to their ability to exist in the face of a rising sea level.

The population of Dare County has greatly increased in recent decades. The value of property on the Outer Banks of Dare County has risen dramatically since 1950. Growth in the area has placed pressure on local governments to provide adequate freshwater supplies and wastewater treatment.

The Dare County coast is susceptible to storms, and several structures are generally lost each year as a result of coastal storms. In the 1930s the Civilian Conservation Corps built protective dunes along the beaches of the Outer Banks from the Virginia border to Ocracoke. With high, artificial barrier dunes protecting the islands from storms and cross-island overwash, a sense of security resulted in increase construction of roads and buildings. An extreme northeaster in October 1991 damaged or destroyed dozens of beach cottages by wave and storm surge, flooded miles of road, and eroded beaches and frontal dunes.

In 1974 the North Carolina General Assembly passed the Coastal Areas Management Act (CAMA) designed to protect coastal resources through a combination of land use planning and state regulation. These regulations require small scale development to be set back from the ocean.

Local governments are aware of potential damage from storms. Under certain worst case scenarios, much of Dare County could be flooded by storm tides and/or wind driven waves. Land Use Plans (LUP) for various jurisdictions consider both beach nourishment and storm hazard mitigation, but in entirely separate sections of the respective plans. The Dare County LUP discusses shoreline recession in the context of barrier island migration, and notes that the alternatives for shoreline management include retreat, armoring with hard structures, and/or beach nourishment. The consideration of storm damage mitigation, on the other hand, notes that the county's "key method" of mitigating property damage is the enforcement base flood elevation standards designed to allow rising water to flow freely under elevated structures (Dare County 1994, p. 94).

This report considers 20 biological communities. There are offshore, marine communities, both pelagic and benthic, from which sand may be taken. There are the nearshore and beach communities which would be impacted by sand placement. Finally, this report covers the upland communities landward of the dune line and the estuarine communities of Albermarle and Roanoke Sounds. While upland and estuarine communities may not be directly impacted by the project, the development which the project would certainly engender will have a profound influence on barrier island uplands and estuarine habitats. These secondary impacts include not only clearing and grading for new construction, but also impacts related to increased demands for freshwater and the problems of increased requirements for wastewater disposal. The communities discussed are: offshore pelagic, offshore benthic (soft substrate bottoms), offshore benthic (hard substrate), nearshore pelagic, nearshore benthic, shoreface and intertidal (wet) beach, subaerial (dry) beach, dunes, overwash flats, low shrub/grasslands, maritime shrub thickets, herbaceous swales and other freshwater wetlands, maritime forests, high marsh (diverse species), high marsh (black needlerush), low marsh (smooth cordgrass), mudflats/sandflats, pelagic areas of the sound, unvegetated benthic areas of the sound, and vegetated benthic areas of the sound

Fish and Wildlife Service Concerns and Planning Objectives - Fish, wildlife, and their habitats are valuable public resources which are conserved and managed for the people by state and federal governments. The Service seeks 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.

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. The Service's first concern is that important habitat values are not eliminated or degraded. The process for selecting 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.

Planning should include a thorough evaluation of all available technologies to reduce storm damage. If artificial beach and dune creation is selected as the preferred alternative, the long-term ramifications of initiating this alternative should be fully explored. Offshore sand mining should be done in a manner and at a time of year so as to avoid negative impacts primary productivity, live bottoms, nationally significant fish wintering grounds, and other marine resources, including marine mammals. 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. The Corps should assess the potential impacts sand washing off the artificial beach-dune system would have on the Oregon Inlet navigation channel.

Evaluation Methods - Descriptions of natural resources within the study area and the assessment of project impacts are based on previous studies for similar projects, published literature, and personal communications with knowledgeable individuals. Dr. Wilson Laney of the Service's South Atlantic Fisheries Resources Coordination Office in Raleigh, North Carolina, Doug Newcomb of the Raleigh Ecological Services Office, and Charles M. Manooch III of the

National Marine Fisheries Service (NMFS) analyzed data on offshore fisheries and prepared recommendations to avoid or minimize impacts on these resources. Dr. Robert Dolan analyzed sediment compatibility of the existing beach and offshore borrow areas. He considered the potential impacts of using offshore sites to construct the artificial beach-dune system.

Existing Fish and Wildlife Resources - The estuarine and marine fish fauna within the project area is varied. Seventy-six species of fish were collected near the Bonner Bridge over Oregon Inlet. The striped bass and other anadromous fish are an especially important consideration for this project. Twenty-five species of freshwater fish have been found in ponds from the Virginia-North Carolina border southward to Oregon Inlet. Amphibians and terrestrial reptiles are limited in the project area.

The variety of upland, pelagic, and wetland communities on the Outer Banks provides a host of habitats for birds, both permanent and seasonal species. Coastal barrier islands probably harbor a greater variety of bird species than any other ecosystem in the continental United States. Within the CHNS, 319 birds are regularly found and an additional 56 species are considered accidentals. The mammalian fauna of the islands within the Outer Banks represents remnant populations that had more widespread paleodistributions, but are now isolated due to the ephemeral nature of inlets, the dynamic geomorphology of barrier islands, and fluctuations in sea level.

Marine mammals occur in offshore and inshore waters of North Carolina. Twenty-nine species of cetaceans have been recorded along the coast of the Carolinas, Virginia, and Maryland. Bottle-nosed dolphins are common in this area.

The Florida manatee, an endangered species, may move north along the Atlantic Coast and occasionally make their way into the coastal waters of North Carolina. There are nine reports of this species from Dare County.

All five Atlantic sea turtles may occur in the coastal waters of North Carolina. The presence of sea turtles in nearshore and estuarine waters of North Carolina appears to be seasonal. Sea turtles are present in the offshore water of North Carolina throughout the year and present in inshore waters from April through December. The loggerhead sea turtle is the most common sea turtle along the North Carolina coast. During the nine-year period of 1990-1998, 24 nests were reported in area under consideration for construction of the beach-dune system. This total includes one, confirmed green turtle nest in 1996.

Piping plovers within the project area are part of the Atlantic Coast population, and are federally listed as threatened. There is evidence that successful nesting occurred during 1998 on Pea Island National Wildlife Refuge. The federally endangered roseate tern generally breeds along the Atlantic Coast. The species is considered a rare coastal transient in North Carolina (Potter et al. 1980, p. 178). It may be present from late March to mid-May and from late July to October. Bald eagles may undertake a seasonal migration to the area when large numbers of waterfowl are present. The federally threatened peregrine falcon is an uncommon, fall migrant and occasional winter resident of the barrier islands.

Future of Project Area Without the Project - With the exception of marine fishes that are subject to commercial harvesting, populations of wildlife and other fisheries resources are likely to maintain present population trends in the near future if the artificial beach-dune system is not constructed. If natural shoreline recession is allowed to continue, the beach will not disappear, but simply migrate landward. To the extent that natural beach movement is allowed to continue, developers may find the risks of construction near the beach to be too great. Any reduction of construction near the shore would be beneficial to sea turtles and shorebirds. The absence of artificial dunes would also facilitate the natural process of island overwash. Such overwashes would benefit early successional wildlife, such as piping plovers, and allow for natural replenishment of sound side marshes.

Overall, any adverse impacts to fish and wildlife resources due to implementing the storm damage reduction project must be fully considered in all environmental documentation. There are no justifications for excluding such impacts on the grounds that other factors would diminish these resources.

Alternatives Considered - Present plans state that the project would consist of the construction of a berm or combination of berm and dune along various reaches of the oceanfront within the study area. The berm would be a subaerial (dry) beach. The only alternatives mentioned were variations in project dimensions and the no action alternative.

The Service believes that the Corps has not presented all alternatives to meet the stated project goal and has not considered an approach that would integrate several options. While the construction of the artificial beach-dune system may be the only alternative that the Corps could undertake unilaterally, it is not the only action alternative which could reduce storm damage. In accordance with the National Environmental Policy Act (NEPA), planning should go beyond alternatives that would constructed by the Corps and consider alternatives that could be implemented by, or in cooperation with, other agencies, e.g., Federal Emergency Management Agency, state agencies, and local governments.

A key step in developing all possible alternatives would be to clearly define three project goals: (1) the categories or intensity level of storms for which protection would be provided; (2) the type(s) of damage which the project is intended to reduce; and (3) the exact area that would receive protection. Both hurricanes and winter storms (northeasters) can vary greatly in intensity and the damage produced is related to the magnitude of winds, flooding, and storm surges produced. Data for hurricane categories should be used in establishing the approximate level of damage which the project would seek to mitigate. The five major processes of high winds, storm waves, storm surge from the ocean, storm surge ebb (water flowing overland from the sound), and high rainfall should be considered. The development of alternatives should state the types of damages which are to be reduced.

As a storm damage reduction option, creation of an artificial beach has several attributes that must be considered. The protection provided is extremely temporary. The sand removed from offshore areas to create the beach may benefit the shoreline in its present offshore location by reducing wave energy offshore. The removal of offshore sand may alter wave refraction patterns and/or wave energy striking the beach. The physical characteristics of the sand placed on the beach may not be compatible with the existing beach sand.

Construction standards and techniques can reduce structural storm damage. The best and most common method of minimizing flood damage due to waves or storm surge is to raise the lowest floor of all structures above the expected highest water level. The Kitty Hawk Land Use Plan recognizes this. In addition to the advantages that better building codes and enforcement would provide to building owners, such measures would benefit the entire community by reducing missiling (flying debris), rafting (floating debris), and ramrodding (floating debris). Zoning and land use planning may be employed to reduce storm damage.

Selection of the Preferred Alternative - The process used to select the preferred alternative has not been discussed. The selection among the alternatives appears to be confused by the degree to which the purposes of storm damage reduction have been intertwined with the unstated goal of erosion control/beach restoration. Although beach/dune restoration may seem to be a reasonable option for erosion control/beach nourishment, it is potentially the most environmentally harmful among options for storm damage reduction. The selection of the preferred alternative should also consider present beach erosion rates in the project area. The issue of long-term impacts on other coastal features must be addressed in the Environmental Impact Statement (EIS). The selection process must specifically consider long-term impacts of sand accumulation at Oregon Inlet and potential adverse impacts on the Oregon Inlet navigation channel.

Description of the Preferred Alternative - The Corps outlined a preferred alternative in a scoping letter released in July 1997. The method of storm damage reduction would be the placement of a sand berm and, where necessary, a berm and dune combination. Initial construction would occur on approximately 13.6 miles of beach. A northern project area would extend for 3.5 miles and a disjunct southern project would extent approximately 10.1 miles with a southern terminus at the boundary of the CHNS. Initial construction is estimated to require 14.6 million cubic yards (cy) of material. Addition sediment placements of 4.63 million cy are estimated to be required on an average interval of three years. The total volume of sand for both initial construction and periodic renourishment during the 50-year life of the project is estimated to be 88.7 million cy. Sand would be taken from five offshore borrow areas. The type of dredging equipment has not been specified. A typical profile of the berm and dune has been developed. The top of the artificial dune would be approximately 13 feet above mean sea level. The landward starting point for sediment placement has not been specified.

Impacts of the Preferred Alternative - Project impacts fall into two broad categories: direct and indirect, or secondary, impacts. There are also long-term ramifications associated with initiating an artificial beach-dune system on a barrier island. The Service has identified ten direct project impacts. Dredging will kill all the plants and animals within the sand removed from borrow sites. The preferred alternative would increase turbidity during dredging of sand at the offshore borrow sites. Dredging would increase offshore sedimentation as suspended particles are carried away from the actual dredging site and settle to the bottom. If hardbottom habitats occur near dredging sites, these unique and valuable habitats could be destroyed. Offshore fisheries could be harmed by lost of food resources and habitat. Sediment flowing off the beaches could harm both nearshore invertebrates, fish, and marine mammals. The material flowing off the beaches would result in sedimentation similar to that produced by offshore dredging. Placement of sediment on the beach will kill the existing infauna through suffocation or loss of access to food. Sediment placement during the sea turtle nesting and hatching season, May 1 through November 15, can lower reproductivity. Work on the beach would disrupt feeding and roosting by shorebirds, including the piping plover. Dredging vessels could risk hitting marine mammals.

The most serious project impacts are likely to be indirect. Removal of sand from the offshore borrow areas may permanently alter the physical characteristics of the areas and impact the benthic flora and fauna adapted to existing conditions. In addition to changes in species composition and abundance, the removal of offshore sand may also reduce primary productivity. There could be a deterioration of nearshore habitat quality due to long-term turbidity from the artificial beach-dune system. Depending on the frequency at which additional sediment is placed on the beach, beach invertebrate populations within the supralittoral and intertidal zones may be eliminated or greatly reduced. Offshore dredging can remove offshore sand bars and shoals that provide important protection to the beaches. Offshore holes produced by dredging may either increase wave energy or change refraction patterns, or both. The introduced material would alter the waves approaching the shore and, to some extent, serve to redirect wave energy. The creation of a steeper slopes immediately seaward of the berm would allow waves with greater energy to strike the beach and speed up the loss of sediment from the beach. The artificial beach-dune system could lose on average 1.54 million cubic yards of sand per year. The predominant north-to-south longshore transport system is likely to carry some of the this sand south to Oregon Inlet. This influx of sand could block the Oregon Inlet navigation channel. The beach-dune system may lead to more development of greater density within shorefront communities that are then left with a future of further replenishment or more drastic stabilization measures. Additional growth and population increases will put pressure on existing freshwater supplies and increase problems associated with wastewater disposal.

The artificial beach-dune system would have indirect impacts on sea turtle reproduction. Changes in the physical characteristics of the beach, which may be considered permanent, would result in adverse impacts on nest site selection, digging behavior, clutch viability, and emergence by hatchlings. Beach compaction and unnatural beach profiles that could result from beach nourishment activities would negatively impact sea turtles regardless of the timing of projects.

The project may produce indirect adverse impact on piping plovers. The construction of houses and commercial buildings on and adjacent to barrier beaches directly removes plover habitat and results in increased human disturbance. Functional habitat loss occurs when suitable nesting sites are made unusable because high human and/or animal use precludes the birds from successfully nesting.

While it is comforting to view the preferred alternative in the relatively short term of only a few decades, many very disturbing problems arise when the time frame is expanded outward to 50, 100, or more years. Efforts to fix the location of the barrier islands will ultimately lead to their destruction, or at the least the destruction of the natural characteristics upon which important fish and wildlife resources depend. First, this project represents a commitment to protect structures in their present location despite a rising sea level that would, under natural conditions, force the island to move landward. Second, this commitment will be extremely difficult to reverse. Pilkey et al. (1998, p. 107) note that once shoreline engineering is started, it can't be stopped. Third, maintaining structures in their present location will become increasingly expensive.

Comparison of Impacts - A comparison of the two broad options for storm damage reduction shows that a combination of land use polices and construction standards has benefits over the creation of an artificial barrier that must be perpetually reconstructed. The former option moves buildings out of harm's way and protects them when, not if, high wind and storm waves reach them. The second option does nothing to prevent wind damage and overland storms surges from the sound. If the barrier is not extremely high, storm surges from the strongest hurricanes will overtop it.

The creation of the artificial beach-dune system has more direct adverse impacts than a combined program of higher construction standards and land use planning. The latter produces none of the direct impacts associated with the former. The latter option produces only two of the 11 indirect impacts associated with the former. Both broad alternatives would allow development and population growth to continue. A relocation strategy for threatened buildings has several advantages which are: (1) removing threats to buildings; (2) allowing natural shoreline processes to continue; (3) preserving the beach; and, (4) the possibility of one-time-only cost.

Fish and Wildlife Conservation Measures and Recommendations - The Service supports the project goal of storm damage reduction and it is only logical to require buildings to be separated from destructive forces. However, there are conservation measures that should be applied to any storm damage reduction endeavors on the Outer Banks. First, the NEPA planning process must be employed to clearly define the project purpose and develop the widest range of alternatives. Second, specific measures to minimize adverse direct impacts of the preferred alternative must be developed. Finally, measures to eliminate or reduce the serious, long-term indirect impacts of the preferred alternative must be considered. Based on the Service's concerns for project impacts, conservation measures have been developed. These measures are summarized in a series of concise recommendations that are presented in numerical order in the following paragraphs.

Regarding the NEPA process, the extent to which the project hopes to reduce storm damage, the project purpose, must be clearly established. It is impossible to eliminate all damage from coastal storms on the Outer Banks. Therefore, certain parameters must be defined that set clear boundaries on what the project can and cannot be expected to accomplish. The Service recommends that:

1. The EIS should define the level of storm for which protection is sought; the type(s) of storm damage which would be reduced; and, those locations within the project area for which protection is sought.

2. The EIS should present the entire range of alternatives that achieve the desired storm damage reduction without regard for cost, social impacts, or the jurisdictional authority of the Corps. Two excellent references (Bush et al. 1996 and Pilkey et al. 1998) should be consulted.

After alternatives are developed, the Corps should explain the evaluation of each alternative and the process leading to the selection of a preferred alternative. The selection of the preferred alternative should be based on an overall consideration of cost, social impacts, and environmental impacts. While the first two categories are more measurable, they should not be allowed to override environmental concerns. The planning process should consider the durability of each alternative. The analysis should consider that greater storm damage reduction may be achieved with smaller scale sediment placements when coupled with improved zoning and construction standards.

The Service recommends that:

3. Once all alternatives have been developed, the Corps should balance the desired level of storm damage reduction against social and environmental impacts in the selection of the preferred alternative. The EIS should discuss the factors that lead to the preferred alternative. Important questions that the EIS should answer are:

    a. Would a series of smaller sediment placements, perhaps on an annual basis, be more cost efficient in achieving the desired level of storm damage reduction?

    b. Would the proposed artificial beach-dune system provide protection against such low intensity storms (e.g., hurricane categories 1 and 2) and to such a limited area of structures that a program of selective relocation, strict zoning/setback requirement, retrofitting existing buildings, and stricter building codes for new buildings be more cost efficient?

If the NEPA process confirms that the current preferred alternative should be constructed, conservation measures should be used to avoid or minimize direct impacts. Elimination of the offshore benthic community in the sediment removed, can be minimized, but this community will be lost in the areas used for borrow material. The Service recommends that:

4. The Corps should establish a program to monitor dredging impacts on primary productivity and benthic invertebrate community composition. The program should assess the biomass and species composition of organisms that recolonize borrow areas. The program should include pre-project baseline data and post-project data at one-, three-, five-, and ten-years after dredging. The program should use at least one area each among the two northern and three southern borrow area groups. At three, five, and ten years after sediment removal, data collected should be compared with offshore fisheries data (e.g., species composition, diversity, food habits, landings, catch per unit effort, and other appropriate information) in order to produce an overall evaluation of dredging impacts on offshore fisheries. If these comprehensive evaluations indicate that fisheries resources have been adversely affected, the Corps should work with the Service and National Marine Fisheries Service to develop a mitigation program for the remaining decades of the project.

5. The Corps should ensure that no 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 borrow sites and the review of data provided by the Southeast Monitoring and Assessment Program (SEAMAP). The Corps should fund a program to measure sedimentation and biological productivity in selected hardbottoms in all areas surrounding the borrow areas. If hardbottoms are adversely affected, the project should include specific measures to mitigate any adverse impacts.

Other conservations measures for direct impacts fall into two broad categories: (1) ensuring that the offshore sand is very compatible with existing beach sand; and, (2) establishing the work period. For some direct impacts, such as disrupting offshore fish, conservation measures may involve both sediment compatibility and seasonal work schedule. In order to reduce both turbidity and subsequent sedimentation, the Service recommends:

6. In order to minimize both the direct and indirect impacts of turbidity and subsequent sedimentation, the Corps should ensure: (1) that the project not use sediment which consists of more than ten percent silt and clay particles; and, (2) the project should use only the three coarsest grades of sand (medium, coarse, and very coarse). These construction restrictions would not only reduce turbidity, but would also prolong the life of the artificial beach-dune system and thereby increase the time between beach-dune reconstruction. The project EIS should contain a Sand Suitability Analysis in accordance with procedures of the Corps' Coastal Engineering Research Center.

There is no single month, or even a single season, when all adverse impacts to important fish and wildlife resources could be avoided. From a strictly biological point of view, the least harmful six-month period would probably be the months of October through March. It is very difficult to assign relative importance to the various fish and wildlife resources in the project area. Offshore fisheries would be harmed by dredging during the winter. However, mitigation alternatives may be available to these species and from an overall perspective, the least damaging time for dredging and beach disposal is the colder months of the year. The Service recommends:

7. Since there is no single period of the year when work could be scheduled to avoid adverse impacts to all the fish and wildlife resources in the project area, the best way to minimize adverse impacts is to reduce the duration of construction. Reduced construction time can be achieved by the simultaneous use of more than one dredge. On balance, the most limited resources, e.g., an undisturbed beach, would benefit from dredging during the winter months. Therefore, the Service recommends that initial construction be accomplished by using at least two dredging vessels that commence work on or after October 1. These vessels would work as weather allows through the winter and attempt to finish initial construction by March 31. If some work remained after March 31, these vessels would continue work into the spring until work was completed. Sediment replacement operations should follow a similar pattern, but with a reduced work period. Replacement operations should be limited to the period from November 1 through the end of February. Scheduling beach disposal outside the larval recruitment period of beach invertebrates will ensure better recovery of these species.

To avoid or minimize harm to nesting sea turtles the Service recommends that:

8. If sediment placement extends into the sea turtle nesting and hatching season, May 1 through November 15 of any year, the Corps must initiate formal consultation in accordance with Section 7 of the Endangered Species Act. Sediment placement during this period will require a program of sea turtle nest monitoring and relocation. Furthermore, the Corps should incorporate measures designed to help state-approved sea turtle monitoring programs into formal project plans.

There must be measures to ensure that whales and porpoises are not directly harmed by the dredging and transport of sediment. Such measures may included observers on the dredging vessels. To avoid or minimize harm to marine mammals the Service recommends that:

9. The Corps should coordinate with the National Marine Fisheries Service to develop procedures to avoid adverse impacts to marine mammals that may occur in the area of the offshore borrow sites.

As with the offshore benthic community, the Corps should develop plans to ensure that adequate populations of beach and nearshore invertebrates are maintained. To that end, the Service recommends that:

10 . The project should include a monitoring program on beach and subtidal invertebrates that form an important food resource for shorebirds. 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 the Cape Hatteras National Seashore just south of the project area. There should be an additional requirement to quantify changes in biomass and community composition at one-. three-, five-, and ten years after initial construction. If any assessment indicates a significant decline in either biomass or the number of species present when compared to control areas, there should definite procedures in place to develop mitigation for this community.

Direct impacts to nearshore and offshore fisheries would be minimized by ensuring strict compatibility of dredged sediment with existing beach sand and working during a period of low biological activity. To protect these important fisheries resources the Service recommends that:

11. The Magnuson-Stevens Fishery Conservation and Management Act and Sustainable Fisheries Act of 1996 (Public Law 104-297) requires that essential fish habitat (EFH) be identified. The Service believes that over the 50-year life of the project, some or all of both nearshore or offshore areas impacted by this project may be designated as EFH. The Corps must consult with the National Marine Fisheries Service regarding the impact of the proposed project on those species for which the proposed borrow sites and adjacent areas have been determined to constitute Essential Fish Habitat (see references, Appendix B, Table 1). Although the study area has not been formally designated as EFH for anadromous species, management councils are mandated to comment to the Corps regarding the impact of the proposed project on those species; therefore, the New England, Mid-Atlantic and South Atlantic Fishery Management Councils, as well as the Atlantic States Marine Fisheries Commission, should be contacted and provided with an opportunity to review the Corps' draft environmental document for the proposed project.

    The consultation process in the Southeast Region of the NMFS is addressed in NMFS (1999). As noted in the Introduction and Table 1 of Appendix B, the study area has been designated as EFH for species other than those addressed herein through the analysis of data from Cooperative Winter Tagging Cruises. NMFS (1999) contains a list of the species managed by the SAFMC and NMFS, their EFH, and the geographically defined Habitat Areas of Particular Concern (HAPC) identified in Council Fishery Management Plans. In North Carolina, the SAFMC identified the sandy shoals of Cape Hatteras, not too distant from the study area, as an HAPC.

    Consultation requirements in the Magnuson-Stevens Fishery Conservation and Management Act direct federal agencies to consult with NMFS when any of their activities may have an adverse effect on EFH (NMFS 1999; see also NOAA 1999 for information on the NMFS northeast region). The EFH rules define an **adverse effect** as "any impact which reduces quality and/or quantity of EFH...[and] may include direct (e.g., contamination or physical disruption), indirect (e.g., loss of prey, reduction in species' fecundity), site-specific or habitat wide impacts, including individual, cumulative, or synergistic consequences of actions." Since the proposed project would result in the removal from the study area of an estimated 88.7 million cy of substrate during the course of the proposed 50-year project life, it would appear that it meets the criteria for constituting an adverse effect and that the Southeast Region of NMFS should be contacted by the Corps for that purpose.

Shallow dredging over an extensive area may cause less environmental harm than deep pit dredging. Shallow dredging may minimize the possibility of deep holes filling with finer grain sand and thereby changing the nature of the bottom substrate. Offshore shoals and underwater ridges are desirable habitats for many species of fish. Benthic plants would benefit from smaller increases in depth. The Service recommends the following measures to minimize the long-term impacts on all offshore benthic organisms:

12. Dredging should leave a sufficient layer of sediment that matches as closely as possible the original surface layer to avoid exposing a dissimilar sediment; and,

13. Borrow material should be removed in thin layers over a wide area rather than from localized areas that would create numerous deep pits that are likely to refill with much finer material and permanently alter the nature of the substrate.

Beach invertebrates would appear to benefit from series of small projects as opposed to a single large project which covers many miles of beach. Such a procedure would allow beach invertebrates to recolonize the impacted zone from nearby, unaffected beaches. Therefore, the Service recommends that:

14. The Corps consider dividing the entire target beach into nine sections and establishing a sequence of work for placing sediment of one-third of the sections each year. Year one would use sections 1, 4, and 7; year two would use sections 2, 5, and 8; and year three would use sections 3, 6, and 9. After three years the process would be repeated.

Harm to fish and wildlife resources will be lessened by prolonging the life of the artificial beach-dune system. Measures which prolong the life of the beach-dune system will minimize all the direct impacts as well as minimize the cumulative impacts by allowing time for impacted population to recover. Certain dredging procedures may lead to altered offshore and nearshore bathymetry that produces increased wave energy striking the beach, altered wave patterns, and a steeper beach profile that also allows greater wave energy to strike the beach. An indirect impact of these changes would be the requirement for more frequent sediment additions that increase all the direct impacts of dredging and sediment placement. Therefore, the Service recommends that:

15. Borrow areas should be seaward of the active shoreface of the beach and sand sources on the Outer Continental Shelf should be considered in order to avoid any significant changes in the bathymetry over which waves approach project area beaches.

16. Existing offshore sand shoals or sand bars should not be removed for use in creating the beach-dune system.

17. The project EIS should include an analysis of changes in wave patterns and wave energy striking the shoreline that would occur as a result of removing sand from the offshore borrow pits. The analysis should determine the effect that changes the offshore bathymetry would have on wave energy reaching the beaches and the possibility for even greater rates of shoreline recession. This analysis should specifically discuss the condition that would exist in the 50th year of the project when as much as 30 feet of sediment may have been removed from some offshore areas.

Based on present calculations, approximately 1.5 million cubic yards of sand would disappear from the project area beaches every year of the 50-year project. Some of this sand will be carried by the predominant north-to-south longshore current to Oregon Inlet where the Corps has had difficulty maintaining the authorized navigation channel. Without adequate planning and resources for additional dredging the Oregon Inlet navigation channel may become blocked to commercial fishing vessels. Therefore, the Service recommends that:

18. The EIS should fully discuss: (1) the potential rates of sediment losses from the beach fill using data on the various grain sizes available (the Sand Suitability Analysis); (2) the likely pathways that may carry as much as 1.5 million cubic yards of sand per year for 50 years away from the beach; and, (3) the likely locations that would ultimately receive the sediment carried away from the beach.

19. In light of the serious difficulties that the Corps has had in maintaining the important navigation channel at Oregon Inlet (USACOE 1999), the EIS should present a plan for dredging the additional sand that will be carried to the Oregon Inlet navigation channel. This plan should consider the feasibility of adding the additional dredging costs to the storm damage reduction project. In order to avoid delays in responding to any closure of the navigation channel, a Memorandum of Agreement should be signed by the Corps, Service, NPS, and the Dare County government that clearly establishes the procedures to be used and the methods of funding for emergency dredging. An EIS without such a plan and a MOA to ensure its implementation would be inadequate.

There are no conservation measures which can be associated with the current project to address the impacts of additional population growth and development. If the current project conveys the idea that a firm commitment has been made to halt beach recession, increased development will occur near the beach.

If beach disposal is conducted anytime during the sea turtle nesting and hatching season, the project may affect the loggerhead and, to a much smaller extent, the green sea turtle. The Corps will be expected to initiate formal consultation under Section 7 of the Endangered Species Act. If formal consultation is initiated, the Service will provide the Corps with a Biological Opinion which specifies reasonable and prudent measures along with term and conditions to minimize adverse impact to sea turtle reproduction. Conservation measures for shorebirds, including the piping plover, involve actions to maintain the productivity of area beaches, preserve water quality, and minimize the time spent working on the beaches.

Summary of Findings and Service Position - Barrier islands and spits are inherently dangerous places for any man-made structures such as roads, houses, or utility infrastructure. The faith in modern technology, government sponsored insurance that the private sector finds too risky, and a recent absence of major storms have resulted in expansive development on an ocean shoreline that is retreating in the face of a rising sea. As the ocean moves closer to fixed structures the risk of storm damage increases. The Service recognizes the increasing risk of storm damage and supports the goal of reducing such damage.

The key question is not whether to seek storm damage reduction, but the best method to achieve this goal on a barrier island. The Corps has proposed the creation of an artificial beach-dune system between the ocean and structures on the shoreline. Current planning documents do not fully explain the alternatives that were considered or the reasoning leading to the selection of this alternative.

The Service finds that the decision to construct an artificial beach-dune system requires greater justification. This is necessary because: (1) the creation of an artificial beach-dune system from sand dredged offshore is not an innocuous procedure; (2) while sand may be added to a beach that is a part on the mainland without a threat to the long-term existence of the uplands behind the beach, an artificial barrier along only one side of a barrier island cannot provide real long-term protection; and, (3) there are proven alternatives to constructing beaches and dunes for storm damage reduction that have not been adequately considered. The Service finds that currently planning for storm damage reduction in northern Dare County has not presented evidence that all direct and indirect environmental impacts of constructing an artificial beach-dune system were fully considered in the selection of the beach-dune system.

The development of alternatives and the selection process for a preferred alternative should include clear definitions of: (1) the level of storm for which protection is desired; (2) the types of damage to be reduced; and (3) the precise area to be protected. These considerations are critical in fully describing the long range, secondary impacts of the project. In regard to a very serious, potential project impact, the Corps and the Service must work together to ensure that the placement of millions of cubic yards of sand on project area beaches is not allowed to close the Oregon Inlet navigation channel without a specific, adequately funded plan in place before the start of any sand placement.

While the Service has reservations about the long-term efficacy of an artificial beach-dune system to protect existing structures on a barrier island, the decision to postpone the day of reckoning ultimately lies with the citizens of the project area and their elected representatives. If the thorough evaluation of all social and environmental factors required by the planning process should confirm that an artificial beach-dune system is the best overall alternative, we believe that the incorporation of the Service's recommendations into the design and construction of the project will avoid or minimize many of the most serious adverse impacts on the fish and wildlife resources in the project area.

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SECTION 1. INTRODUCTION

Authority

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). This Act 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 draft report will be submitted to the NCWRC for their review and comments. The report, when finalized, will include a letter of concurrence from the NCWRC and will constitute the formal report of the Service under Section 2(b) of the FWCA.

Subject of This Report

In 1990 the U. S. Congress authorized funds for a reconnaissance study of problems associated with erosion on the beaches of Dare County. On July 23, 1997, the U. S. Army Corps of Engineers (Corps) published a Notice of Intent (NOI) in the Federal Register to prepare a Draft Environmental Impact Statement (DEIS) for the Dare County Beaches Project, Dare County, North Carolina. The NOI stated that the shoreline protection project would involve the placement of a berm and, where necessary, the establishment of a dune line on approximately 10 miles of beach within Dare County north of Oregon Inlet (Figure 1). The most likely sand sources at that time were various offshore borrow sites. Routine renourishment would be required at 3-5 year intervals, but portions of the project area could require more frequent renourishment.

Scope

The geographic scope of this report includes all areas that would be directly or indirectly impacted by the proposed project. The area includes not only the beaches of Dare County north of Oregon Inlet, 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 the renourished beaches. In all cases these areas represent habitat for fish and wildlife resources, and these resources will be considered.

Prior Studies and Reports

Offshore Mineral Resources

The Offshore Minerals Task Force, a joint effort by federal and State of North Carolina agencies, was formed in 1986 to study phosphorites and heavy metals offshore of North Carolina. The task force, now known as the Offshore Sand Resources Task Force, broadened its scope to assess offshore sand resources for beach nourishment with particular concern for the Outer Banks. The first phase of the study involved conducting a shallow, high-resolution seismic survey to identify potentially suitable sand resources for beach nourishment. The U.S. Minerals Management Service (USMMS) contracted the North Carolina Geological Survey to delineate potential sand sources offshore. The study was conducted within 200 nautical miles offshore of Dare County. Initial seismic surveys were completed in the summer of 1992 for an area north of Oregon Inlet between approximately 1 mile and 15 miles offshore.

Bonner Bridge and Terminal Groin

Other related studies include those concerning protection of Bonner Bridge, constructed in the early 1960s, at Oregon Inlet to the south of the project area. The groin was constructed during 1989-1991. This bridge and the subsequent need for a groin at the north end of Pea Island revealed several important issues associated with shoreline recession and sand management.

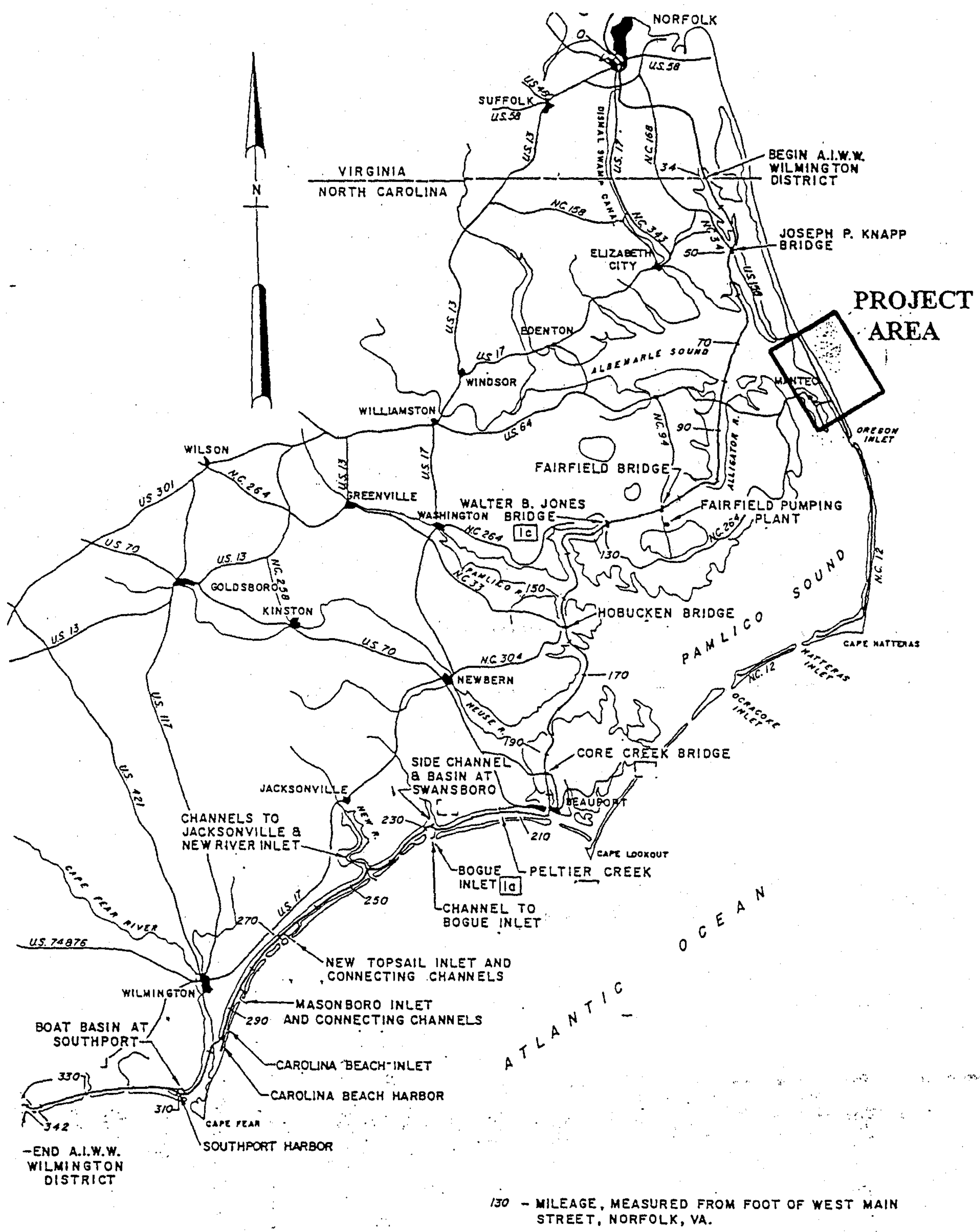

Figure 1. Map of eastern North Carolina showing the general location of the Northern Dare County Storm Damage Reduction Project. Source: Wilmington District, U. S. Army Corps of Engineers, Wilmington, North Carolina.

Coastal conditions at the inlet have been investigated. Moffatt and Nichols (1991) reported on many of the geologic and other physical conditions in the area. The Service prepared an Environmental Assessment prior to issuing a special use permit for the groin (U. S. Fish and Wildlife Service [hereafter USFWS] 1989b). A Draft Environmental Impact Statement (EIS) has been released for the replacement of the existing bridge (North Carolina Department of Transportation [hereafter NCDOT] 1996).

Oregon Inlet Jetties

The construction of a dual jetty system at Oregon Inlet was authorized by the U. S. Congress in 1970 as part of the Manteo (Shallowbag) Bay Project. Due to significant concerns expressed by the Service, the National Park Service (NPS), and National Marine Fisheries Service (NMFS) about the environmental impacts of the jetties, project plans have been modified over the years. A revised EIS was released by the Corps (U. S. Army Corps of Engineers [hereafter USACOE] 1999). Since the dual jetty system would alter natural sediment movement along the coast and influence erosion, many studies have addressed the issue of beach erosion and the sand management system which would be a part of the project. Inman and Dolan (1989) summarized numerous other studies focusing on barrier island geology, inlet dynamics, sediment budgets, morphology, and shoreline changes of the Outer Banks of North Carolina. The Service discussed the environmental issues surrounding potential erosion and the bypassing of sand for placement on area beaches in a Draft FWCA Report (USFWS 1998).

Outer Banks Task Force - NC 12

Following the construction of artificial protective dunes in the 1930s, NC 12 was constructed from Nags Head to Ocracoke Island during the 1950s and 1960s. The highway crosses the Pea Island National Wildlife Refuge (PINWR) and parts of Cape Hatteras National Seashore (CHNS). The erosion of beaches and dunes have left the highway vulnerable to blockage by flooding and deep sand left by ocean overwash and even the threat of direct loss in erosional "hot spots." The North Carolina Department of Transportation (NCDOT) prepared a report on the environmental resources of Hatteras Island (McCrain 1988), and they studied coastal highways in North Carolina to determine which areas are most vulnerable to erosion and flood damage and to determine what can be done about the problem (Stone et al. 1991).

In November, 1993, a formal Memorandum of Understanding (MOU) was signed by the Federal Highways Administration, NPS, U. S. Fish and Wildlife Service, Corps, NC Department of the Environment, Health and Natural Resources, and the NCDOT. The NMFS joined the group in March, 1994. The three goals of the partnership are: (1) preserve and minimize impacts on the natural barrier island system; (2) maintain transportation access to and on the islands that is safe, efficient and causes minimal environmental impact; and (3) develop a formal process to achieve these goals.

Dare County Beaches

In response to increasing concern over beach erosion problems in Dare and Currituck Counties, the North Carolina Coastal Resources Commission (NCCRC) established the Outer Banks Erosion Task Force on January 27, 1984. The task force made recommendations regarding erosion control and reported their findings in the Outer Banks Erosion Task Force Report of July 1984 (North Carolina Coastal Resources Commission [hereafter NCCRC] 1984). The task force recommended that hard structures, such as jetties and bulkheads, not be allowed as beach protection and that temporary measures, such as the use of beach nourishment, sandbag bulkheads, and beach pushing, only be allowed to protect structures until they can be moved landward or until the effect of a short-term erosion event has passed.

In the late 1980s the Corps considered a beach nourishment project for the Town of Nags Head. The beaches under consideration ranged from Whalebone Junction in the north to the southern town limits. Potential borrow areas were estuarine bottoms in Roanoke Sound and the flood tide shoals of Oregon Inlet. The Service prepared a Planning Aid Report (PAR) for the Reconnaissance Study in April 1989 (USFWS 1989a). The Corps prepared an Environmental Reconnaissance Report for that project in July 1989 (USACOE 1989). The Corps' report noted that shoreline erosion ranged from ten feet per year in the southern section of Nags Head to two feet per year near Whalebone Junction. The report stated that "severe beach erosion along the beaches fronting south Nags Head can be expected to continue as a major problem, with the possibility that beachfront cottages along the oceanfront will be lost to erosion."

The 1994 update of the Dare County Land Use Plan considers the issue of shoreline management and beach nourishment. The plan notes that the preferred alternative is beach nourishment (Dare County 1994, p. 91).

The Service prepared an initial PAR on the project in May 1992. Due to changes in the project the Service prepared a revised PAR for the Corps in December 1992.

Acronyms used in this report will be defined when first used. A list of all acronyms used is given in Appendix A.

SECTION 2. STUDY AREA DESCRIPTION

General Project Area

Dare County consists of rural mainland areas and a barrier island system separated from the mainland by Currituck, Roanoke, Croatan, and Pamlico Sounds. The barrier island system is part of the Outer Banks of North Carolina, a series of long, narrow barriers extending south to Bogue Sound (Figure 2). The study area includes the beaches of Dare County from the Currituck County line to the boundary with Cape Hatteras National Seashore, as well as potential sand borrow areas (Figure 1). The locations within the study area experiencing the most severe erosion problems have been or will be identified, and erosion control measures will focus on these highly vulnerable areas. The general project area also includes the uplands and wetlands of the barrier islands that could experience secondary impacts as a result of the project.

The Outer Banks of Dare County north of Oregon Inlet are not technically barrier islands. At the present time that portion of the North Carolina's Outer Banks from the Virginia State Line to Oregon Inlet, a distance of approximately 55 miles, has an unbroken connection to the mainland and is therefore a barrier spit. However, numerous historical inlet locations support the fact that the areas of Kitty Hawk, Kill Devil Hills, and Nags Head were part of a true island in the past and are likely to be a true barrier island in the future (Bush et al. 1996, p. 89). The last inlet into Currituck Sound was Caffey's Inlet near the Dare-Currituck County Line. This inlet opened in the period of 1790-1798 and closed between 1811 and 1829 (Pilkey et al. 1998, p. 139). Within historic times other former inlets north of Oregon Inlet were Old Currituck Inlet, New Currituck Inlet, Musketo Inlet, and Trinity Harbor Inlet. The technical location of the project area is Currituck Spit, but this report will use the convention of others (Bush et al. 1996, p 87, Pilkey et al. 1998, p. 137-138) and refer to the project area as a barrier island.

Physical Environment and Important Coastal Processes

The Outer Banks of North Carolina are unique among the world's coastal landforms in their distance from the mainland and their distinct shape (Frankenberg 1995, p. 1). The islands constitute a classic example of a transgressive barrier island coast with cuspate headlands (Inman and Dolan 1989). Mid-Atlantic barrier islands are typically narrow, linear, and low in elevation. Both Hatteras and Bodie Islands generally have elevations below 10-15 feet above mean sea level (msl), with a few dunes over 100 feet above msl. The nature of the Outer Banks is a function of three, major environmental processes: rising sea level, transport of sand by wind and water, and immobilization of sand by plant growth (Frankenberg 1995, p. xi).

Origin and Development of the Outer Banks

The barrier islands were created approximately 5,000-8,000 years ago (Inman and Dolan 1989) at a time when world sea level was much lower (Figure 3). Some geologists believe that the barrier islands were born at the edge of continental shelf, where it drops off toward the oceanic abyss

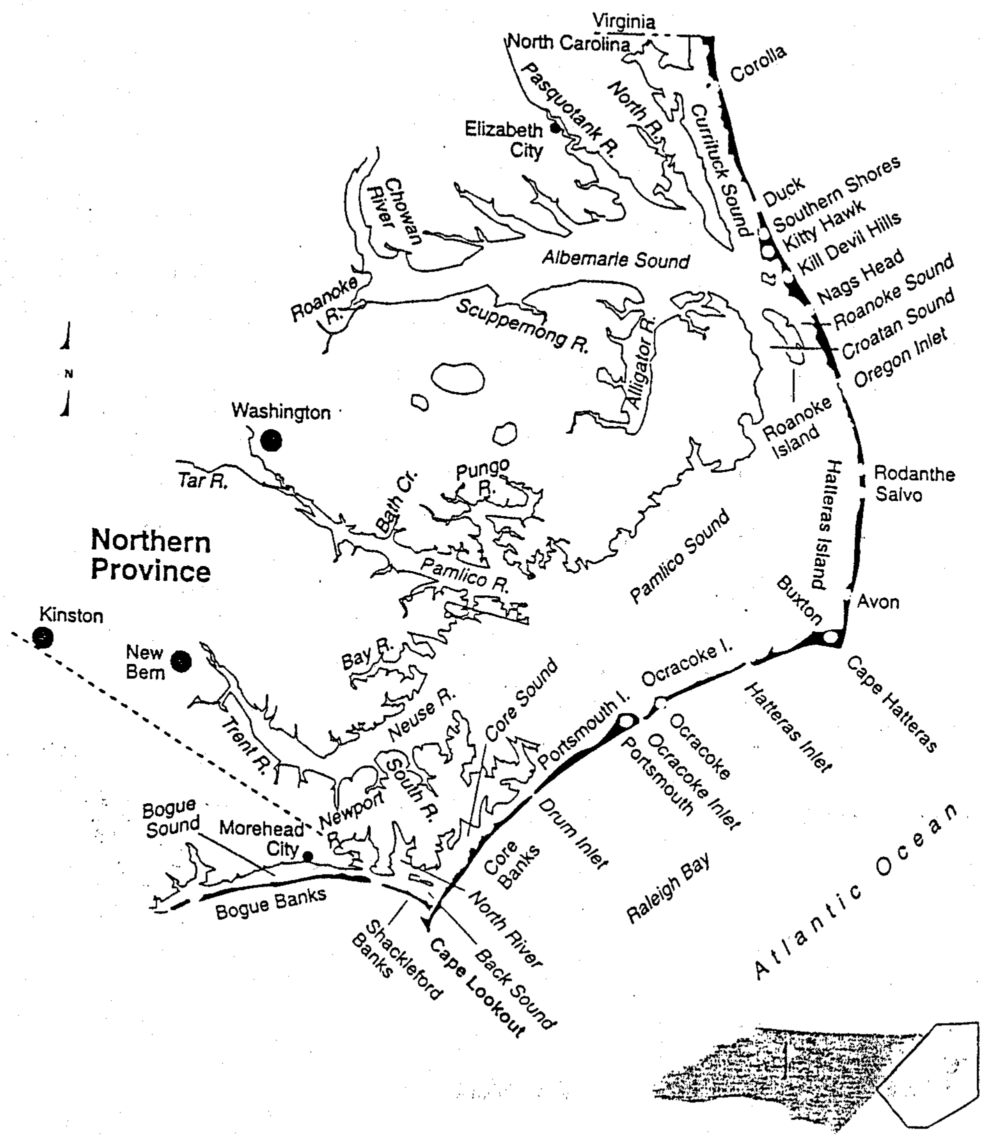

Figure 2. Northeastern coast of North Carolina showing the principle features of the Outer Banks including the three towns (Kitty Hawk, Kill Devil Hills, and Nags Head) that would benefit from the Northern Dare County Storm Damage Reduction Project. Source: Pilkey et al. 1998. p. 10. Used with permission of Duke University Press.

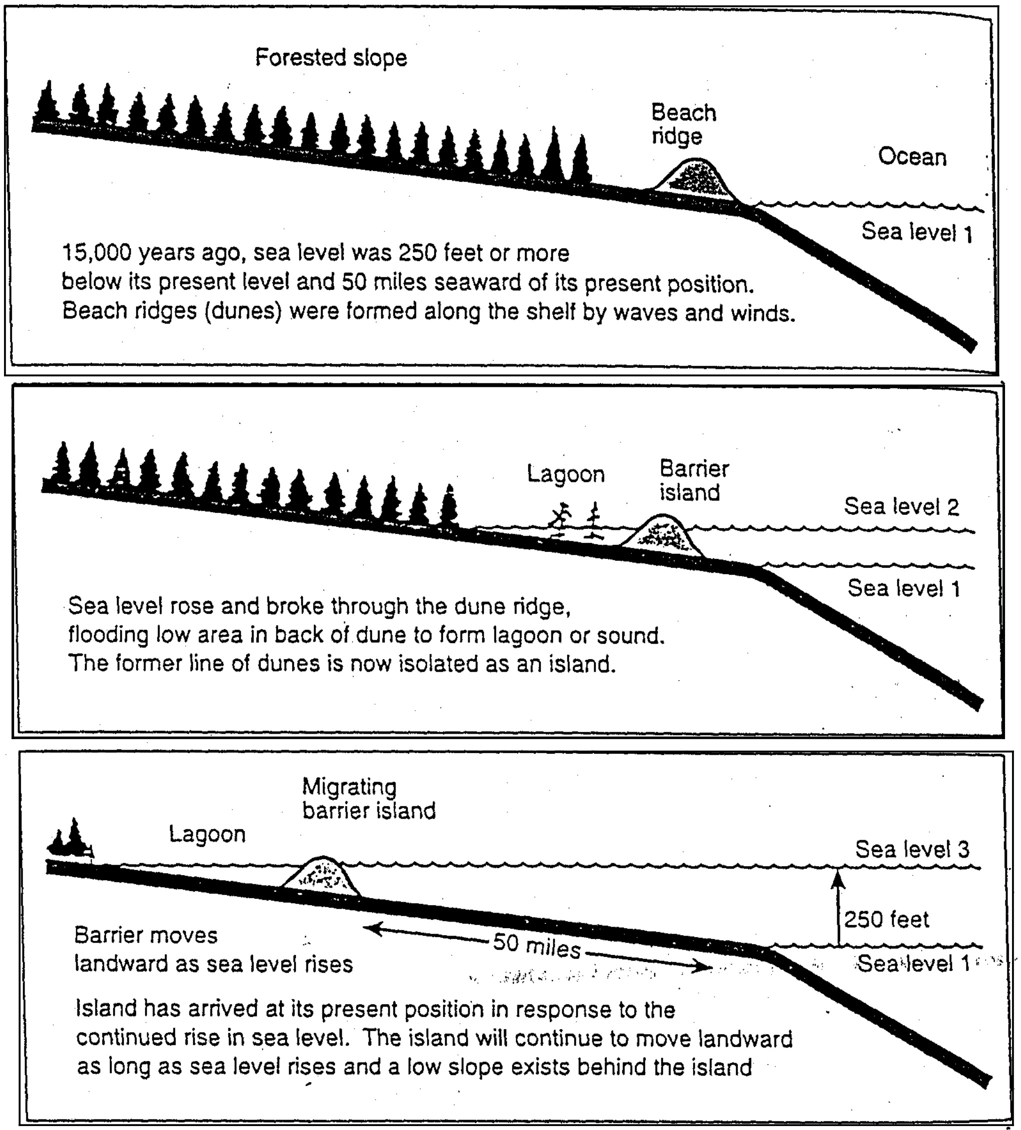

Figure 3. Diagrammatic representation of the possible origin and landward migration of the Outer Banks of North Carolina. Source: Pilkey et al. 1998. p. 42. Used with permission of Duke University Press.

(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. If the original masses of sand which were to become the Outer Banks had been held in place upon their initial formation, the sand ridges would now be miles seaward of their present location and completely underwater.

Rise in Sea Level

Sea level has risen approximately 3.9-7.8 inches during the past century (Michener et al. 1997). The rise is related to a general increase in temperature, but the extent to which global climate change is a natural phenomenon or influenced by human activities is uncertain. Warmer temperatures affect sea level by increasing the melting of large bodies of ice, but also cause thermal expansion since the density of seawater decreases as temperature increases.

The rate of sea level change during the recent past may not be the same that will occur in the future. The rate of sea level rise is likely to increase in the future. Pilkey and Dixon (1996, p. 19) state that sea level has remained "more or less the same" over the last 4,000 years (Figure 4). During this period many islands, such as Bogue Banks in North Carolina, grew seaward rather than retreating toward land. However, over the last century or two some islands along the Atlantic and Gulf Coasts began to narrow on all sides due to erosion. This erosion is probably a response to sea level rise (Pilkey and Dixon 1996, p. 20). Recent data indicate that along much of the United States coast sea level is rising at a rate of 10-12 inches (Titus and Narayanan 1996) or several decimeters (one decimeter = 3.9 inches) (Michener et al. 1997) per century.

Coastal Storms

The project area is subject to two broad types of coastal storms, hurricanes and northeasters.

Northeasters - Northeasters, or nor'easters, may form over land in areas where the atmosphere is unstable and air masses of different temperatures meet. The primary season for northeasters is from October through April, with the most storms during February (Davis and Dolan 1993). These storms commonly produce waves 5-33 feet high (Davis and Dolan 1993) that can be very destructive, but their effect is much greater when accompanied by a high storm surge. A storm surge is defined as the difference between the observed and the predicted water levels (tides) during the passage of a coastal storm. This surge results from the combined effect of wind stress and a rise in the water's surface level caused by the storm's low air pressure. The most severe northeasters can generate storm surges up to 16.4 feet (5 meters) on open coasts. Surges of severe northeasters are especially destructive if slow movement allows them to span several tidal cycles.

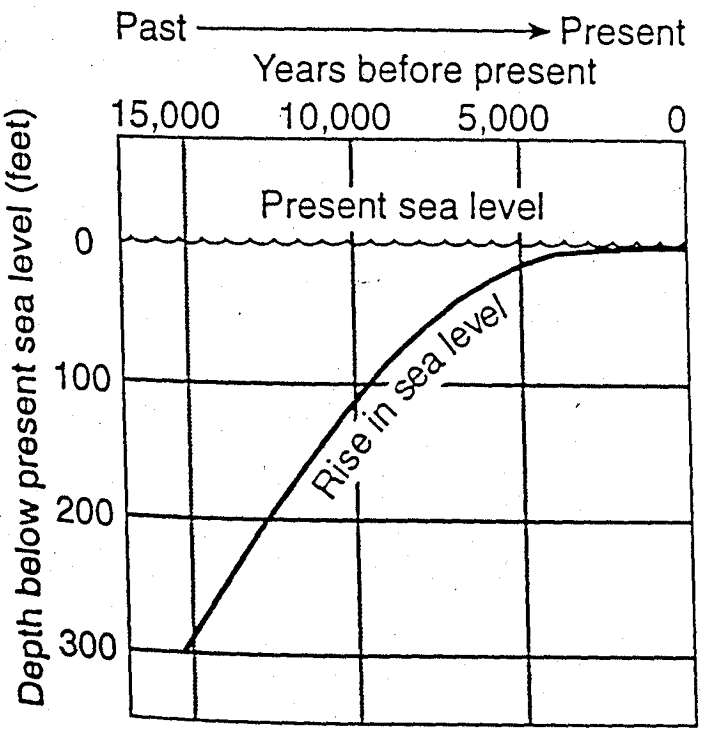

Figure 4. Graph of the rise in sea level over the past 15,000 years. The rate of change has leveled off during the past 4,000 years, but a continued rise in global temperature could cause the rate of rise to increase in the future. Source: Pilkey et al. 1998. p. 41. Used with permission of Duke University Press.

The U.S. coast is periodically hit by strong northeasters. The Ash Wednesday Storm, the most famous northeaster in U. S. history, peaked on March 7, 1962, and produced open-ocean waves over 32 feet (10 meters) high and caused over $300 million in property damage along 600 miles (1,000 kilometers) of the Atlantic coast. A single storm in March 1989 along the Outer Banks accounted for two-thirds of the yearly wave power and sediment transport along the coast (Davis and Dolan 1993). A northeaster during March 1993 created waves approximately 15 feet high along much of the east coast.

Hurricanes - Hurricanes form over tropical water and move northward. The official hurricane season begins on June 1 and lasts for five or six months. The east coast of the United States experienced a relatively hurricane-free period from the 1960s until 1989 when Hurricane Hugo struck South Carolina.

Pilkey et al. (1998, pp. 19-30) discuss hurricanes in the context of North Carolina's Outer Banks. Between 1900 and 1996, 25 hurricanes affected North Carolina and 11 of these hurricanes were rated as "major", a ranking of three or more on the Saffir/Simpson scale. These data indicate that a hurricane is "almost a certainty during the lifetime of a coastal structure." (Pilkey et al (1998, p. 22). The storm surge for storms with a predicted occurrence of once in 25, 50, and 100 years along the coast from the Virginia State Line to Cape Hatteras is estimated to be 7.4, 8.2, and 8.8 feet, respectively, above mean sea level (Pilkey et al. 1998, p. 113).

Recent global-climate modeling efforts have produced mixed results related to future hurricane and tropical storm activity (Michener et al. 1997). There is no evidence that the frequency and intensity of hurricanes have increased as the earth has warmed over the past century. However, critical climate thresholds may not yet have been reached (Folland et al. 1990) and some modeling efforts have predicted an increase in the number of hurricanes (Haarsma et al. 1993).

Island Landward Transgression = Beach Erosion

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." Local governments in the project area recognize the phenomenon of island migration and note that "Coastal geologists have concluded that under natural conditions, barrier islands migrate in a manner dependent upon a number of factors. . . . A combination of these factors result in the natural migration of an undeveloped barrier island (Dare County 1994, p. 90).

The major factor in worldwide shoreline recession, or beach erosion, is rising sea level (Pilkey et al. 1998, p. 45). Kaufman and Pilkey (1983, p. 25) wrote that Dr. Peter Rosen of the Virginia Institute of Marine Science used statistics to prove that the rate of shoreline erosion is everywhere controlled by the rise of sea level. Rosen's study stripped away the many masks that have led scientists and laymen to blame erosion on forces that seemed more susceptible to human control. Inman and Dolan (1989) state that "... extensive geological literature makes it clear that the Outer Banks have migrated landward with rising sea level..." 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; Figure 5). 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 Outer Banks 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 sea level rise would naturally produce a 1,000 foot retreat of the shoreline during the 50 year life of the project.

Numerous studies show that over the past 30 to 50 years the barrier island chain from Cape Henry to Cape Hatteras has been transgressing landward (papers cited by Inman and Dolan 1989). The Atlantic shoreline from Cape Hatteras to 6.8 miles north of Oregon Inlet has an average recession rate of about 5.2 feet per year, or 520 feet per century (Inman and Dolan 1989). These data are consistent with the predictions based on Pilkey et al. (1980, p. 21) earlier work given in the previous paragraph.

Island migration occurs as the island rolls over itself like the tread on a bulldozer (Pilkey and Dixon 1996, p. 16). Geologic data indicate that the landward movement of the Outer Banks has produced a transgressive sequence of coarse-grained, horizontally bedded, overwash sands overlying burrowed to laminated back-barrier and lagoonal silty sands (Heron et al. 1984).

The major processes which produce this movement are: (1) 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 the lagoon 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.

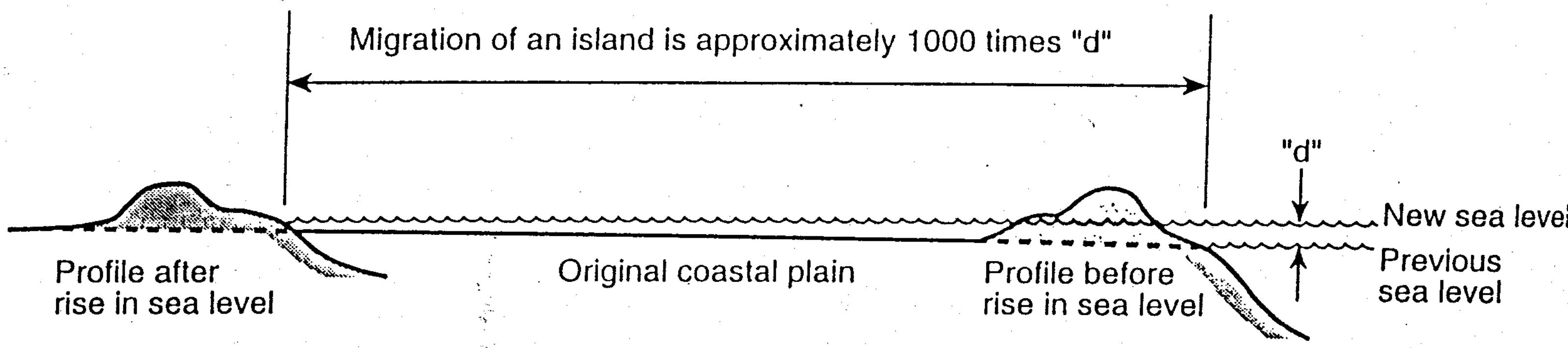

Figure 5. Diagram showing the relationship between a rise in sea level and the horizontal movement of barrier islands. In this example, a one foot rise in sea level on a coastal plain with a very gentle slope would force the islands approximately 1,000 feet up the coastal plain toward the mainland. This process is called island transgression and allow the islands to remain above sea level. Source: Pilkey et al. 1998. p. 44. Used with permission of Duke University Press.

Overwash processes remove more sand from the beaches of the Outer Banks than any other process and account for 39% of the island's landward retreat (Frankenberg 1995, p. 16).

The natural movement of sediment from ocean beaches to the sound side marshes of barrier islands is critical to their ability to exist in the face of a rising sea level. Inman and Dolan (1989) note that if this "rollover" process of barrier island shoreward movement did not exist, the island would have disappeared a long time ago. Kaufman and Pilkey (1983, p. 98) state that "Only the migration of barrier islands keeps them high enough on the coastal plain to stay above sea level. Since sea level is constantly moving, the islands cannot rest."

Not all of the sand leaving the beaches is permanently lost to the barrier island system. Some is washed down to inlets to become part of a flood tide delta, carried landward by the wind, or washed over the island by strong waves. Through a variety of natural processes, some of the sand lost from the beaches is working to build up the landward side of the island and thereby ensure the island's continued existence of the island. The popular concept that beach "erosion" is gradually leading to the destruction of barrier islands is directly contradicted by geologic data.

The geological phenomenon of island transgression is directly tied to issue of shoreline recession which has resulted in some structures being at high risk during coastal storms. Data are available on the average annual rate of beach recession in the project area (Table 1; Figures 6, 7, 8, 9). The annual rates given by Pilkey et al. (1998, pp. 146-151) show a wide range, 2-11 feet per year. The larger rates may be the result of erosional "hot spot", areas with especially high recession rates due to such factors as offshore conditions affecting wave energy and/or physical characteristics of the beach.

Social and Economic Characteristics

The study area has a long history of development. The first English-speaking colony in America was established on Roanoke Island in 1585. Early settlers lived within the security of maritime forests on the estuarine side of the islands. Until the late 1700s homes were built in wooded hammocks on the sound side of the islands that provided some protection against wind and floods (Pilkey et al. 1980, pp. 6-7). Even in the late 1800s, the Outer Banks were described as drifting sand bars that didn't serve much of a purpose other than to fence out the Atlantic Ocean (Maiolo 1994, p. 20). Until the mid-1880s development was limited to the sound side of the islands (Frankenberg 1995, p. 118). At that time the islanders began to sell open land to mainland people and development expanded to the ocean side of the islands. Access bridges were built in the 1920s and 1930s, after which development rapidly accelerated. After a second set of bridges was built in the 1960s, development dramatically increased.

Between 1880 and 1970, the population of Dare County increased by only 4,000. In contrast, between 1970 and 1985, a population boom took place in which 10,000 people moved to Dare County during the 15 year period. Between 1970 and 1980, the population of North Carolina increased by 15.7%, but the population in Dare County increased by 91.2%. In 1990 Dare

Table 1. Rates of annual shoreline recession (erosion) that have been reported in the general area of the Northern Dare County Storm Damage Reduction Project.

Annual Rate (feet/year)	Area	Period	Reference
4 - 5	Dare County	not given	Frankenberg 1995, p. 49
4.7	Virginia State Line south to Cape Hatteras (93 miles)	not given	North Carolina Sand Resources Task Force; web page (1999): www.mms.gov/intermar/north.htm
4.3	False Cape (near Va-NC line) to 7 miles north of Oregon Inlet	1945-1986	Inman and Dolan, 1989
3 - 6.5	Kitty Hawk and N. Kill Devil Hills	not given	Pilkey et al. 1998 p. 146
2	S. Kill Devil Hills and N. Nags Head	not given	Pilkey et al. 1998 p. 146
2 - 3.5	S. Nags Head to Whalebone Junct.	not given	Pilkey et al. 1998 p. 149
2 - 11	Whalebone Junction to just N. of Oregon Inlet	not given	Pilkey et al. 1998 p. 151
10 - 20	Coquina Beach to South Nags Head	recent decades	Riggs 1994

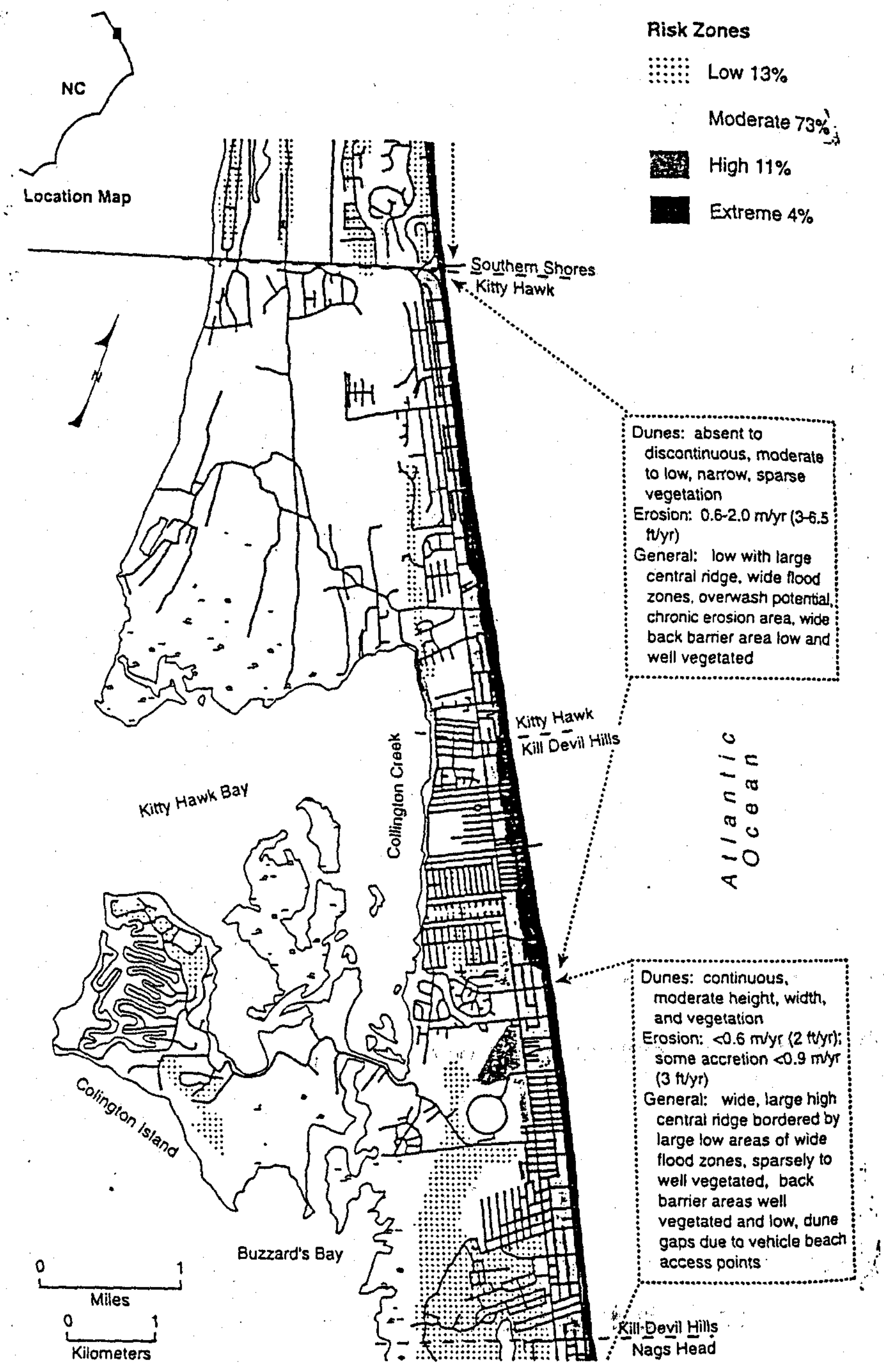

Figure 6. Basic information on dunes, erosion rates, and general storm hazards for the northern part of the Northern Dare County Storm Damage Reduction Project, Dare County, North Carolina. The map includes all of the Towns of Kitty Hawk and Kill Devil Hills. Source: Pilkey et al. 1998. p. 146. Used with permission of Duke University Press.

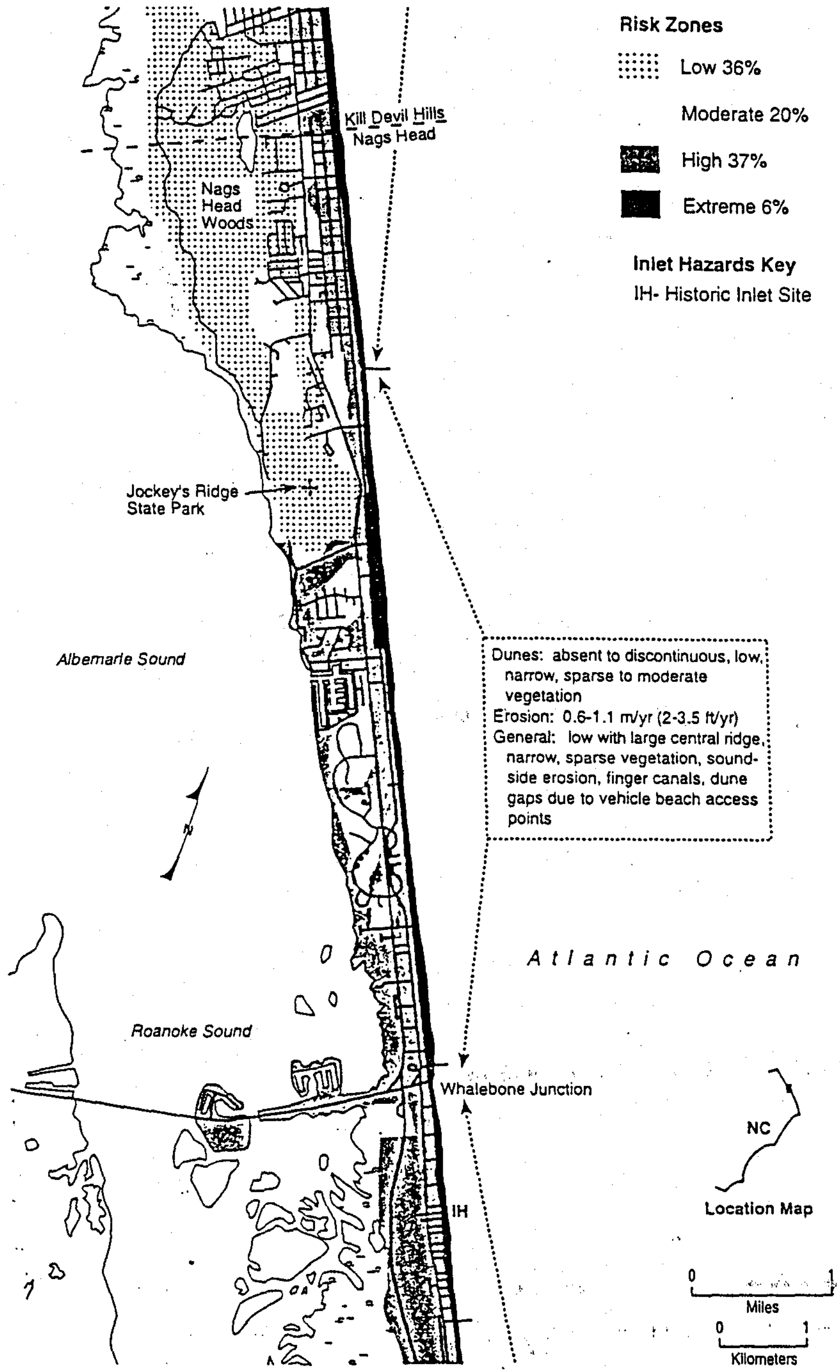

Figure 7. Basic information on dunes, erosion rates, and general storm hazards for the central part of the Northern Dare County Storm Damage Reduction Project, Dare County, North Carolina. The map includes part of the Town of Nags Head. Note the historic inlet site (IH) south of Whalebone Junction. This inlet may have been used by the first English settlers to establish a colony on Roanoke Island. Source: Pilkey et al. 1998. p. 149. Used with permission of Duke University Press.

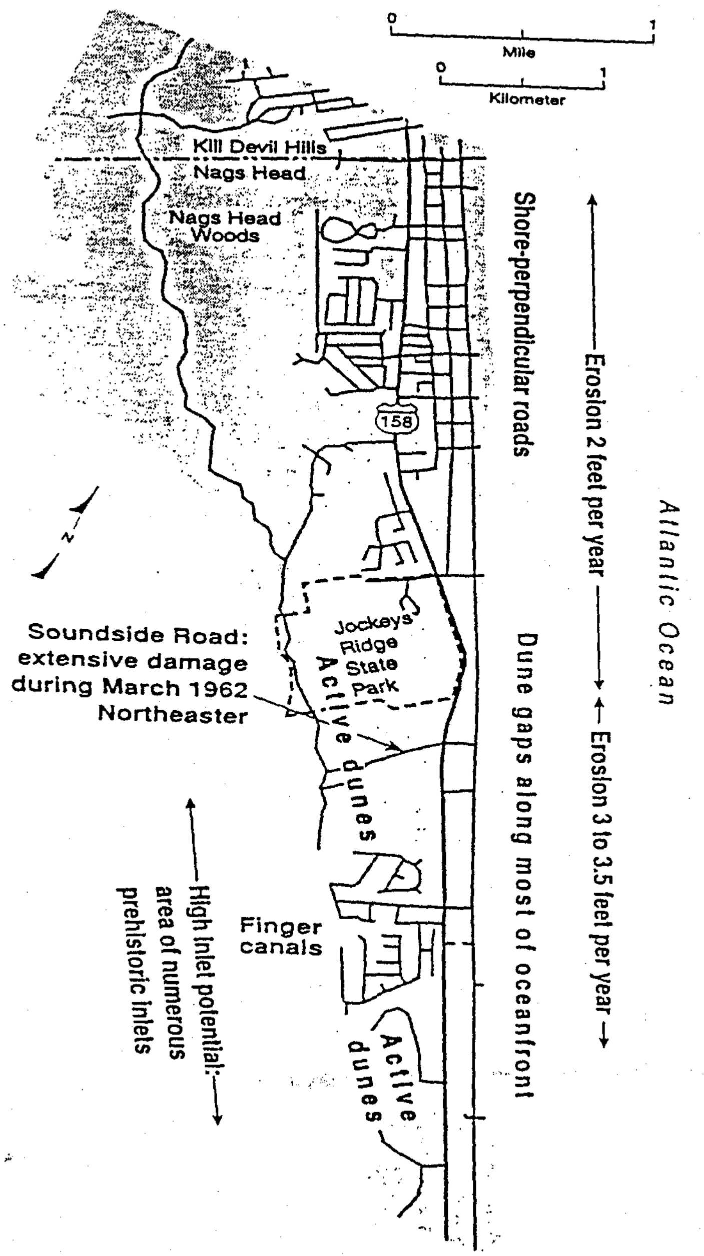

Figure 8. Basic information on dunes and erosion rates for the northern part of the Town of Nags Head, an area within the Northern Dare County Storm Damage Reduction Project, Dare County, North Carolina. Source: Bush et al. 1996. p. 55. Used with permission of Duke University Press.

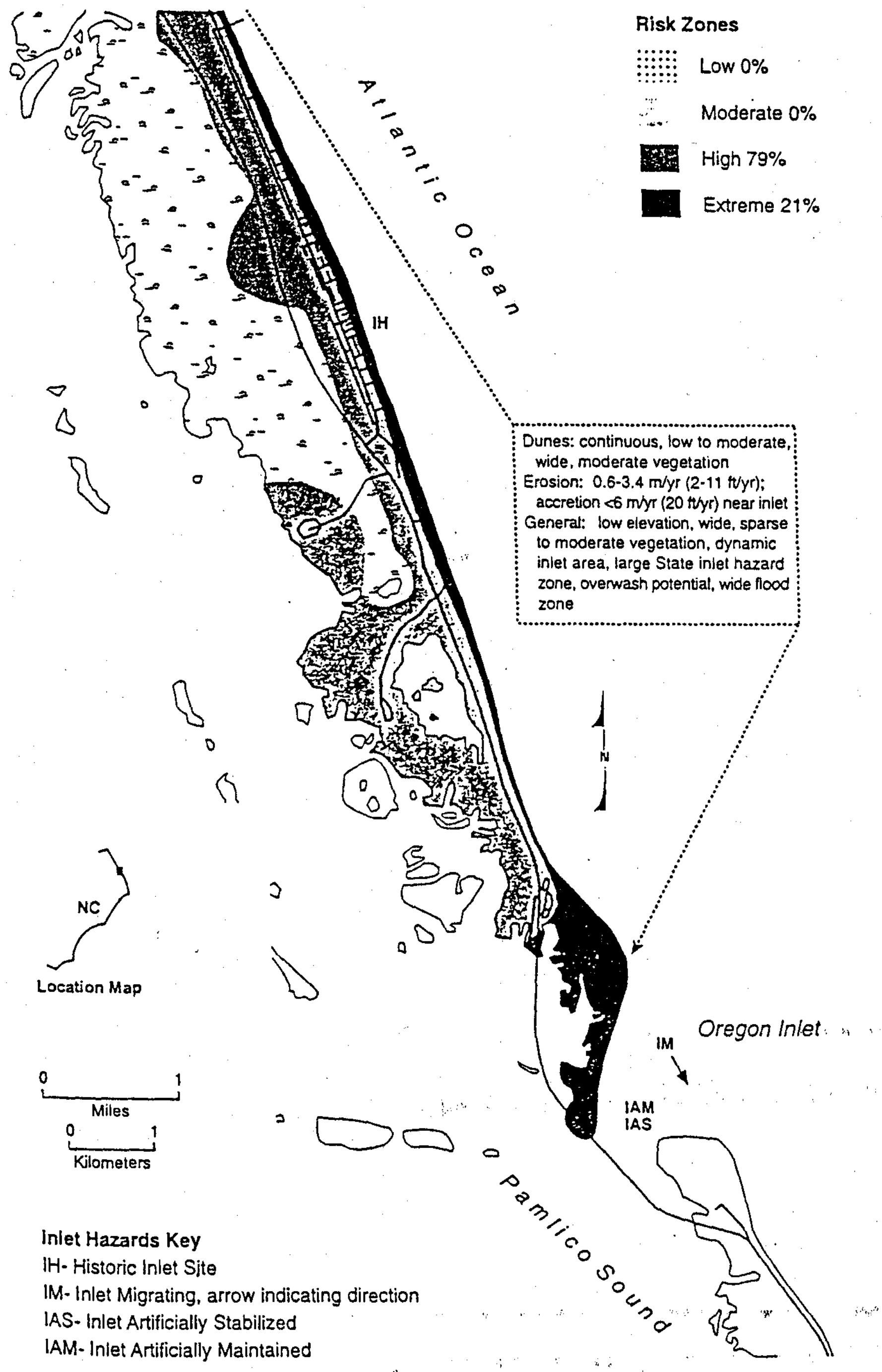

Figure 9. Basic information on dunes, erosion rates, and general storm hazards for the southern part of the Northern Dare County Storm Damage Reduction Project, Dare County, North Carolina. The map includes the southern part of the Town of Nags Head. Note that the entire area is considered to have either a high (79%) or extreme (21%) risk of storm damage. Source: Pilkey et al. 1998. p. 151. Used with permission of Duke University Press.

County had a year-round population of 22,746 and a seasonal peak population of 150,000 (Dare County 1994, p. 9). The county has a large number of homes that are occupied seasonally. The majority of jobs in the county are related, in some way, to the tourism industry which is the largest industry in the county.

The value of property on the Outer Banks of Dare County has risen dramatically since 1950 (Frankenberg 1995, p. 110). This author presents the following data based on information from the Dare County Tax Assessor's Office:

Assessed Value of Outer Banks Real Estate in Dare County, 1950-1993

Year	Assessed Value (in $million)
1950	6.0
1960	18.0
1970	34.0
1981	311.3
1993	3,510.8

Residential development will continue to proliferate with pressure for increased development density adjacent to the shorelines (Dare County 1994, p. 18). It has been recognized that development has generated by-products that have damaged the County's natural resources (Dare County 1994, p. 17). In general, development on barrier islands impacts fish and wildlife habitat directly and indirectly.

Direct impacts result from the alteration or elimination of natural areas for constructing buildings and associated infrastructure, e.g., roads and parking lots. In reference to North Carolina, Bellis (1995, p. 73) notes that ". . . the pace of urban development in maritime forests has quickened . . . to the extent that most currently unprotected maritime will probably not exist as naturally functioning ecosystems sometime in the 1990's." The 1994 Dare County Land Use Plan addressed the issues of protecting existing trees and vegetation (Dare County 1994, pp. 67-68). While noting that natural vegetation helps cleanse rainwater and stormwater, the plan determined that any county regulatory program to prevent clearcutting of trees and vegetation would conflict with private property rights. The plan concludes that the county would develop a brochure to inform property owners about best management practices for tree removal and land clearing.

Closely related to the issue of altering natural communities are the secondary impacts associated with freshwater supples. Two subsurface, geologic formations constitute the groundwater sources which provide the freshwater used on the Outer Banks today (Frankenberg, 1995, p.

128). These freshwater supplies exist as a lens sitting on top of the heavier, denser sea water. As the freshwater is pumped to the surface, sea water pushes in and shrinks the area of freshwater. To the south of the project area, plans to increase water supplies adjacent to the national seashore created concerns within the NPS that the effort would have negative effects on aquatic areas within the national seashore. Dare County is working to ensure adequate supplies of freshwater and expansion of the production capacity of the Dare Regional Water Supply System would most likely come from new wells on the beach (Dare County 1994, p. 32). In regard to the Hatteras aquifer, there is no way of knowing " . . . how changes in the water-removal rate will affect plant communities above it and salt water encroachment into it." (Frankenberg 1995, pp. 133-134). Over withdrawals may have serious consequences. The Hatteras aquifer would take at least a century to recover if destroyed and a salt water contaminated aquifer might never recover (Frankenberg 1995, p. 134).

Another important secondary impact of increased development is wastewater disposal. On the North Carolina Outer Banks, crowded development, improperly maintained systems, and systems installed in soil unsuitable for filtration have resulted in poorly treated or untreated sewage entering the surrounding environment (Pilkey et al. 1998, p. 126). If polluted water is allowed to enter the sounds and marshes, shellfish are contaminated and that resource is ultimately destroyed. Stormwater runoff into estuarine waters may degrade water quality and threaten aquatic life.

There are no publicly owned sewage treatment plants on the Outer Banks and little prospect of any being developed (Dare County 1994, p. 34). On-site septic tanks and drainfield systems serve as the predominant method of wastewater treatment. Some drainfields occur in soil that is too porous to allow adequate time for wastewater impurities to decompose before entering the groundwater (Frankenberg 1995, p. 136). Future development may lead to the construction of centralized wastewater treatment plants. However, treatment plants may still leave some dissolved and particular matter in the water discharged into the environment. Frankenberg (1995, p. 141) believes that "It is almost certain that natural waters receiving wastewater from treatment plans will be environmentally degraded."

Project Purpose and Need: The Nature of the Problem

The Dare County coast is very susceptible to tropical storms and to northeasters, and several structures are generally lost each year as a result of coastal storms. North of Cape Hatteras, the shoreline generally faces east and northeast. The orientation of the Dare County coast makes it particularly vulnerable to winter, northeasterly storms which often remain in the area for several days.

Between the turn of the century and the mid-1930s Bodie Island from Whalebone Junction to Oregon Inlet (Figures 7 and 9) was a low, flat, sparsely vegetated area. The area was frequently overwashed from the ocean to the sound and this natural process helped maintain the integrity of the island. In 1934 one million dollars were made available to the Civilian Conservation Corps

(CCC) to begin building protective dunes along the beaches of the Outer Banks from the Virginia border to Ocracoke. This was intended to prevent island overwash and to stop the movement of sand dunes encroaching on the remaining forests and villages. Sand fences were strung along the berm to trap sand, and beach grasses were planted to hold the palisade dunes in place. The CCC created a linear barrier dune that ranged from 8-25 feet in height.

With high, artificial barrier dunes protecting the islands from storms and cross-island overwash, a sense of security resulted in increased construction of roads and buildings. Pilkey et al. (1998, p. 139) state that:

> "One of the most important events leading to the development of the Outer Banks was the construction in the 1930s of a continuous dune line from the Virginia border to the western end of Ocracoke Island, . . . The large frontal dune changed the Outer Banks, especially south of Southern Shores, from an area dominated by overwash to a dune island. Development became possible in the protective lee of the artificial dune where it would once have been impossible because of frequent overwash."

While the artificial dune line minimized damage due to overwash by low to moderate energy storms, it did not stop shoreline erosion. The absence of overwashes allowed the development of more extensive vegetation, especially woody vegetation. Storms continued to pound against the unnatural dunes and removed large quantities of sand. Because island overwash was blocked, the sand was often lost to the ocean. With a rising sea level as the primary factor and coastal storms as an immediate factor, the shoreline receded landward. Along one stretch of beach in South Nags Head, the houses which were built in the third row from the ocean are now in the first row and one house in Nags Head has been moved back over 600 feet in five separate moves over a period of 100 years (Pilkey et al. 1998, p. 101-102).

The initial, artificial dune set the stage for the construction of a paved highway along the Outer Banks during the 1950s. When first built the road used ferries to cross two inlets. This highway, NC 12, is often flooded, overwashed, and temporarily closed. The Halloween storm of October 1991, an extreme northeaster, damaged or destroyed dozens of beach cottages by wave and storm surge, flooded miles of road, and eroded beaches and frontal dunes. During the 1992 winter storm season, an emergency sandbag revetment was built along a section of Pea Island, where the dune system had been destroyed and Highway 12 was being overwashed.

The NCDOT commissioned a report concerning the State's coastal highways and the threat of erosion to them (Stone et al. 1991). The report identified coastal highway sections that are susceptible to ocean damage and ranked their relative vulnerability to storm damage. The report identified several problem areas in Dare County where NC 12 was particularly vulnerable or would be vulnerable in the near future. One problem area was a 4.5-mile section in Kitty Hawk and Kill Devil Hills. Stone et al. (1991) recommended road relocation for the Kitty Hawk - Kill Devil Hills section.

In 1974 the North Carolina General Assembly passed the Coastal Areas Management Act (CAMA) designed to protect coastal resources through a combination of land use planning and state regulation. Much of the oceanfront development in Dare County occurred prior to CAMA's oceanfront setback regulations. These regulations require small scale development to be located at least 60 feet landward from the first line of stable vegetation, or a distance in feet from the vegetation line which is equal to 30 times the annual erosion rate of the site. Large scale development, such as condominiums and motels require an additional setback. Beach cottages, motels, and condominiums now line much of the Dare County coastline. Many of these structures completely lack dune protection.

Dune construction and stabilization continued through much of the 1970s (Lukin and Mauger 1983 p. 79). Man-made dunes are subject to breaching unless they are regularly maintained. In Kitty Hawk, dunes constructed in the 1930s were lost by the late 1980s (Pilkey et al. 1998, p. 148), making development in exposed areas susceptible to direct wind and wave action.

Local governments in the project area are fully aware of potential storm damages. Dare County recognizes that the configuration of its barrier islands makes these areas particularly susceptible to hurricanes and that much of the remaining land lacks sufficient elevation to preclude floodwaters associated with storm tides and torrential rains (Dare County 1994, p. 94). Under certain worst case scenarios, much of Dare County could be flooded by storm tides and/or wind driven waves with only those areas with a natural elevation exceeding 20-30 feet above sea level being excluded from the certainty of flooding. The Town of Kitty Hawk is very vulnerable to the affects of coastal storms, and the town's current Land Use Plan (LUP) indicates that the term "hazard" in relation to coastal storms is a misnomer in that the term implies only a chance or probability while coastal storms on the Outer Banks are regular occurrences (Kitty Hawk 1994, pp. 75-76).

It is interesting that the LUPs for various jurisdictions in the project area consider both beach nourishment and storm hazard mitigation, but in entirely separate sections of the respective plans. Dare County discusses shoreline recession in the context of barrier island migration, and notes (Dare County 1994, pp. 90-91) that the alternatives for shoreline management include retreat, armoring with hard structures, and/or beach nourishment. The consideration of storm damage mitigation, on the other hand, notes that the county's "key method" of mitigating property damage is the enforcement base flood elevation standards designed to allow rising water to flow freely under elevated structures (Dare County 1994, p. 94). The LUP does not mention the creation of an artificial beach-dune as a storm damage mitigation measure.

The LUP for the Town of Kill Devil Hills states that in 1980 the town policy was to oppose the expenditure of public or private funds in attempts to stabilize ocean beaches (Kill Devil Hills 1993, p. 50). In the early 1980s the town's policies against beach stabilization project were more restrictive than those of the state. By the early 1990s the town altered its policy in support of efforts to maintain and enhance the public trust beach, but also favored non-structural responses to erosion such as relocation and/or acquisition of existing endangered structures, setbacks for new construction, and interim temporary actions to protect property endangered by erosion. Overall, the town concluded that shoreline nourishment is the preferred method of shoreline protection based on the realized value of a wide and stable recreation beach (Kill Devil Hills 1993, p. 50). The discussion of beach nourishment did not mention such construction as a storm damage protection measure. In a separate section the plan noted that natural hazard planning requires a "comprehensive approach" in order to be effective (Kill Devil Hills 1993, p. 67). The plan stated that a major hurricane could create a hazard zone that would encompass the entire community. As of the 1993 LUP, the town permitted development to occur in hazard areas and expected that future development would occur in hazard areas. However, the plan called for such development to be "hazard-resistant." Storm damage mitigation policies included a zoning ordinance, building codes, and a flood damage prevention ordinance. The discussion of storm damage reduction measures did not mention the creation of an artificial beach-dune system.

The Town of Kitty Hawk also clearly separated the issues of beach nourishment and storm damage reduction. In 1994 the town was becoming more vulnerable to routine low pressure systems which generated high winds and caused ocean overwash at high tide due to the loss of frontal dunes to erosion. The town's LUP listed (Kitty Hawk 1994, p. 76) storm damage mitigation measures as: (1) the North Carolina Building Code; and, (2) flood damage prevention measures such as raising structures and participation in the Flood Insurance Program. As with other LUPs storm damage reduction measures did not include creation of an artificial beach-dune system. In another section of the LUP the town acknowledged serious and continuous beach erosion that threatened portions of NC 12 and resulted in the loss of "many beach front cottages" (Kitty Hawk 1994, p. 49). To address beach erosion the town supported the study of beach nourishment projects, if funded by state and federal governments. Again, the issues of beach nourishment were addressed only within the context of shoreline erosion and not as a storm damage reduction measure.

Biotic Communities

This section discusses the physical characteristics of the biotic communities found in the project area. The plants and major invertebrate fauna which form the base of the food chain are described to the extent possible. The vertebrate fauna, i.e., fish and wildlife resources, will be considered in Section 5.

The scope of this report covers a wide range of biological communities (Figure 10). There are the offshore, marine communities, both pelagic and benthic, from which sand may be taken. There are the nearshore and beach communities which would be impacted by sand placement. Also covered are the upland communities landward of the dune line and the estuarine communities of Albermarle and Roanoke Sounds. While upland and estuarine communities may not be directly impacted by the project, the development which the project would certainly engender will have a profound influence on barrier island uplands and estuarine habitats.

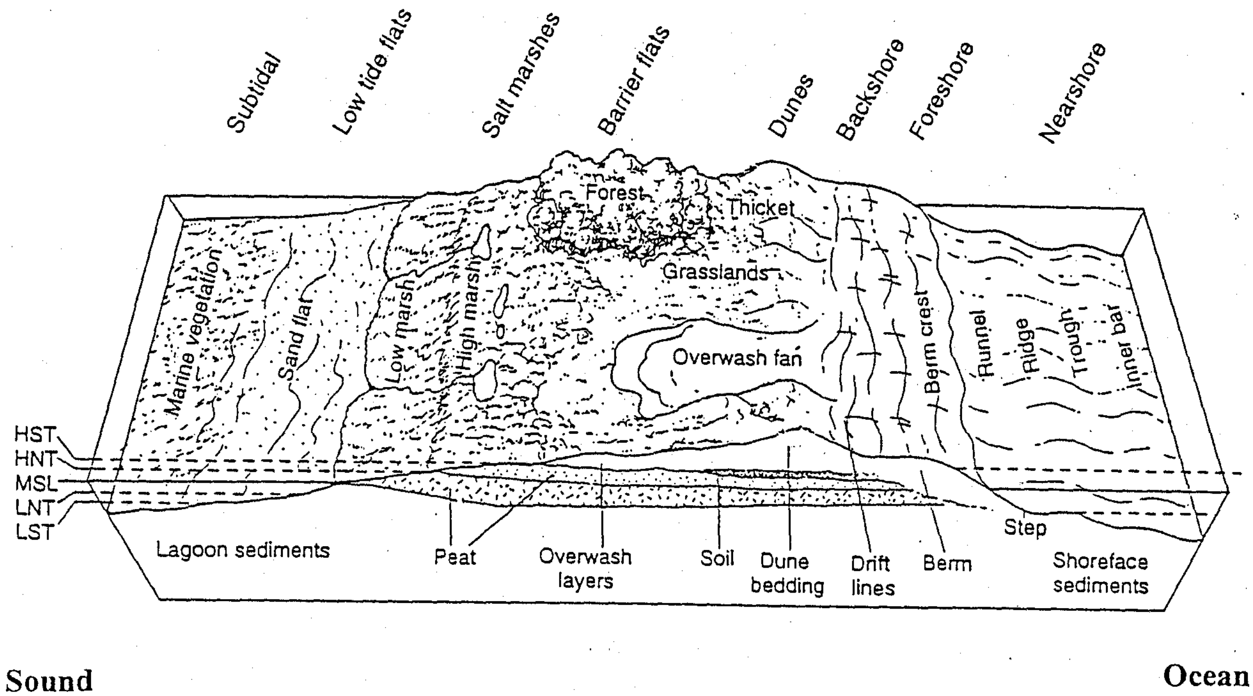

Figure 10. Diagram of the communities associated with a barrier island. HST = high spring tide; HNT = high neap tide; MSL = mean sea level; LNP = low neap tide; and LST = low spring tide. Source: Bellis (1995).

The coasts of continents are physically subdivided by capes and headlands into more or less distinct hydrologic regions with characteristic physical conditions and with reduced interchange of water and organisms between adjacent regions. Cape Hatteras forms a dividing point between the Virginian biogeographic, or faunal, province to the north and the Carolinian biogeographic province to the south (Ruppert and Fox 1988, p. 355-56). The Virginian Province has very few endemic species, i.e., species found only in that province (Gosner, 1978, p. 14). For example, only about 30% of the species of decapod crustaceans found in the Carolinian Province pass through the Cape Hatteras filter to occur north of that point. However, those Carolinian species that do extend north make up about 80% of the northern province's decapod population.

Offshore Pelagic

The division between offshore and nearshore water is somewhat arbitrary, but the offshore zone is generally considered to extend seaward from the point where waves first influence, or scour, bottom sediment (Leatherman 1988, p. 20). Stated somewhat differently, the offshore zone is seaward of the breaker line, the point at which wave energy is influenced by bottom sediment. As noted, the offshore waters of Dare County are considered the southern boundary of the temperate Virginian biogeographic province. This boundary is a result of the northward moving Gulf Stream turning eastward. The mixture of colder and warmer waters produces a seasonally variable environment. Many Atlantic Ocean organisms have their northern or southern distribution limits off this portion of the coast.

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 macroalgae, 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 (Figure 11). 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.

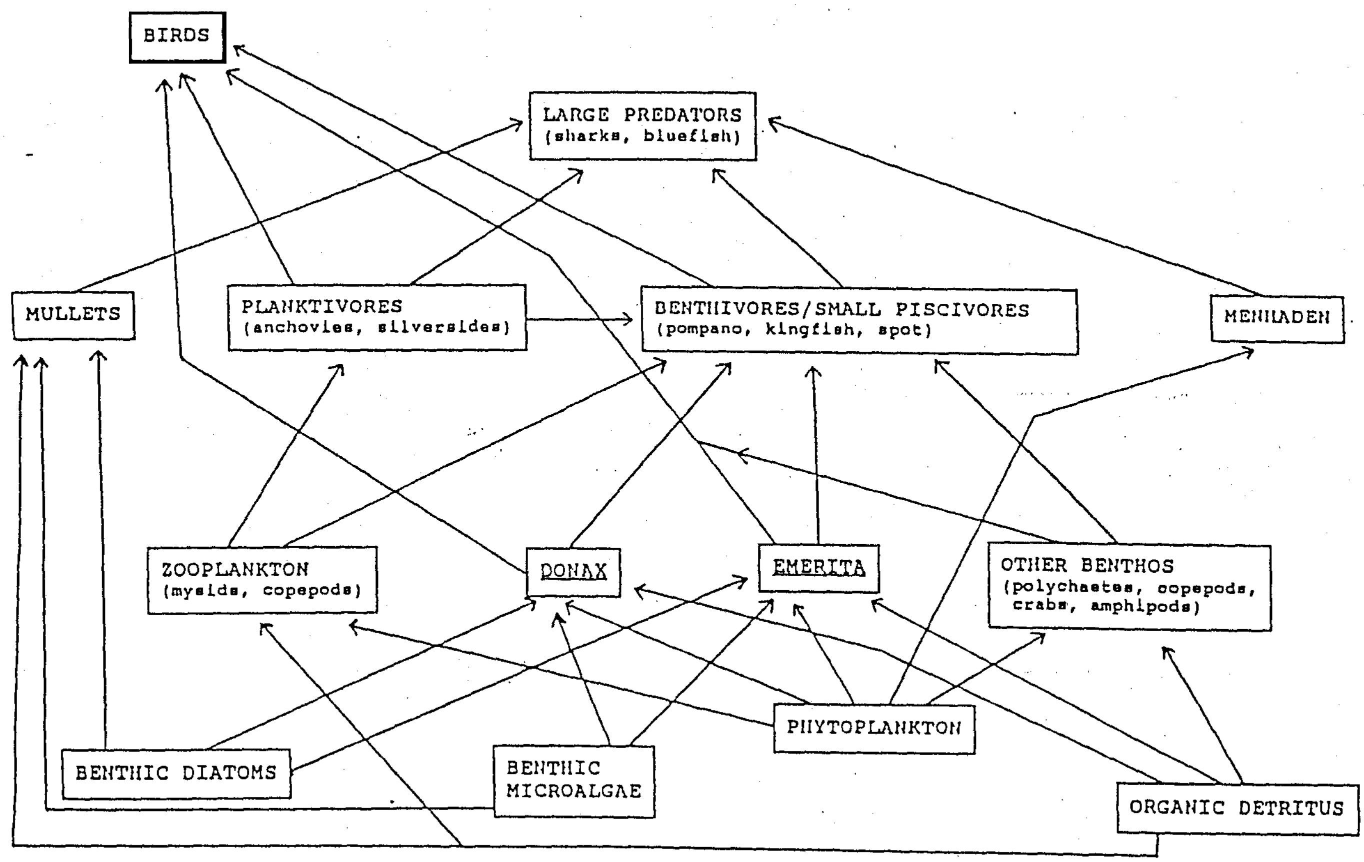

Figure 11. Diagram of the general offshore food chain in the South Atlantic Bight. While this area is technically south of Cape Hatteras, the major components of the food chain and the flow of energy is considered similar to those occurring in the project area. Source: Hackney et al. 1996, p. 51.

Offshore Benthic - Soft Substrate

Water depth, topography, sediment movement, current patterns near the bottom, and the amount of organic matter reaching the bottom affect the distribution of benthic organisms more than does the overlying water mass. A wide diversity of sediment types have been identified along the continental shelf in the Cape Hatteras region, and macrobenthic invertebrate assemblages are related to these sediment types (Weston 1988, as reported in U.S. Minerals Management Service [hereafter USMMS] 1990).

There may be a tendency to regard offshore sandy bottoms as 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.

Off Cape Hatteras, the continental shelf environment as a whole is dominated by annelids, crustaceans, and bivalves. The highest densities of organisms appear to occur in moderately grained sediments such as those with a sand/shell composition (Wigley and Theroux 1981). Research has indicated the existence of a distinct, productive benthic microflora in Onslow Bay, North Carolina, approximately 150 miles southwest of the project area (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 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 (Figure 11). 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 figures 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 x 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.

Offshore Benthic - Hard Substrate

Localized areas not covered by unconsolidated sediments, where the ocean floor consists of hard rock, are known as hardbottoms. Hardbottoms are found along the continental shelf off the North Carolina coasts. Hardbottoms are also called "live-bottoms" because they support a rich diversity of invertebrates such as corals, anemones, and sponges which are refuges for fish and other marine life. While hardbottoms are most abundant in southern portions of North Carolina, they are located along the entire coast (USMMS 1990). Data from the Southeast Monitoring and Assessment Program (SEAMAP) indicate that hardbottoms are located in or near the proposed borrow areas (Appendix B).

Hardbottoms can provide very important habitat for fish and invertebrate species. According to Burgess (1993):

> "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."

In addition to simple, flat, rocky bottoms, areas with high relief such as underwater channels and cliffs, also provide valuable habitat. Areas of "high-relief scarps" create the most productive of hardbottom habitats (Burgess 1993). Rocks which break off these scarps collect as underwater rubble mounds that provide many nooks and crannies that serve as important hiding places for reef fishes and invertebrates such as the arrow crab (*Stenorhynchus seticornis*) and spiny lobster (*Panulirus argus*). Seaweeds such as brown sargassum (*Saragassum* spp.) and green calcareous algae attach to the rock surfaces.

Van Dolah and Knott (1984) sampled the benthos offshore the South Carolina coast, including some hardbottoms. They found 167 species representing nine major taxa. McCrary and Taylor (1986) studied benthic macrofauna assemblages offshore from Fort Fisher, North Carolina. Their grab samples were taken from between approximately 0.5 to 2 miles offshore. They found many polychaete species, isopods, amphipods, decapods, molluscs, echinoderms, many nematodes, and a few Amphioxus (*Brachiostoma caribaeum*) in the benthic samples. In reference to one of their sampling locations located approximately 0.5 mile offshore, they state that it was obvious that a hardbottom was in the vicinity, although hard substrate was not found in the sediment samples of the site. They found 33 individuals of Chrysopetidae, a family which is predominately associated with coral or other hard substrates.

The benthos inhabiting potential offshore borrow areas serve as food for commercially important species and are essential in marine food chains. For example, adult spot (*Leiostomus zanthurus*) are benthic feeders (Benthivores in Figure 11), primarily eating polychaetes and benthic copepods. Atlantic croaker (*Micropogonias undulatus*) are also bottom feeders, preying on polychaetes and bivalves. Pink (*Penaeus duorarum*) and white (*P. setiferus*) shrimp also prefer benthos.

Nearshore Pelagic

The nearshore zone may be defined as the area between the low tide breaker line and the low tide shoreline (Thurman 1994, p. 284). It is generally considered to extend out as far as the point where waves do not scour the ocean bottom. The width of the nearshore area varies, but typically it is described as extending out to a water depth of 30 feet (Leatherman 1988, p. 20). There is considerable sediment transport within the nearshore zone.

Nearshore Benthic

In the nearshore zone (Figure 10), characterized by rippling on the substrate surface due to wave action, 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 (*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.

Shoreface and Intertidal (Wet) Beach

There is no single, technical definition of a beach. Coastal geologists and the typical tourist clearly have different meanings for the term. To the geologist, the recreational beach is only the landward part of a larger zone of active (moving) sand/sediment that extends seaward to the innermost continental shelf. This area of active sediment, the shoreface, plays a major role in the behavior of the barrier islands. The shoreface in North Carolina is a relatively steep surface extending out to depths of 30-40 feet. The Outer Banks do not rest on an infinitely thick substrate of sand, but are in fact ". . . thin accumulations of sand perched on a preexisting and highly dissected surface previously eroded by rivers, channels, and old inlet" (Pilkey et al. 1998, p. 51). It is the complexity of the underlying geologic framework, in association with the physical dynamics of the specific barrier island, that ultimately determines the island's three-dimensional shoreface shape, the composition of beach sediment, and the shoreline erosion rate (Pilkey et al. 1998, p. 51).

Technical beach definitions are sometimes given in terms of sand mobility. For example, the beach may extend from the maximum shoreward movement of water during a severe storm to a seaward limit where ". . . substantial shore-perpendicular motion of sand ceases" (National Resrach Council [hereafter NRC] 1995, p. 20). Leatherman (1988, p. 21) considered a beach to be ". . . an accumulation of wave-washed, loose sediment that extends between the outermost breakers and the landward limit of wave and swash action." Much of the area given in these definitions cannot be used for what is commonly considered as beach recreation. A more traditional definition would include the area extending from the low tide line landward across unvegetated sediment to the beginning of permanent vegetation or the seaward edge of the next geomorphic feature (Davis 1994, p. 154). The feature limiting the landward extension of a beach is usually a natural dune, but may include artificial structures, such as a seawall or a constructed dune. The latter definition, unless otherwise specified, will be used in this report.

The entire beach will be divided into two parts, a wet and dry section. The intertidal zone, or wet beach, is the area between the line of low and high tide and may be called the foreshore or littoral zone (Thurman 1994, p. 284; Figure 10). This part of the beach contains two of the four beach zones given by Reilly and Bellis (1978) who designated a wet zone and a swash zone. The wet zone consists of the unvegetated area below the high tide drift line and above the saturated zone. The swash zone is the area alternately covered and exposed by waves.

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.

Beach - Subaerial (Dry)

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 10. 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. Invertebrates inhabiting this zone include the ghost crab (*Ocypode quadrata*), beach flea (*Talorchestra megalophalma*), and various insects. Vegetation consists primarily of a few annual, succulent species, including sea rocket (*Cakile edentula*), and seabeach amaranth (*Amaranthus pumilis*). 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 (NRC 1995, p. 72). The berm is a primary factor in dissipating wave energy.

Dunes

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.

As noted, most existing dunes within the project area are not natural features. In addition to dunes constructed by the CCC in the 1930s, sand fences were placed just inland from the broad natural beaches, resulting in sand accumulations in the form of a ridge or dune (Inman and Dolan, 1989). Vegetation and fertilizer were added to the dunes along the Outer Banks in the 1960s. As a result, very large, parallel dunes became established and stabilized immediately inland from the beach.

Dune vegetative cover ranges from sparse to fairly dense. The dunes are dominated by species which can withstand the continuous salt spray, shifting sand and excessive drainage found in this dynamic and stressful environment. Dominant vegetation observed during a study involving the Bonner Bridge spanning Oregon Inlet (CZR 1992a) included sea oats (*Uniola paniculata*), American beach grass (*Ammophila breviligulata*), silver panic grass (*Panicum amarum*), saltmeadow cordgrass (*Spartina patens*), broomsedge (*Andropogon virginicus*), seaside goldenrod (*Solidago sempervirens*), and beach elder (*Iva imbricata*). Sea oats are important in building dunes due to their ability to grow upward through the sand which collects around them, as well as their resistance to salt spray and drought conditions. Other common dune plants include ground cherry (*Physalis viscosa* ssp. *maritima*), beach spurge (*Euphorbia* sp.), sand spur (*Cenchrus tribuloides*), and beach bean (*Strophostyles helvola*).

Overwash Flats

Overwash, or washover, fans (Figure 10) are created by the flow of water through the primary dune line. The fan is basically part of the beach and dunes that has spread out over the island. Overwash usually occurs during storms, but smaller events can occur in low areas in the barrier dune line when large breaking waves coincide with a high spring tide. Young overwash fans are essentially unvegetated. However, the areas are capable of normal plant succession and, depending on their location, early seral stages will progress to more stable plant communities.

This community is usually absence or temporary in developed areas such as the project area. However, the importance of overwash areas in the natural geology of barrier islands and the impacts of artificial dunes on the overwash process merit consideration in this report.

Low Shrub/Grassland

Behind the primary dune, sea oats, beach grass, and other dune plants create a prairie that covers the sand with low vegetation (Frankenberg 1995, p. 23; grasslands in Figure 10). 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 (CZR 1992a). 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 terraces behind or between low dunes support grasslands. They may occasionally be overwashed or buried by sand. Vegetation may be moderate or dense except in recently overwashed areas.

McCrain (1988) suggested that the low shrub/grassland community on Hatteras Island developed as a result of extensive fires. Plants found in this community include poison ivy (*Rhus radicans*), seaside/dune evening primrose (*Oenothera humifusa*), marsh pink (*Sabatia campanulata*), seaside goldenrod, and sea ox-eye (*Borrichia frutescens*) which share the dominance with wax myrtle (*Myrica cerifera*), groundsel tree (*Baccharis halimifolia*), and yaupon (*Ilex vomitoria*). The pockets of shrub/grasslands on Bodie Island appear to be the result of clearings under power lines and disturbed areas around the Oregon Inlet Marina. Saltmeadow cordgrass (*Spartina alterniflora*), common cattail (*Typha latifolia*), and poison ivy dominate this vegetative community on Bodie Island.

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.), saltmeadow cordgrass and panic grass (*Panicum amarum*).

Where human and natural disturbances are minimized, the grasslands and high marsh often support scattered wax myrtle, groundsel tree, 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 (Thicket in Figure 10) typically occur landward of the low shrub/grassland community where they are protected from salt spray and harsh winds. The construction of artificial dunes may have allowed this community to develop. The community is characterized by dense shrubs that are usually entangled with vines. Characteristic species include wax myrtle, groundsel tree, yaupon, 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, wax myrtle, yaupon, and groundsel tree. Common vines include poison ivy, catbrier (*Smilax bona-nox*), pepper vine (*Ampelopsis arborea*), and muscadine (*Vitis rotundifolia*).

The plants are shaped by salt-laden winds which stunt the branches on the windward side. Prevalent along the intertidal creeks on Bodie Island, this community is frequently interspersed along the peripheral edges of black needlerush (*Juncus roemerianus*) pockets. In several areas along the NC 12 corridor, especially on Hatteras (Pea) Island, shrub thickets are well established, frequently reaching a height of 1.8-2.4 m (6-8 feet). 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 can also be found leeward of many dunes.

Herbaceous Swale and Other Freshwater Wetlands

This community occurs in interdune areas with elevations near the water table and are protected from salt spray. The community contains a variety of grassland vegetation (CZR, Inc. 1992a). Herbaceous swales also occur in sand flats where the water table is normally just below the surface, old overwash terraces, and in sand-filled marshes. Most herbaceous swales in the project area are seasonally flooded, or saturated, wetlands co-dominated by American bulrush (*Scirpus americanus*), centella (*Centella asiatica*), smartweeds (*Polygonum* spp.), buttonweed (*Diodia virginiana*), saltmeadow cordgrass, and sand rush (*Fimbristylis spadicea*).

A marshy swale just north of the Oregon Inlet Fishing Center parking lot is lower in elevation and flooded more regularly than other swales in the project area. Vegetation in this swale contains a mixture of dominants including common cattail, black needlerush, saw grass (*Cladium jamaicense*), wool-grass (*Scirpus cyperinus*), swamp rose mallow (*Hibiscus moscheutos*), and seashore mallow (*Kosteletzkya virginica*). Other species include saltmarsh bulrush (*Scirpus robustus*), arrowleaf morning glory (*Ipomoea sagittata*), climbing hempweed (*Hikania scandens*), and royal fern (*Osmunda regalis* var. *spectabilis*).

Interdune ponds and other freshwater wetlands are seasonally to permanently saturated. They are densely vegetated with a high diversity of both wetland and mesic species. Interdunal, or swale ponds, are created by a rising sea level that raises the freshwater lens beneath the island until it intercepts the topographic lows between dune ridges (Bellis 1995, p. 69). These ponds are generally dominated by saltmeadow cordgrass, fimbry (*Fimbristylis* sp.), or Gulf muhly (*Muhlenbergia filipes*). Freshwater ponds provide habitat for many species that might otherwise be severely limited by lack of a dependable freshwater supply (Bellis 1995, p. 69).

Broad swales are found between dune ridges within maritime forests. These swales may contain standing water year round and some larger swales have open water. These freshwater wetlands are marsh communities with cattail and saw grass in some areas and swamp forest in others.

Reed stands exists in small patches on Pea Island. The community is dominated by common reed (*Phragmites australis*) and is indicative of previous disturbance. Common reed is an opportunistic species often associated with wetter shrub thickets.

Maritime Forest

An unusual and increasingly rare upland communities on the Outer Banks is the 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. The floristic makeup of maritime forests varies depending on many factors including elevation, hydrology, soils, protection from salt spray, and level of succession. Typical maritime forest vegetation includes live oak, red cedar, yaupon, wax myrtle, red maple (*Acer rubrum*), red bay, sweet bay (*Magnolia virginiana*), and loblolly pine (*Pinus taeda*). The maritime forests such as Nags Head Woods and Kitty Hawk Woods are very diverse, interspersed with wetland areas, such as the maritime swamp forest community as well as more upland communities. Nags Head Woods may be over 50,000 years old (Frankenberg 1995, p. 29). These extensive maritime forests include such canopy species as black walnut (*Juglans nigra*), sweet pignut hickory (*Carya glabra*), American beech (*Fagus grandifolia*), white oak (*Quercus alba*), laural oak (*Quercus laurifolia*), water oak

(*Quercus nigra*), bald cypress (*Taxodium distichum*), and black gum (*Nyssa sylvatica*). A large variety of herbaceous plants also occur in Nags Head Woods, Kitty Hawk Woods, and Buxton Woods including various ferns, orchids, such as pink lady slipper (*Cypripedium acaule*), Southern twayblade (*Listera australis*) and water-spider orchid (*Habenaria repens*); and various grasses and sedges.

The invertebrate fauna of maritime forests has been described (Bellis, V. J. 1995, pp. 48-50). Insect and spiders are conspicuous components of maritimes forests, and as such perform important ecological functions in mineral cycling and energy flow.

High Marsh (Diverse Species)

The high marsh occupies a non-tidal zone between the upland communities and the shore of the sound (CZR, Inc. 1992a). High marsh is generally found on sandy flats of old overwash terraces 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, salt grass, sea ox-eye, and sea lavender.

Some sections of high marsh appear as meadows dominated largely by saltmeadow cordgrass and rushes (*Juncus* spp.). These meadows are most similar to the saltmeadow flats identified by McCrain (1988) on Hatteras (Pea) Island. Other species found in this community include rush (*Juncus polycephalus* [= *J. biflorus*]), toad rush (*Juncus bufonius*), marsh pink, American bulrush, and seaside goldenrod. Where human and natural disturbances are minimized, the high marsh often supports scattered wax myrtle, groundsel tree, and marsh elder. When provided with continued protection, high marsh may eventually succeed into a low shrub-grassland community.

Some areas may be designated as saltmeadow flats which are essentially pure stands of saltmeadow cordgrass. Such flats may be considered as either high or low flats depending on elevation (CZR 1992a). High saltmeadow flats are found 5 feet above msl.

High Marsh (Black Needlerush)

Within the intertidal zone, this emergent wetland community is composed of homogenous stands of black needlerush (CZR, Inc. 1992a). Irregular flooding controls the distribution of this common marsh species, and the community is often called a high marsh. Large stands are found throughout the southern tip of Bodie Island where the unconsolidated sand has accreted and provided conditions suitable for irregular flooding. Smooth cordgrass is often found along the lower fringes of this community. At higher elevations, silverling, saltmeadow cordgrass, and sand rush become co-dominant. Several dredge spoil islands in the sound are dominated by this community, as is the fringe of intertidal creeks on Hatteras Island. Large stands of black needlerush also occur on the sound side of Bodie Island.

These tidal marshes have high primary productivity and provide inorganic and organic nutrients to adjacent aquatic communities. They also protect the sound side of the barrier island from wind and wave action. Many aquatic invertebrates, such as the saltmarsh snail (*Melampus bidentatus*), depend on tidal marshes.

Low Marsh (Smooth Cordgrass Marsh)

This emergent wetland community, like the black needlerush community, is within the intertidal zone. However, flooding is regular and the community is often called low marsh. It occurs in pure stands along the sound side and southern tip of Bodie Island. Along the fringe of tidal creeks, the community receives regular tidal inundation and marsh plants provide stability for the shoreline margins. Spoil islands in the sound are often covered with smooth cordgrass where the land is regularly flooded.

Low saltmeadow flats occur on the sound side of Hatteras Island near Bonner Bridge and along the upper reaches of the intertidal creek just to the south of the bridge. The low flats appear to be restricted to an elevation near 3.5 feet above msl. Salt grass (*Distichlis spicata*), sea lavender (*Limonium carolinianum*), and sea ox-eye are present on the low flats.

The low marsh community typically provides nursery areas for various species of shrimp, crabs, and marine and estuarine fish. In the Chesapeake region, the low marsh provide habitat for the marsh periwinkle (*Littorina irrorate*), Atlantic ribbed mussel (*Geukensia demissa*), and fiddler crabs (*Uca* spp.) (Lippson and Lippson 1997).

Intertidal marshes have high primary productivity. Tidal marshes are among the most productive ecosystems in the world, producing up to 80 metric tons per hectare (71,400 pounds/acre) of plant material annually, or 8,000 grams/m^2/year, in the southern coastal plain of North America (Mitch and Gosselink 1993, p. 249). Gross primary productivity in a Georgia salt marsh was calculated to convert 6.1% of incident sunlight energy, verifying that the community is one of the most productive ecosystems in the world (Mitch and Gosselink 1993, p. 256 based on Teal (1962). Nixon and Oviatt (1973 as given in Mitch and Gosselink (1993, p. 256-257)) report that energy flows during summer and winter in a salt marsh-estuary complex in New England revealed that an estimated 23% of the net productivity of the salt marsh was exported to the embayment. These findings led to the conclusion that the aquatic embayment is actually a heterotrophic ecosystem that depends on the import of organic matter from the autotrophic salt marsh. It is very likely that the high primary productivity of salt marshes in the project area is the foundation for the food chain of many primary (herbivores) and secondary (carnivores) consumers of the area.

Unvegetated, Intertidal, Estuarine Flats (Mudflat and Sandflats)

This tidally influenced community is found on Hatteras Island along the sound side of the marsh and on the southern tip of Bodie Island. It is characterized by saltwort (McCrain 1988). Large areas of unconsolidated sand and mud occur at the southern tip of Bodie Island.

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.

Sound - Pelagic

The estuarine waters of Pamlico Sound provide habitat for a diversity of aquatic life. Large phytoplankton populations, dominated by various diatoms, are grazed upon by larvae of various marine and estuarine fish, invertebrates, and zooplankton.

Sound - Benthic, Unvegetated

Estuarine benthic fauna near Oregon Inlet include polychaetes (*Nereis succinea*, *Laeonereis culveri*, and *Heteromastus filiformis*), decapods (*Rithropanopeus harrisii* and *Palaemonetes pugio*), amphipods (*Corophium lacustre*, *Gammarus fasciatus*, and *G. palustrus*), isopods (*Cyathura polita* and *Cassidinidea ovalis*), tanaids (*Hargeria repax*), and mollusks (*Rangia cuneata*, *Geukensia demissa*, *Macoma balthica*, and *Teredo* sp.). Bottom-dwelling polychaetes, oligochaetes, amphipods, isopods, and the commercially valuable oyster (*Crassostrea virginica*) and hard clam (*Mercenaria mercenaria*) ingest both phytoplankton and zooplankton.

Sound - Benthic, Vegetated

Vegetated benthic areas in the sound contain submerged aquatic vegetation (SAV). Extensive areas of SAV may be called seagrass meadows or seagrass beds. Areas of SAV occur near Oregon Inlet and form a complex and important ecosystem within Pamlico Sound. Submerged beds of eelgrass (*Zostera marina*), shoalgrass (*Halodule wrightii*), and widgeongrass (*Ruppia maritima*) exist together and separately. These beds occur in isolated patches as well as cover extensive areas. Seagrass systems are important to estuarine ecology (Thayer et al. 1979, 1981; Ferguson et al. 1981; Homiak et al. 1982; CZR, Inc. 1992a, Lippson and Lippson 1997, pp. 164-178). Specifically, seagrass habitats serve as important nursery areas for many fish species

(Thayer et al. 1979; Miller and Dunn 1980; Epperly and Ross 1986; Kenworthy et al. 1988; Noble and Monroe 1991; Lippson and Lippson 1997, pp. 172-175).

Areas of SAV are frequently observed to have conspicuously large amounts of biomass (Kenworthy et al. 1988). Such biomass is the result of high rates of net primary productivity. Representative rates for photosynthetic carbon (C) fixation of seagrass leaves are 0.3-0.8 g C/m^2/day for *Z. marina*, 0.9-16.0 g C/m^2/day for *Thalassia testudinum*, and 0.5-0.8 g C/m^2/day for *H. wrightii* (Kenworthy et al. 1988). Some seagrass systems approach productivity rates observed in subsidized agricultural crops. Based on several reports, Kenworthy et al. (1988) note that epiphytic organisms may attach to older seagrass leaves and provide additional sources of primary productivity which may be as much as one-third or more of the primary productivity of the actual seagrass.

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.

General Fish and Wildlife Service 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 provide long-term protection.

The Service recognizes that estuarine sounds, barrier island uplands, beaches, and the nearshore ocean 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 area usurping vast areas of habitat. In some cases, the species that depend on the ocean-beach interface are running out of undisturbed options.

Specific Fish and Wildlife Service Concerns for Direct Impacts

While the Service hopes that alternatives to an artificial beach-dune system will be thoroughly evaluated, such a system is now considered the most likely alternative. 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. The seasonal work schedule and manner of sediment transport would determine the extent of these impacts.

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 could lead to greater and more expensive development. Increased development is likely to 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.

Potential Positive Consequences of the Project

Dr. Stan Riggs of East Carolina University has proposed that if sand covering hardbottoms off of the North Carolina Coast was removed, there could be benefits to fishery resources. Use of sand from offshore areas may create fishery habitat if sand is removed from hardbottoms and the hardbottoms are broken up and colonized by seaweeds and invertebrates (Dr. Stan Riggs, Coastal Geologist, East Carolina University, personal communication, October 1992). According to Dr. Riggs, the amount of sand covering hardbottoms varies tremendously. Some areas are covered by approximately one foot of sand while other areas may be buried by up to 30 feet of sand. Offshore sand tends to move a lot and accumulates in certain areas, covering up rocky bottoms.

In addition to the potential problems associated with the project, there may be opportunities for fish and wildlife resource conservation and enhancement. Benefits to fish and wildlife include the creation of sea turtle and shorebird nesting habitat and possibly even the creation of reef habitat as sand is removed from hard bottoms offshore. The potential for reef creation in association with offshore sand mining should be studied.

Planning Objectives

Careful planning and a conscientious balancing of economic considerations with environmental concerns can produce a projects with minimal, short- and long-term environmental impacts. 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 artificial beach and dune creation 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 the artificial beach-dune system 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, live bottoms, nationally significant fish wintering grounds, 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. Planning should consider creating fishery habitat through removal of sand from hardbottom areas now covered with thin layers of sand.

4. If the artificial beach-dune system 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.

5. The Corps should carefully evaluate the potential impacts which the artificial beach-dune system could have on the Oregon Inlet navigation channel. The predominant north-to-

south longshore current will carry sand to this channel. Without a clear plan of action to meet this contingency, an especially severe storm season may block this vital transportation corridor.

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. 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 on the Outer Banks. The Service has been involved with the Corps on plans to construct a dual jetty system at Oregon Inlet and with the North Carolina Department of Transportation on plans to replace the existing Bonner Bridge over Oregon Inlet. The Service is also part of the Outer Banks Task Force, an interagency group working to provide both short- and long-term measures for ensuring surface transportation along the Outer Banks. A Service biologist conducted a brief tour of the specific area for the Northern Dare County Storm Damage Reduction Project on March 11, 1999.

Dr. Wilson Laney of the Service's South Atlantic Fisheries Resources Coordination Office in Raleigh, North Carolina, Doug Newcomb of the Raleigh Ecological Services Office, and Charles S. Manooch, III of the NMFS worked together to analyze data on offshore fisheries. Dr. Laney provided the fisheries data, Mr. Newcomb coordinated the computer analysis and graphical presentation of these data, and Mr. Manooch provided information on food habits. The results of this collaboration is presented in Appendix B.

The Service entered into a contractual agreement with Dr. Robert Dolan, Professor of Environmental Science at the University of Virginia, Charlottesville. Since 1996 Dr. Dolan has served as a consultant to the Service's Raleigh Field Office and Pea Island National Wildlife Refuge on issues related to the Outer Banks and has contributed to this report. Dr. Dolan has conducted research on the Outer Banks since 1961 and has published over 150 scientific papers and reports on the dynamics of the Atlantic Coast beaches and barrier islands. In 1979, Dr. Dolan joined the group of coastal experts formed by the Department of the Interior (DOI) and originally headed by Dr. Douglas Inman of Scripps Institution of Oceanography. This group, known as the "Inman Committee", advised the DOI throughout the 1980s and produced a series of reports and scientific articles on the coastal processes that would be affected by the jetties. Dr. Dolan has been instrumental in advising the DOI on dredging alternative to the jetties. He continues to direct research on geological processes of the Outer Banks and the impacts associated with sediment disposal on beaches of the Outer Banks. Dr. Dolan analyzed data on sediment from the existing beach and the proposed offshore borrow areas. This analysis addressed the sediment compatibility of the two areas and the potential environmental impacts that could be expected by using the offshore sites to construct the artificial beach-dune system. Dr. Dolan report is given in Appendix C.

Nomenclature in this report follows Tiner (1993) for coastal plants; Rohde et al. (1994) for freshwater fish; Robins and Ray (1986) for marine fish; Martof et al. (1980) for amphibians and reptiles; Potter et al. (1980) for birds; and Webster et al. (1985) for mammals. Both common and scientific names from cited literature follow the original publication. If the Service is aware of a widely accepted synonym for the common name, that synonym is given in brackets. If the Service is aware of a change in the scientific name of a given species, the revised nomenclature is included in brackets following the published name.

SECTION 5. EXISTING FISH AND WILDLIFE RESOURCES

This section presents information on the vertebrate species which occur in the project area. This information is divided into three sections: (1) lists of species, by class, which are not federally protected and have been reported in or near the project area; (2) federally protected species which may occur in the project area; and (3) available information on the vertebrates inhabiting the biological communities listed in Section 2.

Fish and Wildlife Resources by Vertebrate Class

Marine Fish

The estuarine and marine fish faunas within the project area are varied. Surveys at different times of the year with different equipment are likely to produce different results. Table 2 gives 76 species which were collected near the Bonner Bridge over Oregon Inlet (CZR Inc. 1992a), approximately five miles south of the southern limit of possible beaches to be nourished.

Table 2 lists only a single anadromous fish, the blueback herring (*Alosa aestivalis*). However, other anadromous fish could occur the project area. These species include the striped bass (*Morene saxatilis*), hickory shad (*Alosa aestivalis*), alewife (*A. mediocris*), and American shad (*A. sapidissima*). Appendix D presents data on selected species collected in the vicinity of the proposed borrow areas. The major species of concern are Atlantic Coast migratory Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), spiny dogfish (*Squalus acanthias*), striped bass, and weakfish (*Cynoscion regalis*).

The striped bass is an especially important consideration for this project (Appendix B). In the ocean the species is found from breaking waves to several miles offshore over sand and mud substrates. Offshore sandy bottom are the proposed borrow areas for the project.

Appendix D contains additional information on:

1. dominant fish species caught in North Carolina inshore waters by long-haul fishery, sciaenid pound net fishery, and flounder pound net fishery;

2. fish species recorded from commercial reef fish fishery landings at Hatteras, North Carolina; and,

3. dominant species caught in offshore waters of Dare County deepwater trawl fishery, flynet trawl fishery, nearshore flounder trawl fishery, and commercial reef fish fishery.

Table 2. Fish species collected near the Bonner Bridge over Oregon Inlet, south of the beaches to be nourished during the Northern Dare County Storm Damage Reduction Project, Dare County, North Carolina. List taken from CZR, Inc. (1992a) and based on unpublished data from trawl surveys conducted by the North Carolina Division of Marine Fisheries. Life history strategy based on Epperly (1984).

Common Name	Scientific Name	Life history strategy
Blueback herring	*Alosa aestivalis*	Anadromous
American eel	*Anguilla rostrata*	Catadromous
Striped anchovy	*Anchoa hepsetus*	Estuarine indigenous
Bay anchovy	*Anchoa mitchilli*	Estuarine indigenous
Skilletfish	*Gobiesox strumosus*	Estuarine indigenous
Killifish spp.	*Fundulus* spp.	Estuarine indigenous
Inland silverside	*Menidia beryllina*	Estuarine indigenous
Atlantic silverside	*Menidia menidia*	Estuarine indigenous
Dusky pipefish	*Syngnathus floridae*	Estuarine indigenous
Northern pipefish	*Syngnathus fuscus*	Estuarine indigenous
Chain pipefish	*Syngnathus louisianae*	Estuarine indigenous
Spotfin mojarra	*Eucinostomus argenteus*	Estuarine indigenous
Striped blenny	*Chasmodes basquianus*	Estuarine indigenous
Feather blenny	*Hypsoblennius hentzi*	Estuarine indigenous
Sharptail goby	*Gobionellus hastatus*	Estuarine indigenous
Naked goby	*Gobiosoma bosci*	Estuarine indigenous
Green goby	*Microgobius thalassinus*	Estuarine indigenous
Hogchoker	*Trinectes maculatus*	Estuarine indigenous
Largemouth bass	*Micropterus salmoides*	Freshwater transient
Atlantic stingray	*Dasyatis sabina*	Marine transient
Speckled worm eel	*Myrophis punctatus*	Marine transient
Inshore lizardfish	*Synodus foetens*	Marine transient
Oyster toadfish	*Opsanus tau*	Marine transient
Pollock	*Pollachius virens*	Marine transient
Southern hake	*Urophycis floridana*	Marine transient
Spotted hake	*Urophycis regia*	Marine transient
Bluespotted cornetfish	*Fistularia tabacaria*	Marine transient
Lined seahorse	*Hippocampus erectus*	Marine transient
Rock sea bass	*Centropristis philadelphica*	Marine transient
Black sea bass	*Centropristis striata*	Marine transient
Gag	*Mycteroperca microlepis*	Marine transient
Bluefish	*Pomatomus saltatrix*	Marine transient
Atlantic moonfish	*Selene setapinnis*	Marine transient
Lookdown	*Selene vomer*	Marine transient
Mutton snapper	*Lutjanus analis*	Marine transient
Gray snapper	*Lutjanus griseus*	Marine transient
Lane snapper	*Lutjanus synagris*	Marine transient

Table 2. (continued). Fish species collected near the Bonner Bridge over Oregon Inlet, south of the beaches to be nourished during the Northern Dare County Storm Damage Reduction Project, Dare County, North Carolina.

Common Name	Scientific Name	Life history strategy
Sheepshead	*Archosargus probatocephalus*	Marine transient
Southern kingfish	*Menticirrhus americanus*	Marine transient
Atlantic spadefish	*Chaetodipterus faber*	Marine transient
Slippery dick	*Halichoeres bivittatus*	Marine transient
Tautog	*Tautoga onitis*	Marine transient
Northern sennet	*Sphyraena borealis*	Marine transient
Southern stargazer	*Astroscopus y-graecum*	Marine transient
Crested blenny	*Hypleurochilus geminatus*	Marine transient
Atlantic cutlassfish	*Trichiurus lepturus*	Marine transient
Spanish mackerel	*Scomberomorus maculatus*	Marine transient
Harvestfish	*Peprilus alepidotus*	Marine transient
Butterfish	*Peprilus triacanthus*	Marine transient
Northern searobin	*Prionotus carolinus*	Marine transient
Striped searobin	*Prionotus evolans*	Marine transient
Leopard searobin	*Prionotus scitulus*	Marine transient
Bighead searobin	*Prionotus tribulus*	Marine transient
Bay whiff	*Citharichthys spilopterus*	Marine transient
Windowpane	*Scopthalmus aguosus*	Marine transient
Blackcheek tonguefish	*Symphurus plagiusa*	Marine transient
Orange filefish	*Aluterus schoepfi*	Marine transient
Planehead filefish	*Monacanthus hispidus*	Marine transient
Northern puffer	*Sphoeroides maculatus*	Marine transient
Striped burrfish	*Chilomysterus schoepfi*	Marine transient
Atlantic menhaden	*Bevoortia tyrannus*	Migratory marine
Crevalle jack	*Caranx hippos*	Migratory marine
Pigfish	*Orthopristis chrysoptera*	Migratory marine
Littlehead porgy	*Calamus proridens*	Migratory marine
Spottail pinfish	*Diplodus holbrooki*	Migratory marine
Pinfish	*Lagodon rhomboides*	Migratory marine
Silver perch	*Bairdiella chrysoura*	Migratory marine
Spotted seatrout	*Cynoscion nebulosus*	Migratory marine
Weakfish	*Cynoscion regalis*	Migratory marine
Spot	*Leiostomus zanthurus*	Migratory marine
Atlantic croaker	*Micropogonias undulatus*	Migratory marine
Red drum	*Sciaenops ocellatus*	Migratory marine
Striped mullet	*Mugil cephalus*	Migratory marine
Gulf flounder	*Paralichthys albigutta*	Migratory marine
Summer flounder	*Paralichthys dentatus*	Migratory marine
Southern flounder	*Paralichthys lethostigma*	Migratory marine

Freshwater Fish

Several factors influence the abundance and distribution of freshwater fishes in the project area (Schwartz 1992). These are erosion, natural succession of ponds, ponds filling with sediment, drought, and human encroachment. Schwartz (1992) reported 188 isolated ponds throughout the Outer Banks . Selected ponds were sampled in April and September of 1982 and 1983. Table 3 lists the species found in ponds from the Virginia-North Carolina border southward to Oregon Inlet (Schwartz 1992). Sixty of the 96 ponds in this area contained 25 species.

Amphibians and Terrestrial Reptiles

Amphibians recorded from the project area are given in Table 4. The amphibian fauna of the project is limited. This may be due to the requirement for a moist location or standing freshwater in which to lay their eggs. The project is not likely to directly impact amphibians. However, secondary development may impacts these species through direct loss of habitat, increased demands on freshwater resources, and increased discharges of wastewater.

Terrestrial reptiles from the project area are given in Table 5. As with the amphibians, the project is not likely to directly impact these species. However, secondary development may impact terrestrial reptiles in the same ways as amphibians.

Birds

The variety of upland, pelagic, and wetland communities on the Outer Banks provide a host of habitats for birds, both permanent and seasonal species. Coastal barrier islands probably harbor a greater variety of bird species than any other ecosystem in the continental United States (Wells and Peterson, undated). The birds which have been recorded in the project area are listed in Table 6 which is based on a list prepared by Fussell and Lyons (1990). That list contained 319 species regularly found on the Outer Banks and an additional 56 species which are considered accidentals. Table 6 combines three pairs of subspecies or varieties into three individual species. These are: (1) the snow and blue geese as the former; (2) the green-winged and Eurasian teals as the former; and, (3) the Savannah and Ipswich sparrows as the former. Therefore, Table 6 contains 316 species and may be consulted for the scientific names of birds given in this report.

Mammals

The mammalian fauna of the islands within the Outer Banks represents remnant populations that had more widespread paleodistributions, but are now isolated due to the ephemeral nature of inlets, the dynamic geomorphology of barrier islands, and fluctuations in sea level (Webster and Reese 1992). New species continue to disperse, or are introduced, onto the islands and outcompete established species, but the number of species remains more of less constant once each island's carrying capacity, which is dependent on its size and habitat heterogeneity, is reached.

Table 3. Fish species collected from freshwater ponds on the Outer Banks. The species given were found in ponds from the North Carolina-Virginia State line to Oregon Inlet. Source: Schwartz (1992).

Common name	Scientific name
Brown bullhead	*Ameiurus nebulosus*
American eel	*Anguilla rostrata*
Flier	*Centrarchus macropterus*
Sheepshead minnow	*Cyprinodon variegatus*
Common carp	*Cyprinus carpio*
Gizzard shad	*Dorosoma cepedianum*
Ladyfish	*Elops saurus*
Bluespotted sunfish	*Enneacanthus gloriosus*
Redfin pickerel	*Esox americanus*
Marsh killifish	*Fundulus confluentus*
Banded killifish	*Fundulus diaphanus*
Mummichog	*Fundulus heteroclitus*
Eastern mosquitofish	*Gambusia holbrooki*
Spot	*Leiostomus xanthurus*
Longnose gar	*Lepisosteus osseus*
Redbrested sunfish	*Lepomis auritus*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Rainwater killifish	*Lucania parva*
Inland silverside	*Menidia beryllina*
Largemouth bass	*Micropterus salmoides*
White perch	*Morone americana*
Striped mullet	*Mugil cephalus*
Golden shiner	*Notemigonus crysoleucas*
Black crappie	*Pomoxis nigromaculatus*

Table 4. Amphibians reported on Bodie and/or Hatteras Islands. These species are subject to potential direct and indirect impacts of the Northern Dare County Storm Damage Reduction Project, Dare County, North Carolina. Source: National Park Service, Cape Hatteras National Seashore and Bellis (1995).

Common Name	Scientific Name
Eastern narrowmouth toad	*Gastrophryne carolinensis*
Fowler's toad	*Bufo woodhousii*
Gray treefrog	*Hyla chrysoscelis*
Green treefrog	*Hyla cinerea*
Southern leopard frog	*Rana sphenocephala*
Squirrel treefrog	*Hyla squirella*
Two-toed amphiuma	*Amphiuma means*

Table 5. Terrestrial reptiles reported on Bodie and/or Hatteras Islands. These species are subject to potential direct and indirect impacts of the Northern Dare County Storm Damage Reduction Project, Dare County, North Carolina. Sources: a = National Park Service, Cape Hatteras National Seashore and b = Bellis (1995).

	Common Name	Scientific Name	Source
Snakes:	Black racer	*Coluber constricter*	a, b
	(Black) rat snake	*Elaphe obsoleta*	a, b
	Corn snake	*Elaphe guttata*	a
	(Eastern) cottonmouth	*Agkistrodon piscivorous*	a, b
	Eastern kingsnake	*Lampropeltis getulus*	a, b
	Eastern hognose snake	*Heterodon platyrhinos*	a
	(Eastern) ribbon snake	*Thamnophis sauritus*	a, b
	Northern water snake	*Nerodia sipedon sipedon*	a
	Carolina water (salt marsh) snake	*N. s. williamengelis*	a
	Brown water snake	*N. taxispilota*	b
	Rough green snake	*Opheodrys aestivus*	a, b
	Brown snake	*Storeria dekayi*	b
	Canebrake (timber) rattlesnake	*Crotalus horridus*	b
	(Eastern) diamondback rattlesnake	*Crotalus adamanteus*	b
Turtles:	Eastern mud turtle	*Kinosternon subrubrum*	a, b
	Diamondback terrapin	*Malaclemys terrapin*	a
	Snapping turtle	*Chelydra serpentina*	a, b
	Spotted turtle	*Clemmys guttata*	a, b
	Yellowbelly slider	*Chrysemys scripta*	a
Lizards:	Eastern glass lizard	*Ophisaurus ventralis*	a
	Ground skink	*Scincella lateralis*	b
	Southeastern five-lined skink	*Eumeces inexpectatus*	b
	Six-lined racerunner	*Cnemidophorus sexlineatus*	a

Table 6. Birds in the Dare County Storm Damage Reduction Project area. List based on Fussell and Lyons (1990). Additional notes and seasonal abundance are given for species considered by CZR, Inc.(1992a). Seasons are Sp (Spring: March-May), Sum (Summer: June-August), Fall (September November), and Win (Winter: December-February). Abundance is given as abundant (a), common (c), uncommon (u), occasional (o), rare (r), or accidental (-). Notes indicates if abundant is based on sightings at sea (offshore) and species which nest in project area (nest). Note "a" indicates species not considered by CZR.

		Notes/Abundance (CZR 1992)				
			Seasonal Abundance			
Common Name	Scientific Name	Notes	Sp	Sum	Fall	Win
Red-throated loon	Gavia stellata		c	-	c	a
Common Loon	Gavia immer		c	r	c	c
Pied-billed Grebe	Polilymbus podiceps		c	o	c	a
Horned Grebe	Podiceps auritus		c	-	u	a
Red-necked Grebe	Podiceps grisegena		-	-	-	r
Eared Grebe	Podiceps migricollis		-	-	-	-
Northern Fulmar	Fulmarus glacialis	offshore	a	o	a	c
Black-capped Petrel	Pterodroma hasitata	a				
Cory's Shearwater	Puffinus diomedea	offshore	u	u	u	-
Greater Shearwater	Puffinus gravis	offshore	-	c	c	-
Sooty Shearwater	Puffinus griseus	offshore	r	u	r	-
Manx shearwater	Puffinus puffinus	a				
Audubon's Shearwater	Puffinus Iherminieri	offshore	-	a	a	-
Wilson's Storm-petrel	Oceanites oceanicus	offshore	r	a	a	-
White-faced Storm-petrel	Pelagodroma marina		-	-	-	-
Leach's Storm-petrel	Oceanodroma leucorhoa	offshore	r	r	r	-
Band-rumped Storm-petrel	Oceanodroma castro	a				
White-tailed Tropicbird	Phaethon lepturus		-	-	-	-
Masked Booby	Sula dactylatra	a				
Northern Gannet	Sula bassauus		c	r	c	a
American White Pelican	Pelecanus erythrorhynchis		-	-	-	-
Brown Pelican	Pelecanus occidentalis		c	c	c	u
Great Cormorant	Phalacrocorax carbo		-	-	-	o
Double-crested Cormorant	Phalacrocorax auritus		a	r	c	c
Magnificent Frigatebird	Fregata magnificens		-	-	-	-
American Bittern	Botaurus leutiginosus		c	o	c	c
Least Bittern	Ixobrychus exilis	nest	u	u	o	-
Great Blue Heron	Ardea herodias		u	u	u	u
Great (Common) Egret	Casmerodius albus		c	c	c	c
Snowy Egret	Egretta thula	nest	c	c	c	u
Little Blue Heron	Egretta caerulea	nest	c	c	c	u
Tri-colored Heron	Egretta tricolor	nest	c	c	c	u
Cattle Egret	Bubulcus ibis	nest	u	c	c	r
Green (-backed) Heron	Butorides striatus	nest	u	u	u	o
Black-crowned Night Heron	Nycticorax nycticorax	nest	c	c	c	u

Table 6. (continued). Birds in the Northern Dare County Storm Damage Reduction Project area.

		Notes/Abundance				
			Abundance			
Common Name	Scientific Name	Notes	Sp	Sum	Fall	Win
Yellow-crowned Night Heron	*Nyctanassa violacea*	nest	r	u	u	r
White Ibis	*Eudocimus albus*	nest	-	o	o	r
Glossy Ibis	*Plegadis falcinellus*	nest	c	c	c	r
Fulvous Whistling Duck	*Dendrocygna bicolor*		r	-	r	u
Tundra Swan	*Cygnus columbianus*		c	r	c	c
Greater White—fronted Goose	*Anser albifrons*		r	-	-	r
Snow/Blue Goose	*Chen caerulescens*		a	r	a	a
Ross' Goose	*Chen rossii*		-	-	-	r
(Black) Brant	*Branta bernicla*		-	-	r	r
Canada Goose	*Branta canadensis*		a	r	a	a
Wood Duck	*Aix sponsa*		r	-	r	r
Green-winged/Eurasian Teal	*Anas crecca*	nest	a	r	a	a
American Black Duck	*Anas rubripes*	nest	a	u	a	a
Mallard	*Anas platyrhynchos*	nest	u	o	u	u
Northern Pintail	*Anas acuta*		c	-	a	a
Blue-winged Teal	*Anas discors*	nest	a	o	a	r
Northern Shoveler	*Anas clypeata*		c	-	c	c
Gadwall	*Anas strepera*	nest	c	c	c	u
European (Eurasian) Wigeon	*Anas penelope*		-	-	-	r
American Wigeon	*Anas americana*		c	-	c	a
Canvasback	*Aythya valisineria*		u	-	u	c
Redhead	*Aythya americana*		u	-	c	c
Ring-necked Duck	*Aythya collaris*		c	-	c	c
Greater Scaup	*Aythya marila*		c	r	u	c
Lesser Scaup	*Aythya affinis*		c	-	u	c
Common Eider	*Somateria mollissima*		-	-	-	r
King Eider	*Somateria spectabilis*		-	-	-	-
Harlequin Duck	*Histrionicus histrionicus*	a				
Oldsquaw	*Clangula hyemalis*		u	-	r	u
Black Scoter	*Melanitta nigra*		c	-	u	c
Surf Scoter	*Melanitta perspicillata*		c	-	u	a
White-winged Scoter	*Melanitta deglandi*		u	-	u	u
Common Goldeneye	*Bucephala clangula*		r	-	r	o
Bufflehead	*Bucephala albeola*		c	r	c	c
Hooded Merganser	*Lophodytes cucullatus*		u	-	u	c
Common Merganser	*Mergus merganser*		u	-	u	u
Red-breasted Merganser	*Mergus serrator*		a	r	c	a
Ruddy Duck	*Oxyura jamaiceusis*		c	r	c	c
Turkey Vulture	*Cathartes aura*		r	r	r	r
Osprey	*Pandian haliaetus*	nest	u	u	c	-
Swallow-tailed Kite	*Elanoides forficatus*		-	-	-	-

Table 6. (continued). Birds in the Northern Dare County Storm Damage Reduction Project area.

		Notes/Abundance				
			Abundance			
Common Name	Scientific Name	Notes	Sp	Sum	Fall	Win
Bald Eagle	*Haliaeetus leucocephalus*		r	r	r	r
Northern Harrier	*Circus cyaneus*		c	-	c	c
Sharp-shinned Hawk	*Accipiter striatus*		o	-	a	u
Cooper's Hawk	*Accipiter cooperii*		r	-	r	r
Red-shouldered Hawk	*Buteo lineatus*		r	-	r	r
Broad-winged Hawk	*Buteo platypterus*	a				
Red-tailed Hawk	*Buteo jamaicensis*		r	-	r	r
Rough-legged Hawk	*Buteo lagopus*		-	-	-	-
American Kestrel	*Falco sparverius*		c	-	a	a
Merlin	*Falco columbarius*		u	-	c	u
Peregrine Falcon	*Falco peregrinus*		u	-	c	u
Ring-necked Pheasant	*Phasianus colchicus*	nest	c	c	c	c
Northern Bobwhite	*Colinus virginianus*	a				
Yellow Rail	*Coturnicops noveboracensis*		-	-	-	-
Black Rail	*Laterallus jamaicensis*		r	r	r	r
Clapper Rail	*Rallus longirostris*	nest	c	c	c	c
King Rail	*Rallus elegans*	nest	c	c	c	c
Virginia Rail	*Rallus limicola*		u	o	u	u
Sora	*Porzana carolina*		c	u	a	u
Common Moorhen	*Gallinula chloropus*	nest	u	u	u	r
American Coot	*Fulica americana*		a	r	a	a
Black-bellied Plover	*Pluvialis squatarola*		a	u	a	c
Lesser Golden Plover	*Pluvialis dominica*		r	-	o	r
Wilson's Plover	*Charadrius wilsonia*	nest	u	o	u	u
Semipalmated Plover	*Charadrius semipalmatus*		c	u	c	u
Piping Plover	*Charadrius melodus*	nest	u	u	u	u
Killdeer	*Charadrius vociferus*	nest	u	u	u	u
American Oystercatcher	*Naematopus palliatus*	nest	c	u	u	r
Black-necked Stilt	*Himantopus mexicanus*		u	c	c	-
American Avocet	*Recurvivostra americana*	nest	u	u	u	r
Greater Yellowlegs	*Tringa melanoleuca*		a	c	a	c
Lesser Yellowlegs	*Tringa flavipes*		a	c	a	u
Solitary Sandpiper	*Trinva solitaria*		u	o	u	o
Willet	*Catoptrophorus semipalmatus*	nest	c	c	c	u
Spotted Sandpiper	*Actitis macularia*		c	u	c	o
Upland Sandpiper	*Bartramia longicauda*		o	o	o	-
Whimbrel	*Numenius phaeopus*		c	r	c	o
Long-billed Curlew	*Numenius americanus*		-	-	u	-
Hudsonian Godwit	*Limosa haemastica*		r	r	u	-
Marbled Godwit	*Limosa fedoa*		o	u	o	u
Ruddy Turnstone	*Arenaria interpres*		a	u	a	u

Table 6. (continued). Birds in the Northern Dare County Storm Damage Reduction Project area.

Common Name	Scientific Name	Notes/Abundance				
			Abundance			
		Notes	Sp	Sum	Fall	Win
Red Rnot	*Calidris canutus*		c	u	c	u
Sanderling	*Calidris alba*		a	c	a	a
Semipalmated Sandpiper	*Calidris pusilla*		a	c	a	u
Western Sandpiper	*Calidris mauri*		c	u	a	c
Least Sandpiper	*Calidris minutilla*		a	c	a	u
White-rumped Sandpiper	*Calidris fuscicollis*		o	r	c	-
Baird's Sandpiper	*Calidris bairdii*		-	u	u	-
Pectoral Sandpiper	*Calidris melanotos*		u	-	c	r
Purple Sandpiper	*Calidris maritima*		-	-	-	-
Dunlin	*Calidris alpina*		a	u	a	c
Curlew Sandpiper	*Calidris ferruginea*		-	-	-	-
Stilt Sandpiper	*Micopalama himantopus*	a				
Buff-breasted Sandpiper	*Tryngites subrufficollis*		-	-	r	-
Ruff	*Philomachus pugnax*		-	-	-	-
Short-billed Dowitcher	*Limnodromus griseus*		c	c	a	u
Long-billed Dowitcher	*Limnodromus scolopaceus*		u	r	c	u
Common Snipe	*Gallinago gallinago*		a	r	c	a
American Woodcock	*Scolopax minor*		r	-	r	r
Wilson's Phalarope	*Phalaropus tricolor*		r	r	u	-
Red-necked Phalarope	*Phalaropus lobatus*	offsh	c	-	c	-
Red Phalarope	*Phalaropus fulicarius*	offsh	c	-	c	r
Pomerine Jaeger	*Stercorarius pomarinus*	offsh	u	u	c	r
Parasitic Jaeger	*Stereorarius parasiticus*	offsh	r	u	u	-
Long-tailed Jaeger	*Stereorarius longicaudus*	offsh	u	-	u	-
Great Skua	*Catharacta skua*	a				
South Polar Skua	*Catharacta maccormicki*	a				
Laughing Gull	*Larus atricilla*	nest	a	a	a	u
Little Gull	*Larus minutus*		-	-	-	-
Common Black-headed Gull	*Larus ridibundus*		-	-	-	-
Bonaparte's Gull	*Larus philadelphia*		c	-	u	c
Ring-billed Gull	*Larus delawarensis*		a	c	a	a
Herring Gull	*Larus argentatus*	nest	a	c	a	a
Iceland Gull	*Larus glaucoides*		-	-	-	-
Lesser Black-backed Gull	*Larus fuscus*		-	-	u	-
Glaucous Gull	*Larus hyperboreus*		r	-	-	r
Great Black-backed Gull	*Larus marinus*	nest	c	c	c	a
Black-legged Kittiwake	*Rissa tridactyla*	offsh	-	r	u	c
Sabine's Gull	*Xema sabini*	a				
Gull-billed Tern	*Sterna nilotica*	nest	c	c	u	-
Caspian Tern	*Sterna caspia*	nest	u	u	c	o
Royal Tern	*Sterna maxima*	nest	c	c	c	u

Table 6. (continued). Birds in the Northern Dare County Storm Damage Reduction Project area.

		Notes/Abundance				
			Abundance			
Common Name	Scientific Name	Notes	Sp	Sum	Fall	Win
Sandwich Tern	*Sterna sandvicensis*	nest	c	c	c	-
Roseate Tern	*Sterna dougalli*		r	r	r	-
Common Tern	*Sterna hirunda*	nest	c	c	c	r
Arctic Tern	*Sterna paradisaea*	a				
Forster's Tern	*Sterna forsteri*		a	c	r	a
Least Tern	*Sterna antillarum*	nest	c	c	c	-
Bridled Tern	*Sterna anaethetus*	offsh	-	c	u	-
Sooty Tern	*Sterna fuscata*	a				
Black Tern	*Chlidonias niger*		u	c	a	-
Black Skimmer	*Rynchops niger*	nest	c	c	c	u
Dovekie	*Alle alle*		r	-	r	r
Razorbill	*Alca torda*		-	-	-	r
Rock Dove (Pigeon)	*Columbia livia*	a				
Mourning Dove	*Zenaida macroura*	nest	u	u	u	u
Black-billed Cuckoo	*Cocsyzus erythropthalmus*		r	-	r	-
Yellow-billed Cuckoo	*Coccyzux americanus*	nest	u	u	c	-
Common Barn-owl	*Tyto alba*	nest	o	o	o	o
Eastern Screech Owl	*Otus asio*	a				
Great Horned Owl	*Bubo virginianus*	a				
Short-eared Owl	*Asio flammeus*		o	-	u	u
Northern Saw-whet Owl	*Aegolius acadicus*		-	-	-	-
Common Nighthawk	*Chordeiles minor*	nest	o	o	o	-
Chuck-will's-widow	*Caprimulgus carolinensis*		r	r	r	-
Chimney Swift	*Chaetura pelagica*		o	o	o	-
Ruby-throated Hummingbird	*Archilochus colubris*		o	u	u	-
Belted Kingfisher	*Ceryle aleyon*		u	u	c	c
Red-headed Woodpecker	*Melanerpes erythrocephalus*		-	-	o	-
Red-bellied Woodpecker	*Melanerpes carolinus*	a				
Yellow-bellied Sapsucker	*Sphyrapicus varius*		u	-	c	u
Downy Woodpecker	*Picoides pubescens*	nest	u	u	u	u
Hairy Woodpecker	*Picoides villosus*		r	-	r	r
Northern Flicker	*Colaptes auratus*	nest	u	u	a	c
Pileated Woodpecker	*Dryocopus pileatus*	a				
Eastern Wood-pewee	*Contopus virens*		u	u	u	-
Yellow-bellied Flycatcher	*Empidonax flaviventris*		-	-	r	-
Acadian Flycatcher	*Empidonax virescens*		-	-	-	-
Least Flycatcher	*Empidonax minimus*	a				
Eastern Phoebe	*Sayornis phoebe*		u	-	-	-
Great Crested Flycatcher	*Myiarchus crinitus*	nest	u	u	u	-
Western Kingbird	*Tyrannus verticalis*		-	-	u	-
Eastern Kingbird	*Tyrannus tyrannus*		-	c	c	c

Table 6. (continued). Birds in the Northern Dare County Storm Damage Reduction Project area.

Common Name	Scientific Name	Notes/Abundance				
			Abundance			
		Notes	Sp	Sum	Fall	Win
Gray Kingbird	*Tyrannus dominicensis*		-	-	-	-
Scissor-tailed Flycatcher	*Tyrannus forficatus*		-	-	-	-
Horned Lark	*Eremophila alpestris*		r	-	r	r
Purple Martin	*Progne subis*		u	u	c	-
Tree Swallow	*Tachycineta bicolor*		c	u	a	u
[Northern] Rough-winged Swallow	*Stelgidopteryx ruficollis*		-	-	-	-
Bank Swallow	*Riparia riparia*		o	-	u	-
Cliff Swallow	*Hirundo pyrrhonota*		-	-	r	-
Barn Swallow	*Hirundo rustica*	nest	a	a	a	-
Blue Jay	*Cyanocitta cristata*		r	r	r	-
American Crow	*Corvus brachyrhynchos*		u	u	u	u
Fish Crow	*Corvus ossifragus*	nest	c	c	c	c
Carolina Chickadee	*Parus carolinensis*	nest	u	u	u	u
Tufted Titmouse	*Parus bicolor*	a				
Red-breasted Nuthatch	*Sitta canadensis*		c	-	c	-
Brown Creeper	*Certhia americana*		o	-	c	u
Carolina Wren	*Thryothorus ludovicianus*	nest	c	c	c	c
House Wren	*Troglodytes aedon*		u	-	c	u
Winter Wren	*Troglodytes troglodytes*		o	-	u	o
Sedge Wren	*Cistothorus platensis*		c	-	c	c
Marsh Wren	*Cistothorus palustris*	nest	c	c	c	c
Golden-crowned Kinglet	*Regulus satrapa*		u	-	c	u
Ruby-crowned Kinglet	*Regulus calendula*		c	-	c	c
Blue-gray Gnatcatcher	*Polioptila caerulea*		o	-	u	-
Veery	*Cathurus fuscescens*		u	-	u	-
Gray-cheeked Thrush	*Cathurus minimus*		o	-	u	-
Swainson's Thrush	*Cathurus ustulatus*		o	-	c	-
Hermit Thrush	*Cathurus guttatus*		o	-	c	o
Wood Thrush	*Hylocichla mustelina*		-	-	r	-
American Robin	*Turdus migratorius*		u	u	c	c
Gray Catbird	*Dumetella carolinensis*	nest	a	a	a	c
Northern Mockingbird	*Mimus polyglottos*	nest	u	u	u	u
Brown Thraser	*Toxostoma rufum*	nest	u	u	u	u
Water Pipit	*Anthus spinoletta*		u	-	u	u
Cedar Waxwing	*Bombycilla cedrorum*		u	-	u	c
Loggerhead Shrike	*Lanius ludovicianus*		-	-	r	r
European Starling	*Sturnus vulgaris*	nest	c	c	c	a
White-eyed Vireo	*Vireo griseus*	nest	u	c	c	-
Solitary Vireo	*Vireo soliarius*	a				
Yellow-throated Vireo	*Vireo flavifrons*	a				
Philadelphia Vireo	*Vireo philadelphicus*		-	-	o	-

Table 6. (continued). Birds in the Northern Dare County Storm Damage Reduction Project area.

		Notes/Abundance				
			Abundance			
Common Name	Scientific Name	Notes	Sp	Sum	Fall	Win
Red-eyed Vireo	*Vireo olivaceus*	nest	u	u	u	-
Blue-winged Warbler	*Vermivora pinus*		-	-	-	-
Golden-winged Warbler	*Vermivora chrysoptera*	a				
Tennessee Warbler	*Vermivora peregrina*		r	-	u	-
Orange-crowned Warbler	*Vermivora celata*		u	-	u	c
Nashville Warbler	*Vermivora ruficapilla*		-	-	u	-
Northern Parula	*Parula americana*		c	-	c	-
Yellow Warbler	*Dendroica petechia*	nest	u	c	c	-
Chestnut-sided Warbler	*Dendroica pensylvanica*		-	-	r	-
Magnolia Warbler	*Dendroica magnolia*		-	-	c	-
Cape May Warbler	*Dendroica tigrina*		-	-	c	-
Black-throated Blue Warbler	*Dendroica caerulescens*		u	-	c	-
Yellow-rumped (Myrtle) Warbler	*Dendroica coronata*		a	-	a	a
Black-throated Green Warbler	*Dendroica virens*		-	-	u	-
Blackburnian Warbler	*Dendroica fusca*		-	-	r	-
Yellow-throated Warbler	*Dendroica dominica*		-	-	r	-
Pine Warbler	*Dendroica pinus*		-	-	u	-
Prairie Warbler	*Dendroica striata*	nest	u	a	a	-
Palm Warbler	*Dendroica palmarum*		c	-	a	c
Bay-breasted Warbler	*Dendroica castanea*		-	-	r	-
Blackpoll Warbler	*Dendroica striata*		c	-	c	-
Black-and-white Warbler	*Mniotilta varia*		u	-	c	-
American Redstart	*Setophaga ruticilla*		c	-	a	-
Prothonotary Warbler	*Protonotaria citrea*		o	-	o	-
Worm-eating Warbler	*Helmitheros vermivorus*	a				
Ovenbird	*Seiurus aurocapillus*		r	-	r	-
Northern Waterthrush	*Seiurus noveboracensis*		o	-	c	-
Connecticut Warbler	*Oporornis agilis*		-	-	r	-
Common Yellowthroat	*Geothlypis trichas*	nest	c	c	a	u
Hooded Warbler	*Wilsonia citrina*		-	-	r	-
Wilson's Warbler	*Wilsonia pusilla*		-	-	r	-
Canada Warbler	*Wilsonia canadensis*		-	-	r	-
Yellow-breasted Chat	*Icteria virens*	nest	o	o	u	o
Summer Tanager	*Piranga rubra*		o	-	r	-
Scarlet Tanager	*Piranga olivacea*		-	-	r	-
Northern Cardinal	*Cardinalis cardinalis*	nest	c	c	c	c
Rose-breasted Grosbeak	*Pheucticus ludovicianus*		-	-	u	-
Blue Grosbeak	*Guiraca caerulea*		-	-	u	-
Indigo Bunting	*Passerina cyanea*		o	-	u	-
Painted Bunting	*Passerina ciris*	a				
Dickcissel	*Spiza americana*		-	-	u	-

Table 6. (continued). Birds in the Northern Dare County Storm Damage Reduction Project area.

		Notes/Abundance				
			Abundance			
Common Name	Scientific Name	Notes	Sp	Sum	Fall	Win
Rufous-sided Towhee	*Pipilo erythrophthalmus*	nest	a	a	a	a
Chipping Sparrow	*Spizella passerina*		o	-	c	o
Clay-colored Sparrow	*Spizella pallida*		-	-	u	-
Field Sparrow	*Spizella pusilla*	nest	u	u	c	u
Vesper Sparrow	*Pooecetes gramineus*		-	-	c	u
Lark Sparrow	*Chondestes grammacus*		-	u	c	u
Savannah/Ipswich Sparrow	*Passerculus sandwichensis*		a	-	a	a
Grasshopper Sparrow	*Ammodramus savannarum*		-	-	u	o
Sharp-tailed Sparrow	*Ammodramus candacutus*		a	-	a	a
Seaside Sparrow	*Ammodramus maritimus*	nest	a	c	a	a
Fox Sparrow	*Passerella iliaca*		o	-	u	o
Song Sparrow	*Melospiza melodia*	nest	a	a	a	a
Lincoln's Sparrow	*Melospiza lincolnii*		-	-	u	-
Swamp Sparrow	*Melospiza georgiana*		o	-	a	a
White-throated Sparrow	*Zonotrichia albicollis*		u	-	a	u
White-crowned Sparrow	*Zonotrichia leucophrys*		-	-	c	o
Dark-eyed Junco	*Junco hyemalis*		u	-	u	u
Lapland Longspur	*Calcarius lapponicus*		-	-	-	-
Snow Bunting	*Plectrophenax nivalis*		o	-	o	o
Bobolink	*Dolichonyx oryzivorus*		c	-	c	-
Red-winged Blackbird	*Agelaius phoeniceus*	nest	a	a	a	a
Eastern Meadowlark	*Sturnella magna*	nest	c	c	c	a
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	a				
Rusty Blackbird	*Euphagus carolinus*		-	-	r	-
Boat-tailed Grackle	*Quiscalus major*	nest	a	a	a	a
Comnon Grackle	*Quiscalus quiscula*	nest	r	r	r	r
Brown-headed Cowbird	*Molothrus ater*		c	-	c	c
Orchard Oriole	*Icterus spurius*	nest	u	u	-	-
Northern Oriole	*Icterus galbula*		-	-	a	-
Purple Finch	*Carpodacus purpureus*		-	-	u	u
House Finch	*Carodacus mexicanus*					
Pine Siskin	*Carduelis pinus*		-	-	u	u
American Goldfinch	*Corduelis tristis*		u	-	c	u
Evening Grosbeak	*Coccothraustes vesgertinus*		-	-	r	-
House Sparrow	*Passer domesticus*	nest	u	u	u	u

Webster (1988) noted that the mammalian diversity in Currituck-Bodie Island is greater than on any other forested barrier island in North Carolina or adjacent coastal state. This may be due to the periodic formation of land bridges to the mainland that served as dispersal corridors from southeastern Virginia and east-central North Carolina. The area also provides a diversity of habitats.

Bats are considered to be regular and widespread on the Outer Banks, at least during autumnal migrations (Webster and Reese 1992). The mammal list of the CHNS contains only the red bat (*Lasiurus borealis*), but the Chiropterans are difficult to survey and other species are likely to exist in the project area. Table 7 contains 23 mammals known to occur within the national seashore (Marcia Lyons, CHNS, personal communication, July 1997).

Federally Protected Species

Cetaceans

Marine mammals are protected by the Marine Mammal Protection Act of 1972. Some species are also protected by the ESA. Marine mammals occur in offshore and inshore waters of North Carolina. Twenty-nine species of cetaceans have been recorded along the coast of the Carolinas, Virginia, and Maryland (Webster et al. 1985, p. 206). Some species occur only in deeper offshore waters beyond the project limits, but other species which occasionally appear in waters close to shore could occur within the project area.

Whales - The humpback whale (*Megaptera novaeangliae*) and the federally-endangered [northern] right whale (*Eubalaena* [*Balaena*] *glacialis*) are spring and fall migrants off North Carolina's coast. Both species may be found in nearshore waters. During spring migration, right whales migrate immediately adjacent to the coast, and probably utilize deeper waters during fall migration. Since 1991, humpbacks have been spotted off the North Carolina coast in every month, with a peak of abundance occurring in January through March (McLellan 1997). The right whale may migrate through areas that are potential borrow areas for the project (McLellan 1997). The long-finned pilot whale (*Globicephala melaena*) and short-finned pilot whale (*G. macrorhynchus*) are primarily oceanic, but frequently move inshore when food resources are more plentiful there (Webster et al. 1985, p. 217). The sei whale (*Balaenoptera borealis*) and blue whale (*Balaenoptera musculus*) occur in North Carolina offshore waters on an irregular basis.

The sperm whale (*Physeter macrocephalus*), dwarf sperm whale (*Kogia simus*), and pygmy sperm whale (*K. breviceps*) inhabit the offshore waters of North Carolina (Webster et al. 1985, p. 220). While the sperm whale favors the deeper waters off the continental shelf, they may use shallow waters to calve or in times of sickness (Webster et al. 1985, p. 222). The sperm whale is a year-round resident of the continental shelf edge and pelagic waters. This species probably moves farther offshore during the winter.

Table 7. Mammals (excluding bats) reported within the Cape Hatteras National Seashore on Bodie and/or Hatteras Islands. Sources: National Park Service (NPS), Cape Hatteras National Seashore and Webster et al. (1985). Abundance data from the NPS.

Common Name	Scientific Name	Abundance
opossum	*Didelphis virginiana*	common
southeastern shrew	*Sorex longirostris*	rare
least shrew	*Cryptotis parva*	common
eastern mole	*Scalopus aquaticus*	abundant
eastern cottontail	*Sylvilagus floridanus*	abundant
marsh rabbit	*Sylvilagus palustris*	data not provided
gray squirrel	*Sciurus carolinensis*	common
marsh rice rat	*Oryzomys palustris*	common
white-footed mouse	*Peromyscus leucopus*	common
cotton mouse	*Peromyscus gossypinus*	common
house mouse	*Mus musculus*	abundant
meadow vole	*Microtus pennsylvanicus*	common
muskrat	*Ondatra zibethicus*	common
black rat	*Rattus rattus*	common
Norway rat	*Rattus norvegicus*	common
nutria	*Myocastor coypus*	abundant
gray fox	*Urocyon cinereoargenteus*	common
raccoon	*Procyon lotor*	abundant
mink	*Mustela vison*	uncommon
river otter	*Lutra canadensis*	uncommon
house cat	*Felis domestica*	common
harbor seal	*Phoca vitulina*	occasional
white-tailed deer	*Odocoileus virginianus*	common

Dolphins and Porpoises - Bottle-nosed dolphins (*Tursiops truncatus*) and harbor porpoises (*Phocoena phocoena*) utilize nearshore waters including bays, estuarine creeks, and sounds.

Bottle-nosed dolphins are common in this area. This species (also known as the Atlantic bottlenose dolphin) is the most abundant cetacean along the Atlantic coast (Webster et al. 1985, p. 213). It inhabits inshore waters and frequently enters sounds, rivers, and tidal creeks of North Carolina (Webster et al. 1985, p. 213). Lippson and Lippson (1997, p. 251) report these dolphins as summer inhabitants of the lower Chesapeake Bay where they are often seen feeding in the swift currents near the Elizabeth and James Rivers. Coastal migratory bottlenose dolphins are regularly seen in the waters off the project area from April to November (McLellan 1997).

The harbor porpoise is the only member of the Family Phocoenidae that enters the coastal waters of the mid-Atlantic region. The species spends summer and fall farther north in cold, subarctic water, but migrates southward to the mid-Atlantic region during the winter and spring (Webster et al. 1985, p. 218). Yearlings are relative common from January through May. Inshore waters and shallow coastal bays are used by the species. Since the early 1990s harbor porpoises have been collected on the beaches of the mid-Atlantic, from November to May, as far south as Ocracoke Island (McLellan 1997).

West Indian Manatee

This aquatic mammal, also known as the Florida manatee, is classified as endangered. In the United States the species occurs primarily in Florida. Generally, manatees remain in the coastal waters of the Florida peninsula during the winter and disperse during summer months. Individuals may move north along the Atlantic Coast and occasionally make their way into the coastal waters of North Carolina (Webster et al. 1985, p. 224). Clark (1987, p. 18) writes that "Although the migratory North Carolina population is undoubtedly small, regular reports of this animal from our coastal rivers suggest that the occurrence of the manatee in North Carolina should not be considered exceptional. . . . manatees frequent shallow, nearshore marine and estuarine habitats and move up sluggish rivers for variable distances."

Schwartz (1995) summarized data on the occurrence of 68 manatee sightings at 59 sites in North Carolina from 1919 through 1994. The species has been recorded in 11 coastal counties of North Carolina, including nine reports from Dare County. Four North Carolina records have been from inlet-ocean sites and six occurred in the open ocean. Open ocean reports include single sightings off Avon and Kitty Hawk, both in Dare County. Manatees have been reported in the state during nine months, with most sightings in the August-September period. Within Dare County manatees have been reported from Pamlico Sound (June 1975, September 1983, October 1983), Albermarle Sound (September 1983, October 1983), Collington Bay near Kitty Hawk (September-October 1986), Wanchese Harbor (September 1983), and the vicinity of Rodanthe (September 1987) (Schwartz 1995).

Manatees are strictly herbivorous and in the sound they are likely to feed on a wide variety of aquatic plants, including SAV. The presence of adequate food resources would be important in ensuring that these animals are able to return to warmer waters before the onset of winter.

Sea Turtles

All five Atlantic sea turtles are protected by the ESA and may occur in the coastal waters of North Carolina (Epperly et al. 1995). These species are the federally threatened loggerhead sea turtle (*Caretta caretta*), the federally threatened green sea turtle (*Chelonia mydas*), the federally endangered Kemp's ridley sea turtle (*Lepidochelys kempi*), the federally endangered hawksbill sea turtle (*Eretmochelys imbricata*), and federally endangered leatherback sea turtle (*Dermochelys coriacea*).

The presence of sea turtles in nearshore and estuarine waters of North Carolina appears to be seasonal. Sea turtles are present in the offshore water of North Carolina throughout the year and present in inshore waters from April through December (Epperly et al. 1995). As waters cool in the fall, turtles emigrate from inshore waters of temperate latitudes and migrate southward. As waters warm in the spring, immature turtles migrate inshore and northward, repopulating the inshore waters. Such an inshore-offshore seasonal migration may mean that several species of sea turtle pass through Outer Banks inlets on a seasonal basis.

Survey data from North Carolina and other areas suggest that temperate and subtropical waters are important as developmental habitats for immature Kemp's ridley, green, and loggerhead sea turtles (Epperly et al. 1995). Post-pelagic juvenile green and loggerhead turtles appear to recruit to estuaries along the Atlantic coast.

The leatherback is not common in North Carolina waters. Leatherbacks occur along the entire coast of the state (Palmer and Braswell 1995, p. 41). About 40 individuals were reported from state waters and beaches between 1968 and 1980. Most leatherbacks were reported in the ocean, usually in relatively shallow water over the continental shelf, but away from beaches. Most records are from mid-April to mid-October. One leatherback was captured in Pamlico Sound during a 1989-1992 survey (Epperly et al. 1995).

The hawksbill is primarily tropical and not abundant in North Carolina waters. Hawksbills are omnivorous with the young apparently more herbivorous than the adults. One hawksbill was captured in Pamlico Sound during a 1989-1992 survey (Epperly et al. 1995).

The Kemp's ridley probably ranges along the entire coast of the state, but it is not common and is generally considered the most endangered sea turtle in the world (Palmer and Braswell 1995, p. 34). Most individuals have been reported in shallow water of high salinity areas of sounds near the sea. The species feeds mainly on clams, crabs, and snails.

Adult green sea turtles are mainly tropical and are only occasionally found in state waters, but immature greens are still relatively common along the North Carolina coast (Palmer and Braswell 1995, p. 30).

The loggerhead sea turtle is the most common sea turtle along the North Carolina coast. Loggerheads occur in the ocean and various saltwater environments. However, they may survive for extended periods in freshwater. Most nesting occurs between mid-May and late August (Palmer and Braswell 1995, p. 29), but nesting may occur into September.

Data are available on sea turtle nesting in the project area (Table 8). The NCWRC has established one-mile Sea Turtle Management Zones (STMZ) along the entire coastline of the state. Zones are numbered from north to south. Data are given for recorded nests extending from STMZ # 35 in Kitty Hawk, near the northern edge of the project area to STMZ # 52, at the boundary of South Nags Head and the Cape Hatteras National Seashore. During the nine-year period of 1990-1998, 24 nests were reported in area under consideration for beach nourishment. This total includes one, confirmed green turtle nest in 1996. These data indicate an average nesting utilization of 1.33 nests/mile (24/18) for the entire period, or an overall utilization rate of 0.15 nests/mile/year (1.33/9). These data are only for nests that were observed. It is likely that additional nests were inadvertently missed. Inclusion of a factor to account for missed nests would produce a higher, more realistic nesting utilization rate for sea turtles in the project area.

Piping Plover

The piping plover is a small, nearctic shorebird which breeds in three geographic regions: the Northern Great Plains, the Great Lakes, and the Atlantic Coast. Piping plovers within the project area are part of the Atlantic Coast population, and are federally listed as threatened.

North Carolina represents the southern limit for regular breeding and the northern limit for regular wintering by the species. The Atlantic Coast population nests on barrier islands and beaches from Newfoundland to North Carolina. Piping plovers nest above the high tide line on coastal beaches; on sandflats at the ends of sandspits and barrier islands; on gently sloping foredunes; in blowout areas behind primary dunes (overwashes); in sparsely vegetated dunes; and in overwash areas cut into or between dunes. The species requires broad, open, sand flats for feeding, and undisturbed flats with low dunes and sparse dune grasses for nesting.

The breeding cycle of the species has been documented (USFWS 1996, pp 4-8). Territorial establishment, courtship, and copulation may occur as early as the March-April period and extend into July. Incubation, which averages 27-30 days, ranges from April through August, and brood-rearing occurs during the May-late August period. In the project area nesting activities can begin as early as March (CZR, Inc. 1992b).

Table 8. Number of recorded sea turtle nests in 18 one-mile Sea Turtle Management Zones (STMZ) that extend from Lillian Street in Kitty Hawk (# 35) southward to the South Nags Head/Cape Hatteras National Seashore boundary (#52). Data cover nesting seasons during 1990 through 1998. All nests were laid by loggerhead sea turtles except as noted (* = a single, confirmed green turtle nest). Source: Sea Turtle Coordinator, North Carolina Wildlife Resources Commission.

	Year									
STMZ	90	91	92	93	94	95	96	97	98	Total
35	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0
37	1	0	0	0	0	0	0	0	0	1
38	0	0	0	0	0	0	0	0	1	1
39	0	0	0	0	1	0	1	0	1	3
40	0	0	0	0	0	1	0	1	1	3
41	0	0	0	0	0	1	0	0	1	2
42	1	1	1	0	0	0	0	0	0	3
43	0	0	0	0	0	1	0	0	0	1
44	0	0	0	0	0	0	0	0	0	0
45	0	0	1	1	0	0	0	0	0	2
46	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	2	1	0	1	4
48	0	0	0	0	0	0	2*	0	0	2
49	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	2	0	0	0	0	2
Total	2	1	2	1	3	5	4	1	5	24

Feeding areas include intertidal portions of ocean beaches, overwash areas, mudflats, sandflats, wrack lines and shorelines of coastal ponds, and lagoons or salt marshes (Coutu et al. 1990, USFWS 1996).

In the past the species nested on Hatteras (Pea) Island, but breeding birds apparently did not survive the arrival of domestic cats in 1908 (Potter et al. 1980, p. 140). Summer surveys during the 1970s indicated that piping plovers were reestablishing their breeding range in North Carolina. At that time the species was found to nest sparingly along the coast southward to Shackleford Banks, south of the project area.

In 1989 the NPS began conducting annual surveys of suitable habitat within the national seashore. Through the summer season of 1995 no nesting activity was observed. However, in 1996 two piping plover nests were found in the immediate vicinity of Oregon Inlet. One nest was on the sandy spit accreting on the southern tip of Bodie Island and east of the Bonner Bridge. The other nest was in the sand fillet created by the terminal groin on the northern end of Hatteras (Pea) Island.

During 1997 a total of four nests were found near Oregon Inlet, two each on the northern and southern sides. The two northern nests represented an original nest and a renesting attempt by a single pair. The two nests on Pea Island were both on the sandy fillet of the terminal groin, the same area as the single nest of 1996. Neither nest on Pea Island produced young during 1997.

While there is no evidence that any of these six nests successfully fledged any birds, these data do signify that piping plovers have found suitable nest sites in the project area after an absence of decades. Furthermore, the limited data from 1996-97 show an increase in nesting activity, and the first 1997 nest on Bodie Island may have been the return of the pair from 1996.

There is evidence that successful nesting occurred during 1998 on PINWR (Dennis Stewart, Pea Island National Wildlife Refuge, Personal communication, March 1999). In June 1998 a piping plover was observed on a nest within the sand fillet of the terminal groin. At times four adult plovers were observed, but a second nest was not seen. In July two plover chicks were observed. During July-August a total of six plovers (4 adults and 2 chicks) were observed foraging. By September three plovers remained in the area, including one immature bird.

The Atlantic Coast piping plover population is believed to overwinter primarily along the Atlantic Coast from North Carolina south to Florida, and in the Caribbean. Wintering plovers on the Atlantic Coast are generally found at the accreting ends of barrier islands, along sandy peninsulas, and near coastal inlets. Wintering piping plovers appear to prefer sandflats adjacent to inlets or passes, sandy mudflats along prograding spits, and overwash areas as foraging habitats. These substrate types may have a richer infauna than the foreshore of high energy beaches and often attract large numbers of shorebirds. Roosting plovers are generally found along inlets and adjacent ocean, estuarine shorelines and their associated berms, and on nearby exposed tidal flats (Fussell 1990, Nicholls and Baldassarre 1990b). Diverse, coastal systems may be especially attractive to plovers, and may concentrate wintering piping plovers when there is a juxtaposition of roosting and feeding areas (Nicholls and Baldassarre 1990a).

Along coastal North Carolina, piping plovers are most widespread during migration. These periods include mid-March to mid-April and August to October (Fussell 1994, p. 426). During these periods they are frequently seen on the ocean beaches.

Roseate Tern

The federally endangered roseate tern generally breeds along the Atlantic coast from Long Island, New York, northward. They spend the winter from the West Indies to Brazil. The species is considered a rare coastal transient in North Carolina (Potter et al. 1980, p. 178). It may be present from late March to mid-May and from late July to October. The species feeds in salt bays, estuaries, and the ocean.

This coastal bird has a distinct preference for sandy, open beaches and interdune areas. Fussell (1994, p. 41) notes that many records of this species have been at common tern colonies at capes and inlets, immediately adjacent to the ocean. The species may also be found on mudflats and in open water. There is one recorded nesting by the species on Core Banks, south of the project area, in 1973 (Potter et al. 1980, p. 178). There are no records that the species nests in the project area.

Bald Eagle

This federally threatened species is most common in the project area during the cooler months. North of the project area, bald eagles from Maine and the Canadian Maritime provinces overwinter in the Chesapeake Bay area (Lippson and Lippson 1997, p. 211), and some of these eagles may also constitute the winter eagle population of the Outer Banks. These birds may undertake a seasonal migration to the area when large numbers of waterfowl are present. Sightings of bald eagles are becoming more frequent on Bodie Island (Fussell 1994, p. 146). There is no evidence that the species nests in the project area.

Peregrine Falcon

This federally threatened raptor is an uncommon, fall migrant and occasional winter resident of the barrier islands (Fussell 1994, p. 34).

Seabeach Amaranth

This federally threatened plant is a fleshy-stemmed, annual, herbaceous species found exclusively on sandy beaches and dunes. Suitable habitat for this species does exist in the vicinity of Bonner Bridge (NCDOT 1996). The NPS has conducted annual surveys within the CHNS, but through 1995 no plants have been found. The USFWS has no records of the species on PINWR. The nearest known population is at Cape Point, approximately 64.4 km (40 miles) south of the inlet.

Species by Project Area Habitats

This section presents information on those species that have been reported from a specific habitat. This material is not meant to be a definitive list of all vertebrates that occur in each habitat. Some areas have received greater study than others. Scientific names given in the tables earlier in this section will not be repeated.

Offshore Pelagic

Fish - In offshore waters, certain estuarine dependent species spawn and their larvae make their way through inlets into the estuaries for growth and development. Examples include spot, croaker, weakfish, red drum, southern flounder, summer flounder, penaeid shrimp, and Atlantic menhaden. The waters between the surf zone and the 60-foot contour off of Dare County, particularly north of Oregon Inlet, serve as a major wintering ground for the east coast migratory population of striped bass (Appendix B). These waters also are wintering grounds for summer flounder and weakfish. Other pelagic species include blue marlin (*Makaira nigricans*), white marlin (*Tetrapturus albidus*), sailfish (*Istiophorus platypterus*), swordfish (*Xiphias gladius*), dolphin (Coryphaena hippurus), yellowfin tuna (*Thunnus albacares*), bluefin tuna (*Thunnus thynnus*), and bigeye tuna (*Thunnus obesus*) (Huntsman 1994). There are about 20 species of large, coastal sharks (Huntsman 1994).

Reptiles - Reptiles which use this habitat are the five species of sea turtles (Epperly et al. 1995).

Birds - This area is used by a variety of pelagic species, such as the loons, grebes, shearwaters, cormorants, scoters, mergansers, gulls, terns, and skuas.

Mammals - This area is used by cetaceans, such as whales and dolphins.

Offshore Benthic Soft Substrate

Fish - Huntsman (1994) discusses coastal demersal fishes, species that live on the bottom. This group includes Atlantic croaker, spot, southern flounder, summer flounder, and weakfish. Another group known as northern demersal, oceanic bottom fish with southern range limit at Cape Hatteras, include black sea bass and scup (*Stenotomus chrysops*) (Huntsman 1994).

Offshore Benthic - Hard Substrate

Fish - Huntsman (1994) states that there are more than 300 species of reef fish along the South Atlantic. These are species that might be expected at 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 (*Lutjanus campechanus*), and warsaw grouper (*Epinephelus nigritus*). Some of these are extremely overfished (Huntsman 1994)

Nearshore Pelagic

Fish - The nearshore zone typically extends out to about 30 feet of water, including the surf zone where waves break (Leatherman 1988). Many fish species are found within the surf zone and some species occur in both offshore and nearshore waters. Huntsman (1994) writes that coastal pelagic species, those living in the nearshore water column, include Atlantic menhaden, Spanish mackerel, King mackerel (*Scomberomorus cavalla*), bluefish, and little tunny (*Euthynnus alletteratus*). Other fishes that may occur in this area are the summer flounder, Atlantic croaker, spot, weakfish, red drum, cobia (*Rachycentron canadum*), black sea bass, spiny dogfish, northern sea robin, and pompano (*Trachinotus carolinus*).

Hackney et al (1996. . p. 52) state that "Apparently, many surf zone fishes not only exhibit ontogenetic changes in diet, but also shift diets in relation to prey availability. . . Such opportunism has great advantages in a variable environment like the surf zone. The ability to modify feeding could also mitigate impacts from beach renourishment."

There are two species of small coastal sharks, the dogfish and spiny dogfish (Huntsman 1994).

Reptiles - The two species of sea turtles, loggerheads and greens, that are known to nest on the beaches of the project area would use this area on their approach to the beaches.

Birds - Gulls (*Larus* sp.), terns (*Sterna* sp.), brown pelicans (*Pelecanus occidentalis*), ospreys (*Pandion haliaetus*), gannets (*Morus bassanus*) and loons (*Gavia* sp.) feed in the surf zone and nearshore waters.

Mammals - The bottle-nosed dolphin (*Tursiops truncatus*) is common in the nearshore waters of North Carolina and other cetaceans also enter the nearshore waters occasionally. The manatee may migrate through nearshore waters.

Nearshore Benthic

Fish - This area may be utilized by the same benthic fishes that occur in deeper waters.

Birds - No birds have been specifically linked to this area.

Mammals - No mammals have been specifically linked to this area.

Intertidal (Wet) Beach

Reptiles - This area is traversed by sea turtles moving from the ocean to nesting sites higher on the beach.

Birds - Shorebirds such as willets, sanderlings, and whimbrels feed directly on the invertebrates within the intertidal beach zones. Data from PINWR indicate that shorebird numbers peak on the ocean beach during the months of August and September, with numbers reaching up to 5,800 individuals within the 12 miles of the refuge shoreline. Dominant shorebird species found on the beach include: sanderlings; semipalmated, least and western sandpipers; semipalmated and black-bellied plovers; willets; whimbrels; ruddy turnstones; and American oystercatchers. Other species which utilize area beaches include the brown pelican, double-crested cormorant, and numerous gulls and terns.

A recent survey found 21 species of shorebirds using the beaches of the Outer Banks (Dinsmore et al., in press). The most abundant species were the sanderling, red knot, and willet. As an assemblage, shorebirds were most abundant in May and August. The relative abundance was slightly greater during the fall, 68 birds/km (0.6 mile), than in the spring, 50 birds/km (0.6 mile). This work indicates that the Outer Banks constitute an important staging area for Atlantic populations of piping plovers, whimbrels, and sanderlings. The Outer Banks also provides a critical link in the migratory path of several shorebirds.

Mammals - Terrestrial mammals forage on the area beaches. Raccoons, opossums, foxes, and other small mammals prowl the beaches at night for prey (Lippson and Lippson 1997, p. 24)

Subaerial (Dry) Beach

Reptiles - Loggerhead sea turtles nest on the upper beach and interdunal areas during the spring and summer. At least one green sea turtle nest has been reported from the project area (Table 8).

Birds - Various shorebirds nest along the upper beach including willets and American oystercatchers. In certain areas, colonial waterbirds such as least terns and black skimmers nest along the upper beach. Large monospecific and mixed species flocks of shorebirds often rest on the upper beach during migration and/or during the winter. Shorebirds utilizing the area during the winter and during migration include the common black-headed gull (*Larus ridibundus*), great black-backed gull (*Larus marinus*), Forster's tern (*Sterna forsteri*), American oystercatcher, piping plover, killdeer (*Charadrius vociferous*), whimbrel, marbled godwit (*Limosa fedoa*), willet, ruddy turnstone (*Arenaria interpres*), sanderling, and red knot (*Calidris canutus*). Shorebird surveys on the ocean beach of Pea Island NWR have been conducted yearly since 1986, generally during the months of April through September or October. Within the 12-mile long survey area, numbers reach as high 5,800 individuals using the beach habitats.

Colonial waterbirds nest on undisturbed beaches of the Outer Banks. A 1993 survey found both the common and least terns nesting on beaches at the northern end of Hatteras (Pea) Island (Parnell et al. 1995). The number of nests for these two terns was 16 and 256, respectively. Historically, an estimated 300 willets, 50 oystercatchers, 40 black skimmers, 100 least terns and 20 gadwall ducks have been produced annually on PINWR's beaches and dunes (USFWS 1989b). Others species which have nested on the ocean beach at PINWR include royal and sandwich terns.

Mammals - This area probably hosts the same mammals that forage on the intertidal beach.

Dunes

Amphibians - The area is used by Fowler's toad (CZR, Inc. 1992a).

Reptiles - The area is used by the eastern hognose snake, black racer, and six-lined racerunner (CZR, Inc. 1992a).

Birds - The sparsely vegetated low dunes are used by the Lapland longspur, snow bunting, and horned lark. One unique, winter resident of area dunes is the Ipswich sparrow, a distinct race of the Savannah sparrow. The northern end of Hatteras Island may be the best place in the Carolinas to find this "rare and elusive" species (Potter et al. 1980, p. 376-377). Boat-tailed grackles (*Quiscalus major*) and red-wing black birds (*Agelaius phoeniceus*) often utilize the dunes. Arctic peregrine falcons (*Falco peregrinus tundrius*) and merlins (*Falco columbarius*) use the dunes for foraging during migration and occasionally as winter residents. The red-tailed hawk, a casual winter visitant, also forages over dunes, as does the American kestrel (*Falco sparverius*), which is a common winter resident. Other avian species utilizing area dune and interdunal habitats include the northern harrier, barn owl, and ring-neck pheasant. The bald eagle may forage over dune areas.

Mammals - Species found in dune areas include the opossum, eastern cottontail, gray fox, raccoon, least shrew, eastern mole, meadow vole, house mouse, and feral house cat (CZR, Inc. 1992a).

Overwash Flats

This habitat is transitory and undergoes succession as colonizing plants move into the area. Since its occurrence is periodic, there are not likely to be any permanent resident amphibians, reptiles, or mammals that depend solely on such areas. It is conceivable that sea turtles could nest in overwash fans.

Birds - The primary beneficiaries of overwash fans are migratory shorebirds, especially the threatened piping plover, that can move over large areas to find these ephemeral habitats.

Low Shrub/Grassland

This area probably contains species which inhabit both the dunes and the thicker shrub habitats. As a transitional community, the area has a diverse assemblage of animals (CZR, Inc. 1992a). Utilization may depend partly on the wetness of the area.

Maritime Shrub Thicket

Reptiles - Various reptiles also inhabit the shrub thicket, as they are offered protection from the salt spray. Quay (1959) noted that the eastern glass lizard, eastern ribbon snake, eastern hognose snake, black racer, and eastern kingsnake can be found in shrub thickets.

Birds - Shrub thickets provide critical habitat for many migrating birds. Species which may be found here include lark and clay-colored sparrows, western kingbird, and dickcissel. Spring migrants include the scarlet tanager, rose-breasted grosbeak, blue grosbeck, northern oriole, Blackburnian and bay-breasted warblers, and gray kingbird. Some of the rarest migrants include the white-winged dove (*Zenaida asiatica*), vermilion flycatcher (*Pyrocephalus rubinus*), scissor-tailed flycatcher (*Muscivora forficata*), tropical kingbird (*Tyrannus melancholicus*), Sprague's pipit (*Anthus spragueii*), and Townsend's warbler (*Dendroica townsendii*) (Fussell 1994, p. 158).

Common residents include the Carolina wren, gray catbird, northern cardinal, and boat-tailed grackle (Parnell et al. 1989). Breeding birds include great crested flycatcher, prairie warbler, yellow-breasted chat, indigo bunting, and field sparrow (Fussell 1994, p. 148). Other species which use these thickets include rufous-sided towhee, common yellowthroat, yellow-billed cuckoo, eastern wood pewee, eastern kingbird, white-eyed vireo, and pine warbler (Fussell 1994, p. 150).

Breeding birds in the wetter shrub thickets include the common yellowthroat and red-winged blackbird (Fussell 1994, p. 148). Shrub thickets may also harbor the white-crowned and clay-colored sparrows. Winter residents include the yellow-rumped warbler, yellow-bellied sapsucker, downy woodpecker, brown creeper, hermit thrush, and both the golden-crowned and ruby-crowned kinglets (Fussell 1994 p. 151).

Sharp-shinned hawks, fairly common transients and winter residents, forage at the edge of shrub thickets.

Mammals - Species that are common in shrub thickets, especially on Bodie Island, include the opossum, least shrew, gray fox, and raccoon.

Herbaceous Swale and Other Freshwater Wetlands

Swales, typically wet transition zones, supports a variety of animals species found in both the drier dune communities, as well as the wet marsh areas.

Fish - Permanent freshwater bodies are the only available habitat for the freshwater fish listed in Table 3.

Amphibians - Areas of standing water provide breeding sites for amphibians.

Reptiles - Those snakes that feed on amphibians are likely to hunt near freshwater areas.

Birds - While the freshwater wetlands in the developed areas of the Outer Banks may support less birds than those within CHNS or PINWR, these areas should support some wetland species such as the red-wing blackbird and marsh wren.

Mammals - Freshwater areas on the Outer Banks may provide habitat for muskrats, nutria, mink, and river otters.

Maritime Forest

Maritime forests provide some of the best fish and wildlife habitat on the barrier islands. Frankenberg (1995, p. 29) states that Nags Head Woods contains 100 species of birds and 65 land vertebrates, including 46 species of reptiles and amphibians and six species of freshwater fish. The vertebrate fauna of Southern Atlantic coast maritime forests is discussed by Bellis (1995, pp. 50-60).

Amphibians - Depending on the extent of wet environments, maritime forests may provide habitat for all amphibian species known to occur in the project area.

Reptiles - Bellis (1995, p. 520) lists four turtles, two lizards, and 10 snakes that may occur in the maritime forests of North Carolina (Table 5).

Birds - Maritime forests are important resting and foraging sites for many migratory birds such as yellow-bellied sapsuckers (*Sphyrapicus varius*), magnolia warblers (*Dendroica magnolia*), black-throated blue warblers (*Dendroica caerulescens*), palm warblers (*Dendroica palmarum*), and ruby-crowned kinglets (*Regulus calendula*), as well as for resident species, such as the Carolina wren, the chuck-will's widow (*Caprimulgus carolinensis*), yellow-rumped warbler (*Dendroica coronata*) and gray catbird (*Dumetella carolinensis*).

Mammals - They also provide habitat for the raccoon, gray squirrel (*Sciurus carolinensis*), gray fox, white-tailed deer and other mammals.

High Marsh (Diverse Species), High Marsh (Black Needlerush), and Low Marsh (Smooth Cordgrass)

Fish - Salt and brackish marshes are considered essential habitat for many fish species. They serve as nursery grounds for numerous fish including flounder (Bothidae), herring (Clupeidae), and drum (Sciaenidae).

Primary nursery areas are located in the Roanoke Sound at Dough Creek and Scarborough Creek which is off of Shallowbag Bay, and Broad Creek. There are also numerous primary and secondary nursery area designations in sections of northern Pamlico Sound which are located landward of the Dare County barrier island system.

Reptiles - The diamondback terrapin inhabits coastal marshes, bays, lagoons, creeks, mudflats, and similar environments characterized by salt or brackish water (Palmer and Braswell 1995, p. 59). The species probably occurs on most of the Outer Banks. Terrapins are relatively common in a few places where damage to their habitats has been minimal (Palmer and Braswell 1995, p. 58). Populations in many areas have been, and continue to be, depleted by extensive coastal development and the alteration of marshes.

The Carolina water snake, a coastal subspecies of the northern water snake, is endemic to the Outer Banks and several areas on the adjacent mainland (Palmer and Braswell 1995, p. 206-7). These snakes are found in brackish and salt marshes as well as tidal creeks, canals, and freshwater impoundments.

Birds - Various birds forage on the seeds of saltmarsh cordgrass including seaside sparrows (*Ammodramus maritimus*) and sharptailed sparrows (*Ammospiza caudacuta*). Many waterfowl species including black ducks (*Anas rubripes*), mallards (*Anas platyrhynchos*), and northern pintails (*Anas acuta*) use brackish marshes as wintering ground. Many other species use the brackish marshes during spring and fall migration. Clapper rails (*Rallus longirostris*) are common summer residents of tidal marshes in the area, nesting in salt and brackish marshes. Belted kingfishers (*Ceryle alcyon*) forage in and around marsh habitats during the summer. Bald eagles hunt in estuarine marshes.

Saltmeadow flats contain many of the species which also use the wetter saltmarsh. Fussell (1994, p. 162) discusses salt flats within the refuge. These areas are sparsely vegetated with marsh grasses and other herbaceous species. Such flats may be similar to the saltmeadow flats considered by CZR, Inc. (1992a). The salt flats are used by shorebirds during spring and fall migrations. Flats are favored loafing spots for terns from April through October. Wading birds are common during the warmer months. Birds using the salt flats include the lesser golden plover, buff-breasted sandpiper, Baird's sandpiper, long-billed curlew, black-necked stilt, Wilson's phalarope, white ibis, glossy ibis, yellow-crowned night heron, whimbrel, seaside sparrow, black rail, as well as the gull-billed, black, and sandwich terns (Fussell 1994, p. 163).

Birds frequently encountered in the high marsh include the northern harrier, savannah sparrow, seaside sparrow, eastern meadowlark, red-winged blackbird, and boat-tailed grackle (CZR, Inc. 1992a). All marshes may be used by the king, clapper, Virginia, and black rails. The sora and yellow rails inhabit marshes during migration.

Mammals - Mammals inhabiting these marshes can be divided into two groups: (1) species living there by necessity; and, (2) those which chose to venture into the area. The first group contains those species which are specially adapted to this wet environment and contains the muskrat, nutria, river otter, mink, marsh rabbit, and marsh rice rat. The second group contains species which are adapted to a wide range of upland and wetland habitats and includes the raccoon, gray fox, and white-tailed deer.

Unvegetated, Intertidal, Estuarine Flats (Mudflats and Sandflats)

Fish - The unvegetated intertidal zone is an important environment for many coastal and marine fishes (Peterson and Peterson 1979). Numerous fishes live and feed on intertidal flats during high tides while other species are dependent on those species which forage in these areas. Peterson and Peterson (1979) present extensive data on fish which utilize intertidal flats in North Carolina.

Birds - These areas provide habitat for piping plovers, Lapland longspurs and snow buntings (Fussell 1994, p. 145). Oystercatchers occur here all year. During migration these areas are used by the semipalmated plover, marbled godwit, dunlins, and short-billed dowitchers. Other species found on the flats include the red knot, western sandpiper; sandwich, common, and roseate terns; and lesser black-backed, Iceland, and glaucous gulls.

Sound - Pelagic

Fish - Fish in sounds are a mix of anadromous, catadromous, migratory, and indigenous species. Estuarine dependent fish use sounds as a passageway to nursery and feeding grounds. Commercially important species include Atlantic croaker, spot, summer flounder, and southern flounder.

Reptiles - Sea turtles use the pelagic waters of North Carolina sounds. Leatherback sea turtles have been seen in Chesapeake Bay (Lippson and Lippson 1997, p. 252). The most common species in the project area is the loggerhead sea turtle.

Birds - Large groups of ducks and geese overwinter in the sound waters. Both the common and king eiders were observed in a tidal bay near the Bonner Bridge (Fussell 1994, p. 155). Other waterfowl include the red-breasted and hooded mergansers, bufflehead, oldsquaw, and the scoters. Waterfowl commonly seen in the inshore sound include tundra swan, Canada geese, northern pintails, green-winged teal, and American widgeon. Offshore sound waters are used by redheads , ring-necked duck, canvasback, common goldeneye, and bufflehead (Parnell et al. 1992).

Mammals - The manatee may occur in the sound. The bottle-nosed dolphin inhabits inshore waters and frequently enters sounds, rivers, and tidal creeks of North Carolina (Webster et al. 1985, p. 213). Lippson and Lippson (1997, p. 251) report that bottlenosed dolphins are summer inhabitants of the lower Chesapeake Bay where they are often seen feeding in the swift currents near the Elizabeth and James Rivers. Dolphins occur throughout the Chesapeake Bay area and move up the Potomac River to areas near Washington, D.C.

Sound - Benthic, Unvegetated

While some fish may utilizes these areas, no species of the other vertebrate groups are exclusively found in this community.

Sound - Benthic, Vegetated

Fish - Fish populations in areas of SAV, or seagrass beds, are abundant and diverse. Some fish are permanent residents of seagrass meadows, but because of seasonal variations in plant growth, most fish are seasonal residents composed primarily by juveniles (Kenworthy et al. 1988). In temperate areas there is an increase in plant abundance during the warmer months. This period coincides with the larval, post-larval, or juvenile stages of estuarine and estuarine-dependent, marine fishes. Larvae and juveniles of bluefish, mullet, spot, croaker, herrings and others appear in *Zostera* beds in the spring and early summer (Kenworthy et al. 1988). Many of these fish reside only temporarily in the grass beds in order to forage, spawn, or escape predators. Some species remain in these areas until the fall when they return to the coastal shelf waters to spawn.

Reptiles - Sea turtles, such as the green and immature hawksbills feed on submerged aquatic plants.

Birds - Areas of submerged aquatic vegetation provide food for wintering diving ducks, such as the canvasback, redhead, the scaups, and ring-necked duck.

Mammals - Manatees may feed in these areas.

__Summary__

The vertebrate fauna of the project area is extremely diverse. Over the course of a year, the area is by as many as 500 vertebrate species. Birds are clearly the dominant class with approximately 320 species occurring regularly in the area and an additional 50-60 species as accidentals. The next class in terms of species diversity is the fish with over 20 freshwater species and roughly 60 recorded marine and/or estuarine species occurring either as adults of larvae. Mammals are the third most diverse group. Terrestrial mammals, bats, cetaceans, and the manatee represent more than 80 species. The terrestrial reptiles and the five marine sea turtles constitute approximately 30 species. The least diverse group, as might be expected of animals which require freshwater for reproduction, is the amphibians with seven known species.

Many, perhaps a majority, of the vertebrates found in the project area occur on a seasonal, or even temporary, basis. Nesting by a sea turtle may require only a few hours, but those hours are critical to the survival of the species. Likewise, the stay of some neotropical, migratory birds may be measured in days, but this time may be critical in conserving energy and feeding for the next leg of a long journey.

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 creation of the artificial beach-dune system.

General Habitat Values Within the Project Area

The Outer Banks in the northern part of Dare County, between the towns of Duck and South Nags Head, will continue to urbanize with limitations imposed by the availability of suitable land, soil constraints, water supplies, and local land use regulations, zoning regulations, and ordinances. It is likely that all available uplands which are not protected by designation as a conservation area within local LUP will be developed. Existing oceanfront setback regulations require the construction of buildings to be set back 30 times the established annual erosion rate, or a minimum of 60 feet, from the shoreline and require buildings to be built behind protective dunes. Dare County has adopted a Sand Dune Protection Ordinance, and the LUP indicates that the County is committed to maintaining a "low density" character. The Town of Kitty Hawk's LUP states that the Town supports the continuation of adopted policies and regulations that preserve and promote the Town's development as a low density, low rise, residential beach community (Kitty Hawk 1994, p. 47).

The dominant factors in determining habitat values in the project area will continue to be greater development and a rising sea level. 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 Outer Banks. However, in the absence of the project, prudence would dictate that development avoid areas near the beaches.

Sea level rise can be expected to increase shoreline recession rates and associated problems. Beach front property will continue to be lost to the ocean due to storms and general shoreline retreat. If the state and local governments adopted a policy of letting nature take its course with regard to island migration, developers might focus their attention in areas away from the immediate beach area, if only to avoid problems with bank loans and insurance. As the earliest settlers of the Outer Banks realized, the best and most efficient way to reduce storm damage is to build as far away from the beaches as possible.

Without the proposed project, offshore areas which are now designated as borrow sites, would remain relatively unchanged. Although the pelagic and benthic resources of these area may be subjected to some increases in pollution from the nearby coastline, any changes by factors other than large-scale dumping or dredging would be relatively minor. In the absence of the project, the primary production that these areas provide to the marine food chain would not be significantly altered.

The biota of the nearshore (subtidal) area might be expected to remain relatively unchanged without the project. Changes in currents and sediment deposits can be expected to change depths for specific locations. However, over a wide area the amount of nearshore habitat will probably remain fairly stable when compared to the sudden and pronounced changes produced by dredging and the removal of sediment. Any hardbottoms near the project would continue to be subject to normal coastal geologic processes.

The absence of an artificial beach-dune system would also increase the occurrence of island overwash from the ocean. An increase of overwashing can be expected to increase the addition of sediment to sound side marshes as oceanfront sand is naturally transported to the sound side of the island. This orderly, natural process would ensure the continued existence of both ocean beaches and sound side marshes. The periodic additions of sediment would allow these marshes to overcome the gradual erosion due to wind driven waves from the sounds and drowning by a rising water level in the sound. Overall, the habitat values of sound side marshes are likely to be enhanced without the project.

General Influences on All Fish and Wildlife Resources

Tropical hurricanes and northeasters will periodically hit the project area. Without the project, development associated with the tourist industry may gravitate to the more protected areas of the island. Some development might relocate to the mainland. The limitation of development would alleviate pressure on habitats near the beach and could allow some habitats, such as overwash fans, that have been greatly diminished to return naturally. The threat to the natural freshwater supply would be reduced and the extent of freshwater wetlands would remain stable or increase. Overall, the future of the area without the project could be less pressure on existing natural areas and the possible recovery of some natural areas which have been lost.

Outlook for Classes of Vertebrates

Marine and Estuarine Fish

The future of these fishes is likely to be a continuation of present trends. On a global scale, marine fishes face a serious threat from overfishing. The problem of overfishing has been characterized as simply too many fishermen and not enough fish (Parfit 1995). The 50-year boom in fishing technology has created an immensely powerful industrial fleet of 37,000 ships crewed by about a million people worldwide (Parfit 1995). A modern freezer trawler can catch and process a ton or more of fish per hour.

The primary factor in the future of the many marine fish will be the efficacy of regulations to allow harvests which are sustainable. The state's 1997 Fisheries Reform Act and the management plans created under it seek to maintain viable fish stocks using flexible methods of gear and area restrictions (Powell 1999). Fishing pressure from commercial and recreational fishermen will continue. If overfishing is allowed, some species may not survive.

In the absence of the proposed project, marine and anadromous species would not be periodically harmed by offshore dredging required to maintain the beach-dune system. A policy designed to move buildings back from the receding shoreline or simply the no action alternative would generally be beneficial to marine fishes. Estuarine fish would benefit from island overwashes that maintain the sound side marshes as important nursery areas.

Freshwater Fish

In the short-term, one to two decades, these species are expected to continue present population trends. However, ever without the project, long-term population levels are uncertain. New development will continue to encroach on isolated freshwater wetlands. Increased withdrawals from underground aquifers may diminish bodies of open water, and runoff from development may reduce water quality. An increase in septic systems may also reduce water quality. The long-term viability of existing freshwater fish depends on the extent to which zoning regulations are established and enforced to protect the limited areas of freshwater.

Amphibian and Terrestrial Reptiles

In general, the future of these species will also be strongly influenced by the level of development. The creation and enforcement of land use plans that favor low density development away from environmentally sensitive areas will increase the chances that current population trends will continue.

All amphibian and reptile populations will continue to experience periods of severe stress, such as droughts, island overwashes, and hurricanes. However, these are natural forces to which the species have adapted, and populations should recover. Overall, amphibian and terrestrial reptile populations in the project area are likely to remain similar to present conditions.

Birds and Mammals

As with other terrestrial wildlife, the future of these species are dependent on the level of future development. Allowing natural barrier island processes to continue will enhance the long-term viability of all mammalian and avian species. The establishment and enforcement of zoning regulations to preserve existing natural areas, especially maritime forests, will benefit these species.

Federally Protected Species

Without the project, the seasonal use of the project areas by the manatee, roseate tern, bald eagle, and peregrine falcon is likely to be unaffected.

Piping Plovers

The developed nature of the project area limits its use by the piping plover for nesting. The area may receive limited use for foraging and roosting. For such uses, the future habitat value for this species is similar to that of other shorebirds.

Sea Turtles

The future value of the project area for sea turtle nesting is uncertain. The overall impact of measures to keep existing buildings in their present location does not bode well for the future of any beach. If this commitment remains over the coming decades, the rising sea level in combination with the ever rising cost of continuously placing sand on the beach may lead to a decision to use a more permanent structure to protect buildings, such as a seawall. Such a decision would ultimately lead to the elimination of beaches in front of the wall (Pilkey et al. 1998, p. 88-91).

Without any project to stabilize the shoreline, natural beach recession will continue. The beaches would continue to exist, but would not be in exactly the same location from year to year. However, sea turtles have adapted to shifting beaches for millions of years and this factor would not harm nesting success.

Summary of Future Fish and Wildlife Resources Without the Project

With the exception of marine fishes that are subject to commercial harvesting, populations of wildlife and other fisheries resources are likely to maintain present population trends in the near future if the artificial beach-dune system is not constructed. If natural shoreline recession is allowed to continue, the beach will not disappear, but simply migrate landward. To the extent that natural beach movement is allow to continue, developers may find the risks of construction near the beach to be too great. Any reduction of construction near the shore would be beneficial to sea turtles and shorebirds. The absence of artificial dunes would also facilitate the natural process of island overwash. Such overwashes would benefit early successional wildlife, such as piping plovers, and allow for natural replenishment of sound side marshes that provide valuable habitat for fish and wildlife.

Overall, any adverse impacts to fish and wildlife resources due to implementing the storm damage reduction project must be fully considered in all environmental documentation. There are no justifications for excluding such impacts on the grounds that other factors would diminish these resources.

SECTION 7. ALTERNATIVES CONSIDERED

The alternatives developed for any federal project should arise directly from the stated project purpose. In the project area, hurricanes and winter storms regularly damage or destroy structures near the shoreline (Notice of Intent, Federal Register, Vol. 62, No. 141, July 23, 1997). The Notice of Intent (NOI) states that the project would consist of the construction of a berm or combination of berm and dune along various reaches of the oceanfront within the study area. The berm would be a subaerial (dry) beach. The only alternatives mentioned in the NOI were variations in project dimensions and the no action alternative. The Corps' request for scoping comments during July 1997 also indicated that the only action alternative would be the creation of a berm or berm-dune combination. Again, the only discussion of action alternatives addressed the dimensions and location of the artificial beach-dune system.

The Service believes that the Corps has not presented all alternatives to meet the stated project goal and has not considered an approach that would integrate several options. The National Environmental Policy Act (NEPA) and associated regulations state that federal action agencies may consider alternatives that are outside their jurisdiction. While the construction of the artificial beach-dune system may be the only alternative that the Corps could undertake, it is not the only action alternative which could reduce storm damage. The local community may also see an artificial beach-dune system as the most desirable form of storm damage protection, but this preference should not deter a complete evaluation of alternatives. The NEPA document should go beyond the construction alternatives and consider alternatives that could be implemented by other federal agencies, e.g., Federal Emergency Management Agency, state agencies, and local governments.

A key step in developing all possible alternatives would be to clearly define three items: (1) the categories or intensity level of storms for which protection would be provided; (2) the type(s) of damage which the project is intended to reduce; and (3) the exact area that would receive protection. The forthcoming NEPA document should clearly address these issues and the Service offers the following points on these important issues.

Categories of Storms for Which Protection Would Be Provided

Both hurricanes and winter storms can vary greatly in intensity and the damage produced is related to the magnitude of winds, flooding, and storm surges produced. Table 9 gives general data on wind speeds, storm surge heights, and general level of damage associated with the five categories of hurricanes. A similar 5-level classification system has been developed for northeasters (Davis and Dolan 1993). These data should be used in established the approximate level of damage which the project would seek to mitigate. Project planning should also take into account projects designed to protect against only minor hurricanes, categories 1-2, that would leave the area vulnerable to damage by major storms which would range from extensive to catastrophic.

Table 9. Basic characteristics of hurricanes by the category number of the Saffir/Simpson scale that ranges from 1-5. Source: Pilkey et al. 1998, p. 23. Based on Simpson (1971, 1974).

Category	Wind Speed (mph)	Storm Surge (feet)	Damage
1	74-95	4-5	Minimal
2	96-110	6-8	Moderate
3*	111-130	9-12	Extensive
4*	131-155	13-18	Extreme
5*	> 155	> 18	Catastrophic

* Hurricane categories 3-5 are generally considered "major" hurricanes

The Types of Damage Which the Project Is Intended to Reduce

The local LUP considers coastal storm hazards to include high winds, storm surge, flooding, wave action, and erosion (Dare County 1994, p. 95). Bush et al. (1996, pp. 19-40) give a thorough account of natural storm processes and physical processes that affect barrier islands and may produce property damage (Figure 12). The five major storm processes are high winds, storm waves, storm surge from the ocean, storm surge ebb (water flowing overland from the sound), and high rainfall (Bush et al. 1996, p. 19) and these major storm processes are summarized in Table 10 and Figure 13.

Storm Winds

It is doubtful that an artificial beach-dune system would be able to mitigate damage caused by wind or wind in combination with heavy rain. In 1969 Hurricane Camille hit the Gulf coast with winds of 190 miles per hour (mph) and in 1992 Hurricane Andrew hit south Florida with winds of 180 mph (Bush et al. 1996, p. 28). Bush et al. (1996, p. 28) note that the highest winds of hurricanes, what they refers to as the universal agent of destruction, are rarely recorded because wind-measuring instruments are destroyed or blown away. Even behind a low dune high winds can rip off roofs and wind-borne debris would still have to potential to strike other buildings, a process known as missiling. Much hurricane damage is caused by falling trees which may crash through walls and roofs. Buildings with damaged roofs, walls, and windows would be subject to water damage by heavy rain.

Storm Waves

Damage produced by storm waves results from water breaking directly against structures and may be considered independently from water damage or flooding (Table 10). Bush et al. (1996, pp. 28-29) discuss the formation of waves in coastal storms. Waves are actually a form of energy carried through water. A cubic yard of water weighs about three-quarters of a ton (1,500 pounds) and breaking waves moving shoreward at 30-40 miles per hour can be one of the most destructive elements of a hurricane (Pilkey et al. 1998, p. 219). Table 10 gives several examples of the ways in which waves may cause damage. Hurricanes create huge waves that batter the coast. The greater the energy, the larger the wave. Wave energy exists both above and below the water's surface. As wave energy interacts with the bottom, the energy begins to dissipate and the wave breaks. The protective functions of beaches results from absorbing wave energy and causing the waves to break before reaching land. Frontal dunes serve as a final barrier to storm waves.

Northeasters also produce damaging waves. Dolan and Davis (1992) developed a classification of Atlantic extratropical storms based on a "wave power index." By definition a storm is characterized by deep water waves of at least five feet (Dolan and Davis 1992). The "All Hallow's Eve" storm of October 1991 produced deep water waves of 35 feet, the highest recorded over the past 50 years. These waves were larger than the 30-foot waves associated with

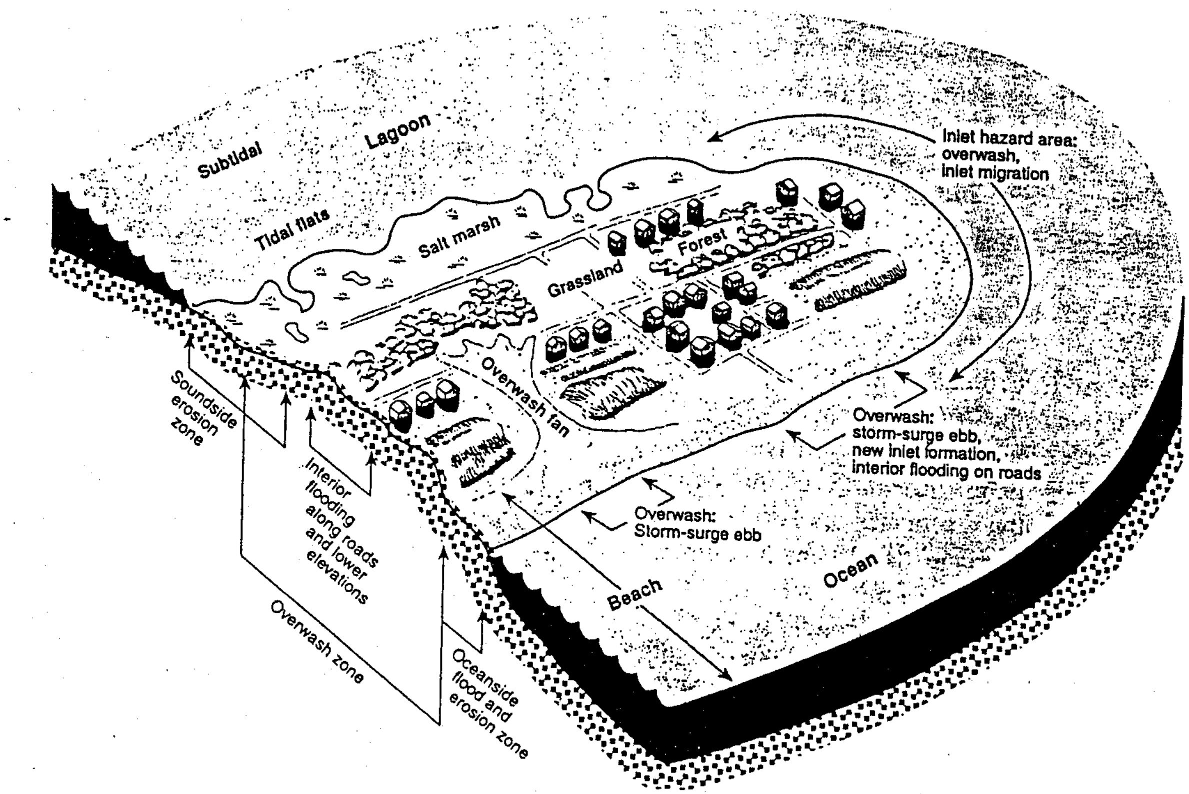

Figure 12. Diagram of barrier island showing the major storm processes and the areas likely to be affected. Source: Bush et al. 1996, p. 6. Used with permission of Duke University Press.

Table 10. Storm processes associated with hurricanes and winter storms (northeasters) and examples of damage that each process may cause. Overall storm damage may result from the combined effects of two or more processes. Adapted from Bush et al. 1996, p. 19.

Major Storm Process	Examples of Causes of Storm Damage
Storm wind	attack on building, e.g., rip off shingles, roofes, siding flying debris (missiling) sand blown onto island, burying roads sand blown off island, undercutting structures
Storm waves	direct attack on buildings floating debris (ramrodding) thrown against structures scouring around foundation footings overwash with burial and blockage of roads loss of vegetation due to erosion and exposure to saltwater local flooding
Storm surge (from ocean)	flooding pushing floating debris (rafting) against structures widens inlets island overwash with scouring and burial of structures scouring cross-island channels and undercutting buildings increases zone of wave influence formation of new inlets; severing roads; destroying houses drives off-shore directed currents resulting in permanent removal of sand from nearshore system saltwater flooding creates sterile soil and contaminates groundwater
Storm-surge ebb	formation of new inlets; severing roads; destroying houses scouring cross-island channels and undercutting buildings island overwash with scouring and burial of structures
High rainfall	water damage to structures opened up by wind damage enhanced flooding, especially low lying inland areas enhanced erosion due to runoff

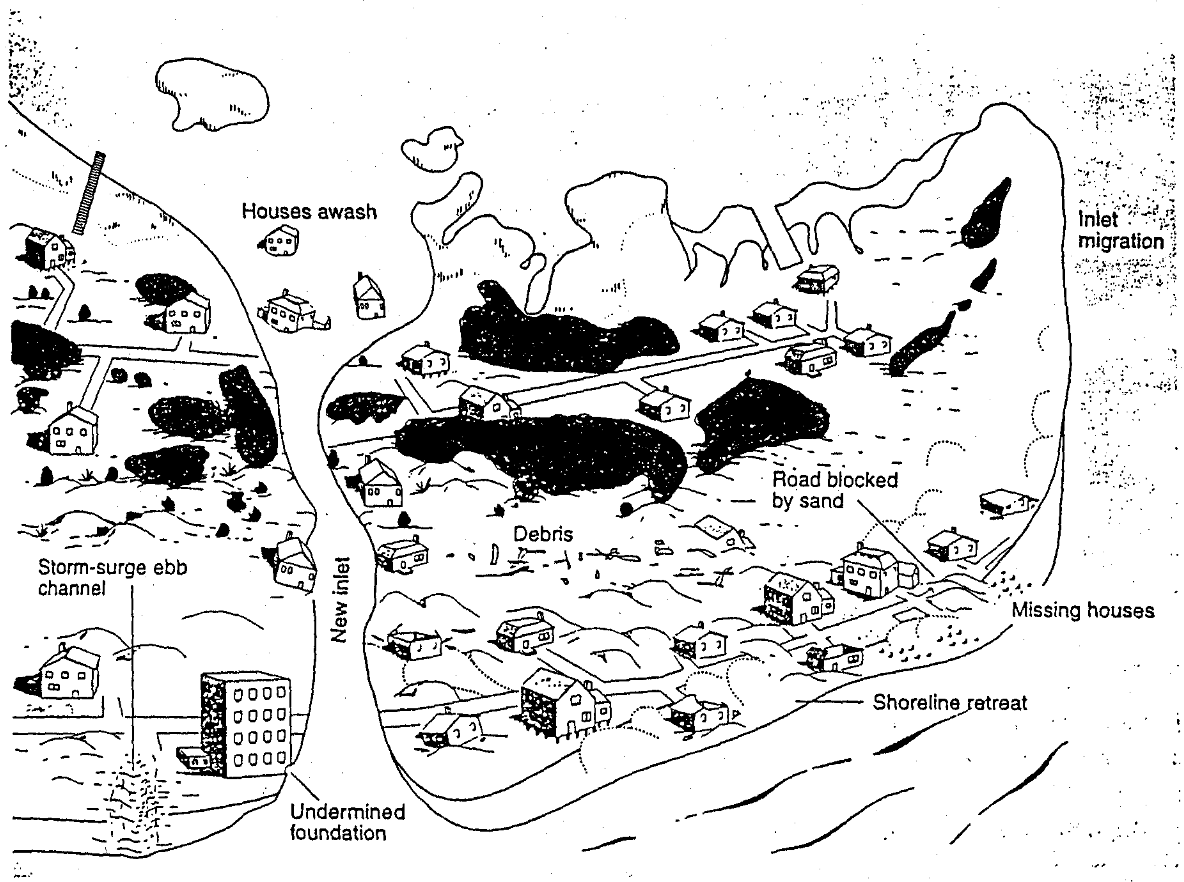

Figure 13. Diagram of the impacts of a major storm to a barrier island. Note that new inlets may form, usually as a result of the storm surge ebb coming from the estuary behind the island. Source: Bush et al. 1996, p. 21. Used with permission of Duke University Press.

the famous Ash Wednesday storm of March 1962. At Duck, North Carolina, immediately north of the project area, waves of 17.7 feet were recorded in water 66 feet (20 meters) deep and waves in 30 feet of water were recorded at almost 15 feet (4.5 meters) (Davis and Dolan 1992).

While smaller storms produce smaller waves, the alternatives for storm damage reduction should include explanations of the ways in which each alternative would mitigate wave damage, both large and small.

Storm Surge From Ocean

A storm surge is the superelevation of the still-water surface that results from the transport and circulation of water induced by wind stresses and pressure gradients in an atmospheric storm (Pilkey et al. 1998, p. 35). Pressure gradient refers to the lowered atmospheric pressure in storms which by itself can cause a rise in sea level. Within the area of low pressure the ocean water is literally sucked upward and the upward movement in combination with landward winds causes the ocean to flow over areas normally above sea level. The overland flow of the ocean causes flood damage and, by allowing waves to occur further inland, increases the area normally subject to wave attack.

Table 10 indicates that storm surges associated with hurricane categories may range from four to more than 18 feet. Pilkey et al. (1980, p. 148) states that the storm surge at the coast may reach a height of 15 to 20 feet or more about sea level. The storm still water surge levels along the coast from Virginia to Cape Hatteras for one-in-25, -50, and -100 year storm frequency is approximately 7.43, 8.20, and 8.80 feet above mean sea level, respectively (Pilkey et al. 1980, p. 54). These figures do not include the additional height created by waves. In September 1996 Hurricane Fran, a category 3 storm, created a storm surge of 12-14 feet across Topsail Island (Pilkey et al. 1998, p. 29). There was extensive overwash and flooding that destroyed dunes, overtopped seawalls, and cut swash channels.

Northeasters with their weaker wind fields and higher pressures seldom generate storm surges in excess of 6.6 feet (2 meters) (Dolan and Davis 1992). The storm surge along with waves are the most destructive forces generated by northeasters (Pilkey et al. 1998, p. 31). The 1962 Ash Wednesday northeaster flooded and overwashed the project area. The damage from this storm was exacerbated by its occurrence during spring high tides and its persistence over five, high tide cycles.

The development of alternatives should consider the protective value of each alternative against storm surges along the entire oceanfront of the project area. The 1962 Ash Wednesday storm broke through the remnant dunes of the 1930s and covered most of Kitty Hawk, Kill Devil Hills, and Nags Head with two to four feet of water (Pilkey et al. 1998, pp. 145 and 147). Therefore, protective dunes may fail in severe storms. A storm damage reduction project which does not propose a continuous line of dunes is likely to allow some flooding as water moves through gaps and around the ends of the artificial dune.

Storm Surge Ebb From Sound

Storm damage may result from water flowing over the island from the sound rather than the ocean. Flooding from the sound is due to the storm surge ebb. This phenomenon occurs when water that has been piled up by winds blowing landward is suddenly pushed seaward by an abrupt shift in wind direction. Storm surges from the sound occur at the same time that sea level on the ocean side is low due to strong seaward winds. A storm surge ebb leads to flood flows across the island in a seaward direction, resulting in erosive scour around buildings and may create new inlets as masses of water are pushed toward the sea. Hurricane Emily in August 1993 stayed completely offshore from the Outer Banks. However, strong winds blowing over Pamlico Sound created a maximum storm surge on the back side of Hatteras Island with greater wave height and water levels on the sound side than on the ocean side (Bush et al. 1996, p. 31). County officials recognize that sound side areas are susceptible to flooding and the impact of wind driven waves during hurricanes and other weather events (Dare County 1994, p. 23). The back side of barrier islands need as much attention for storm damage reduction as the ocean side. (Bush et al. 1996, pp. 31-32) state that "A mighty fortress (e.g., a seawall) is worthless if the attack comes from the rear."

Heavy Rainfall

Coastal storms produce heavy rainfall that results in damage completely independent of any overwash from the ocean or the sound. As noted in Table 10, rainfall may produce flooding and erosion damage in low-lying areas of the barrier islands without the introduction of ocean or estuarine waters. An artificial beach-dune system would provide little, if any, protection from flooding due to heavy rainfall.

The Area for Which Storm Damage Reduction is Expected

The third major consideration in developing alternatives is the area that the project seeks to protect. Both hurricanes and northeasters are massive storm systems that may cover hundreds of square miles. As these storms develop, there is no way to predict the exact location of future damage. High winds in combination with heavy rain can cause property damage many miles from the coastline (Figure 14). Much of Dare County is subject to flooding by storm tides and wind driven waves and only those areas with a natural elevation above 20-30 feet above sea level have a reasonable certainty of escaping flood damage (Dare County 1994, p. 94).

The National Flood Insurance Program (NFIP) has defined different zones of flood hazard. The base flood is flooding to which a community is subject at a one percent or greater chance in any given year, also referred to a 100-year flood. In the NFIP for coastal areas, flooding is divided into an A Zone, or area of special flood hazard and a V Zone, or coastal high-hazard area (Figure 15). The separation of these zones is based on the occurrence of 3-foot breaking waves which by definition may occur in the V Zone, but not in the A Zone. In general, the V Zone extends inland to the point where the stillwater depth during the 100-year base flood decreases to less than four

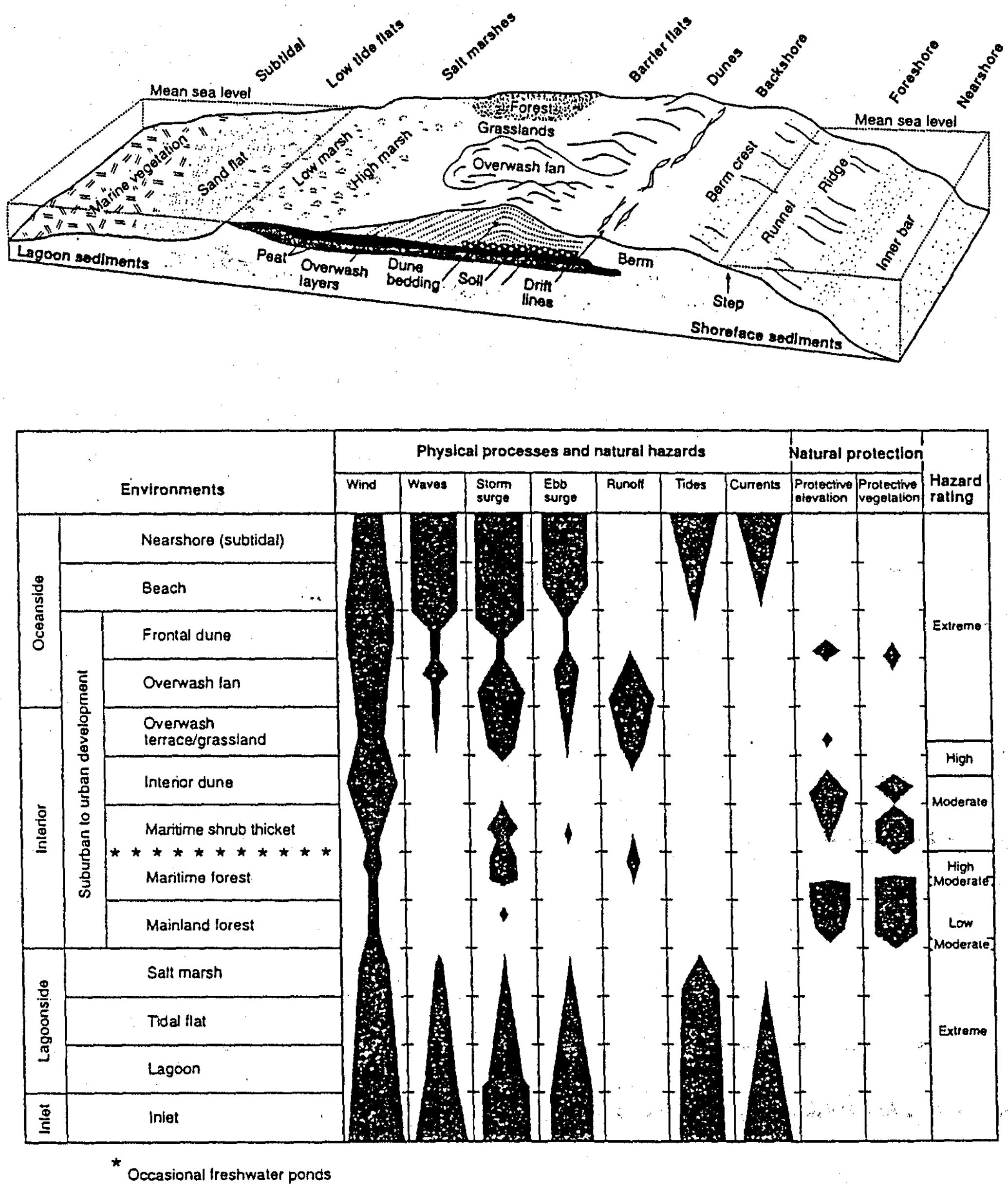

Figure 14. The major environments of a barrier island that may be impacted by the various components of a coastal storm. Note that the interior and sound side, or lagoon side, are subject to some storm forces. Both the ocean and sound sides are given an extreme hazard rating. Source: Bush et al. 1996, p. 10. Used with permission of Duke University Press.

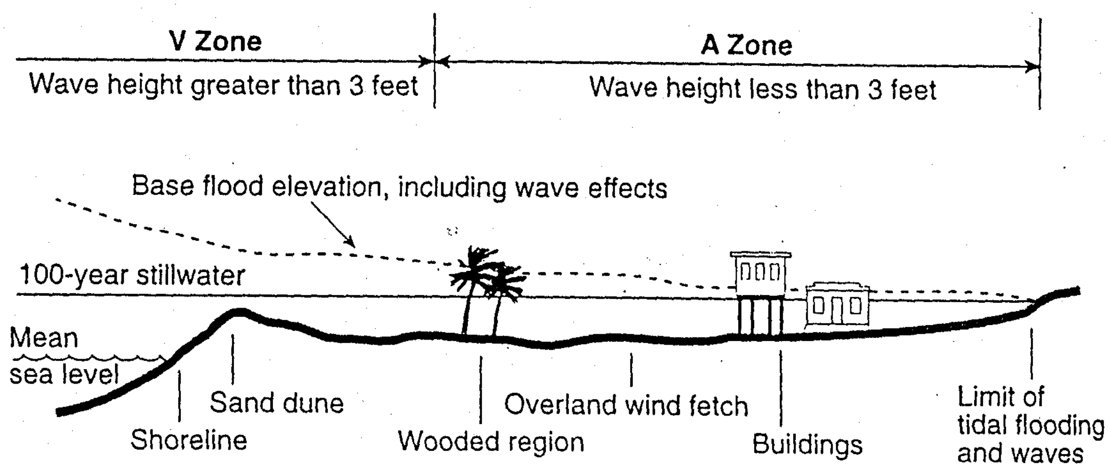

Figure 15. The V-zone and A-zone in an area subject to coastal flooding as defined by the Federal Emergence Management Agency. Source: Pilkey et al. 1998, p. 204. Modified from National Research Council (1990) report on "Managing Coastal Erosion" by the Committee on Coastal Erosion Zone Management.

feet (FEMA 1986 as cited in NRC 1995, p. 65). Therefore, by definition the A Zone is only subject to storm waves less than three feet high. The main point with regard to any storm damage reduction project is that only a limited area will experience flooding in combination with high waves while a much larger area will simply be flooded.

With such a large area at risk from coastal storms (Figure 16) it is important to define the geographic extent of protection that a specific project is expected to provide. The geographic area of protection would, to some extent, be an extension of the category of storm and the type of damage for which the project seeks to provide protection. For example, to protect against storm surge flooding of a category two hurricane, an unbroken barrier at least eight feet high (Table 9) would be needed along the coastline. If one or both ends of the artificial barrier occurred at a point on the beach without an existing dune, the extent to which the storm surge would come around one or both ends of the barrier would need to established. Development near the abrupt ends of any artificial barrier would be subject to flooding by the storm surge moving around and behind the barrier. The area behind the central part of the artificial barrier would be the geographic area protected by barrier. However, the area protected from the storm surge would still be subject to wind damage, heavy rains, and any storm surge ebb washing over from the sound.

Alternatives That Should Be Considered For Storm Damage Reduction

In any shoreline management project the twin goals of protecting structures and providing a recreational beach are constantly intertwined. However, a problem arises due to the fact that the federal government feels that protecting property is a valid national concern while ensuring a sandy playground for tourists is not really an appropriate expenditure. There may be reasons to wonder whether creating an artificial beach-dune system represents a means to an end (i.e., reducing storm damage) or is actually an end itself (i.e., replacement of the recreational beach lost to shoreline recession in the face of a rising sea).

The answer to the question posed above will be found in the development and evaluation of alternatives for the stated project goal. The LUPs of the project area clearly separate the problems of storm damage mitigation from those of shoreline management/stabilization. The county considers beach nourishment as a form of shoreline management (Dare County 1994, p. 90-91) and considers storm hazard mitigation in an entirely different section (Dare County 1994, p. 94-101). The Town of Kitty Hawk likewise has a section of its LUP for natural hazards (Kitty Hawk 1994, pp. 72-78) and considers beach nourishment separately (Kitty Hawk 1994, p. 2-30). Kill Devil Hills also considers beach erosion and beach nourishment (Kill Devil Hills 1993, p. 50-52) separately from natural hazard planning (Kill Devil Hills 1993, p. 67-71).

Historically, measures to counteract the encroachment of the sea were designated as erosion control projects. Erosion in such cases was not specifically related to major storms. While major storms did eat away at the beach, it was the steady gradual loss of the beach that led to the disappearance of the land on which structures were built. At some point a decision was made

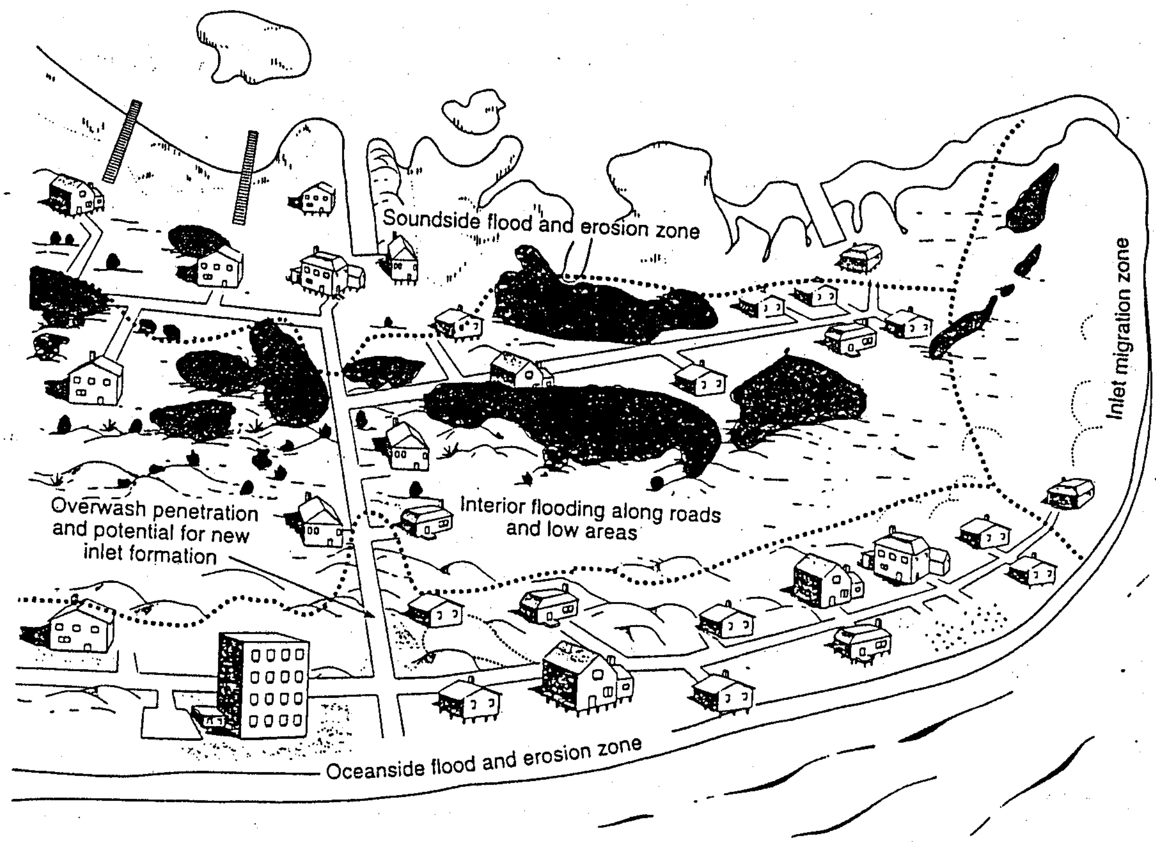

Figure 16. Diagram of the general areas of a typical barrier island subject to various forms of storm damage. Note that the entire island is subject to some forms of damage. Bush et al. 1996, p. 20. Used with permission of Duke University Press.

that shoreline projects could not really "control" the erosion produced by the sea. Seawalls would protect structures for a while, but the sea would eventually remove the beach. The accumulated results of shoreline management led to the need for better terms to describe efforts aimed at saving man-made structures threatened by the sea and the recreational beaches which ultimately created the need for such buildings. With a tacit acknowledgment that the slow, steady advancement of the sea could not be controlled, the emphasis turned to controlling storm damage, a goal with a clearly defined economic value.

Assuming that shore erosion and recession cannot be eliminated, three broadly defined strategies are available to a community faced with the encroachment of the sea toward existing structures (NRC 1995. p. 27). These are: (1) construct a structure, such as a seawall or groin, to limit the continuing damage or threat of damage; (2) initiate a program of periodic renourishment of the beach to provide the desired level of protection, perhaps in conjunction with hard structures; or (3) abandon or move buildings or other facilities that are damaged or endangered by continuing erosion.

When the emphasis changes from restoring a lost recreational beach to the reduction of storm damage, the options are similar. However, some hard structures that are placed perpendicular to the shoreline, such as groins and jetties, are strictly for erosion control. Seawalls are not generally considered a storm damage reduction measure. Pilkey et al. (1980, p. 45) state that "While a seawall may extend the lives of beachfront structures in normal weather, it cannot protect those on a low-lying barrier island from the havoc wrought by hurricanes; it cannot prevent overwash or storm surge flooding." However, a major exception is the seawall in Galveston, Texas. After the hurricane of 1900 killed more than 6,000 people, the town constructed a seawall four miles long and 17 feet high (Bush et al. 1996, p. 160). The city also pumped 16 million cubic yards of sand into the city to raise the elevation of the island. Despite these efforts Bush et al. (1996, p. 160) believe Galveston remains "extremely vulnerable to hurricanes" and a storm of the same magnitude as the 1900 hurricane would still demolish much of the city.

Leaving aside hard structures such as a seawall, there are a number of options for reducing storm damage. A list of available options based on material presented by Bush et al. (1996, p. 69) is given in Table 11. Each of these is considered below.

Abandonment/Retreat/Relocation From the Shoreline

Abandonment was the choice in some locations following the 1962 Ash Wednesday Storm (NRC 1995, p 28). The Towns of Nags Head and Kitty Hawk have used the retreat option by gradually removing individual buildings; either by their owners or through destruction in relatively small storms (NRC 1995, p. 28). Abandonment may be an economically sound option when buildings have existed beyond their design life and the cost of relocation or protection is greater than the buildings' value (Bush et al. 1996, p. 93).

Table 11. Options for reducing storm damage to communities near the ocean. Hard stabilization options have been omitted. Source: Bush et al. 1996, p. 69

Abandonment

Relocation

- Active (relocate before damage)
- Passive (rebuild destroyed structures elsewhere)
- Long-term relocation plans for communities

Soft Stabilization

- Adding sand to beach
    - Beach replenishment
    - Beach bulldozing/scraping
- Increasing sand dune volume
    - sand fencing
    - raise frontal dune elevation
- Vegetation
    - stabilize dunes (oceanside)
    - plant marsh (sound side)

Modification of Development and Infrastructure

- Retrofit houses
- Elevate houses
- Curve and elevate roads
- Block roads terminating in dune gaps
- Improve placement of utility and service lines

Zoning and Land Use Planning

- Recognize and avoid development in harzard areas
- Setbacks
- Chose elevated building sites
- Lower density development

Relocation of threatened beach structures has been undertaken by the federal government. The Upton/Jones amendment (Section 544) of the Housing and Community Development Act of 1987 authorized the NFIP to pay for the relocation or demolition of structures that are subject to imminent collapse as a result of shoreline erosion. The law allowed homeowners of threaten buildings to use up to 40 percent of the federally insured value for building relocation purposes (Bush et al. 1996, p. 93). Bush et al. (1996, pp. 93-94) state that this program:

> ". . . recognized relocation as a more economical, more permanent, and more realistic way of dealing with long-term erosion problems. . . . [the government] would pay a relatively small amount to assist in relocating a threatened house rather than paying a larger amount to help rebuilt it, only to see the rebuilt house destroyed in a subsequent storm, and paying to rebuild again . . . and again."

The Upton-Jones program was replaced in 1995 with the National Flood Mitigation Fund which provides grants to state and local governments for planning and mitigation assistance to reduce the risk to structures covered by the NFIP. Demolition and relocation activities are eligible for grant assistance under this program, but these actions must now compete with other mitigation measures such as floodproofing structures, acquisition of flood zone property for public use, and technical assistance.

Bush et al. (1996, p. 99) report that Nags Head adopted a mitigation policy that recognized shoreline retreat as inevitable. The town determined that it is better to adopt a policy of planned retreat than to wait for a disaster to force retreat. In Nags Head, deep lots running perpendicular to the shore provide room for relocation. Within the town, funds were requested for 35 demolitions, average cost $74,409, and 19 relocations, average cost $30,211 (Williams 1993 as cited in Bush et al. 1996, p. 99). Bush et al. (1996, p. 99) note that removal costs have been less than the nourishment costs for 4.5 miles of beach. Furthermore, beach nourishment would need to be repeated every three years, while if all the threatened structures are removed, it would be 20 to 25 years before the number of threatened structures returns to current levels. Overall, the retreat option would cost about $2 million every 20 to 25 years, while beach nourishment would cost about $9 million every three years.

It is only logical to conclude that storms can only damage structures placed in their path. If those buildings which are at the greatest risk are removed or relocated, the extent of storm damage would be greatly reduced. If the goal of this project is strictly to reduce storm damage, the option of a removal/relocation program should be fully considered. A relocation program may be aesthetically superior in the long run (Bush et al. 1996, p. 93).

Soft Stabilization: Beach Nourishment

Table 11 indicates that beach nourishment may have several distinct components, but it is generally considered to be the creation of an artificial beach with or without a dune. While all the other major storm damage reduction options are directed solely at storm damage reduction, beach nourishment is considered by some as primarily a method to check shoreline erosion and replace lost beaches. The County LUP (Dare County 1994, pp. 90-91) states:

> "A study of the shoreline management alternatives for the Outer Banks was completed in 1984. The study entitled 'Outer Banks Erosion Control Task Force Report' recommended beach nourishment as the preferred management alternative. The issue was also reexamined as a part of the LUP update process. After considerable discussion, it was agreed that beach nourishment should be the County's preferred shoreline management alternative."

As noted, measures for storm hazard management are considered elsewhere in the plan.

Longevity - An important, but often overlooked, aspect of beach nourishment for storm damage protection is the extremely temporary nature of the protection. An artificial beach may be referred to as a "sacrificial" barrier because it will certainly be washed away over time. This is logical since the natural forces that eliminated the natural beach are still at work and will in time eliminate the artificial beach.

The disappearance of the artificial subaerial beach is due, in part, to the fact that all beach creation projects are directed at only the narrowest upper part of the real beach (Figure 17). The true beach is actually the entire shoreface, a layer or wedge of sediment resting uneasily on the more permanent continental shelf, or as the colorful metaphor of (Kaufman and Pilkey 1983, p. 85) states "an insomniac on a firm mattress." The shoreface is a broad, thin band of restless sand and gravel, whose slope is much steeper than the almost flat shelf (Kaufman and Pilkey 1983, p. 88). In cross section it has the concave curve of a shallow saucer. Pilkey et al. (1983, p. 216) write that:

> "The true beach . . . is more than a bathing strand. It is a wedge of sediment three or four miles wide stretching underwater to depths of thirty or forty feet. Replenishment drops sand only on the thin visible strip of upper beach. For obvious reasons no one has yet suggested building up the entire shoreface to thirty feet below the surface of the sea.

Sufficient money is never available to replenish the entire beach out to a depth of 40 feet. Thus, only the upper beach is covered with new sand, so that, in effect, a steep beach is created. This new steepened profile often increases the rate of erosion (Pilkey et al. 1980, p. 40). Coastal geologists seem to agree that created beaches almost always disappear faster than their natural predecessors (Pilkey et al. 1998, p. 96; Bush et al. 1996, p. 81).

An interesting aspect of the beach longevity issue as it relates to the real, or perceived, purpose of the beach is that local interests often expect a wide, dry, recreational beach regardless of the purpose for which it was build. Pilkey and Dixon (1996, pp 103-125) recount the experience of

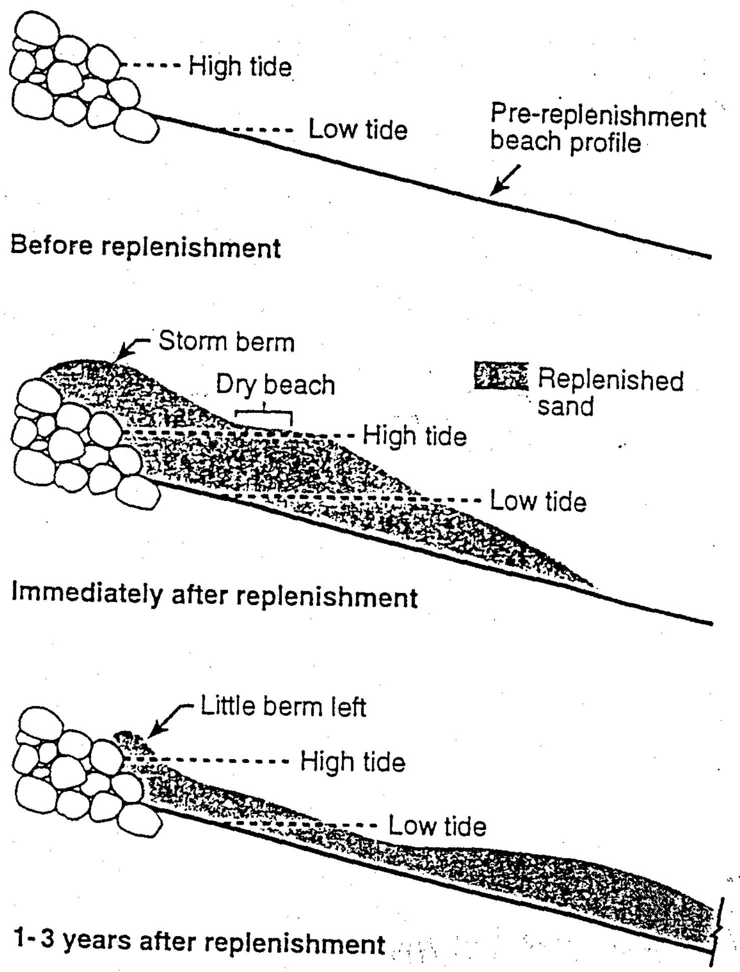

Figure 17. Diagram showing the loss of the subaerial (dry) portion of a beach created by beach nourishment. If the sand remains near the shore, it will continues to provide some storm damage reduction. If the sand move far offshore, it will provide neither recreational or storm damage benefits. Source: Pilkey et al. 1998. p. 99. Used with permission of Duke University Press.

Folly Beach, South Carolina, with an artificial beach and dune design to protect the community from storms. The new beach and dune were constructed in 1993 and soon begin to disappear at a rapid rate; the width of the dry beach declined from 200 feet to 75 feet within the first year. The Corps assured local interests that "... the sand was still all there, just offshore, still providing storm protection for the city" (Pilkey and Dixon (1996, p. 121). In theory, local officials should have been pleased that offshore sand was indeed continuing to provide storm protection, the official purpose of the project. By 1995 little of the dry beach remained and the storm berm, or dune, was largely gone. A local official noted that the Corps' post-project declarations of a protective underwater beach was inconsistent with the way the Corps sold the project to Folly Beach residents.

The story of Folly Beach highlights the degree to which the objectives of storm damage protection and restoring a wide recreational beach can become intertwined. While there is certainly no problem with using a single project to achieve two objectives, one objective must dominate and form the basis for developing alternatives. The fact that offshore sand, essentially an underwater beach, is taken as a project failure by some despite the fact that such sand does mitigate storm damage indicates that restoring a lost recreational beach may be the primary goal in some beach-dune creation projects.

Location of Borrow Areas - A major design feature of the currently preferred alternative is the source of sand for beach placement. The five designed borrow areas are relatively close to shore. The Service believes that offshore sources are better than estuarine sites that have been used for other projects in North Carolina.

Project design should carefully consider the location of borrow areas in relation to closure depth, the water depth at which no appreciable movement of bottom sediment results from wave action (NRC 1995, p. 8). At depths less than the closure depth wave energy is reduced by friction with the bottom sediment and removal of this sand allows stronger waves to strike the beach. A comprehensive study (NRC 1995, p. 97) reports that:

> "It is essential that material obtained from the sea be located a sufficient distance offshore that the sand placed in conjunction with the nourishment will not be carried back into the borrow areas. In most cases, borrow areas need to be a minimum of 2 km [1.24 miles] from the shoreline, well seaward of the depth of closure."

In this regard sand sources farther off the coast should receive consideration.

Grain size Compatibility Between Existing Beach and Borrow Areas - The issue of grain size compatibility is critical to many aspects of the project's success, such as longevity, and the adverse environmental impacts, such as turbidity and sedimentation. This issue is summarized by the statement (NRC 1995, p. 97) that:

> "The most important borrow material characteristic is the sediment size. Borrow material grain size matching the native material is considered synonymous with quality. A candidate borrow area may be considered unacceptable if the silt and clay fractions exceed a certain percentage. . . . Fine material also adversely affects project performance. Early projects constructed without regard for grain size performed relatively poorly, and recent developments indicate that nourishment sand that is only slightly smaller than native sand can result in significantly narrower equilibrated dry beach width compared to sand the same size as (or larger than) native sand."

Project planning must collect comprehensive, grain size data on both the existing beach and all potential borrow sites. While nearshore sites would create lower transportation costs, the use of nearshore sites with fine grained material would result in more frequent renourishment and higher turbidity. Over the 50 years of official project life, the greater costs of borrow areas farther offshore, but with larger grain sediment, could increase the time between required additional sediment placements. The cost savings from longer beach life could offset the greater transportation costs involved with more distant sites.

Design and Construction Options - Several major features of design and construction have not been established. These options will influence the ultimate environmental impacts of the project.

First, whether there should be large sand placements spaced several years apart or smaller sand placements annually. Pilkey and Dixon (1996, p. 83) recount the beach nourishment experience of Virginia Beach, Virginia, less than 50 miles north of the project area. In 1972 a study committee, which included the Corps, concluded that the small annual renourishment technique that had been used was superior to large nourishment projects spaced several years apart. This was due, in part, to a determination that larger volumes of sand disappeared more rapidly. However, by 1995, without evidence that would contradict the 1972 report, the Corps chose to put large volumes of sand on the beach at three year intervals. This aspect of a storm damage reduction option should be evaluated. In North Carolina, a small beach nourishment project could be on the order of 100,000 to 200,000 cubic yards of material per mile of beach (Pilkey et al. 1998, p. 100).

Second, the landward starting point for sediment placement has not been specified. This is important because years of shoreline recession has left many structures, primarily single family homes on or, in few cases, seaward of the existing dune (Pilkey et al. 1998, p. 147). In Kitty Hawk, Pilkey et al. (1998, p. 148) note that it is not possible to replace the original frontal dune because the beach has retreated past its former location. The authors suggest that a new frontal dune landward of original dune, approximately at the location of the road paralleling the beach, would be an effective and low-cost storm blocker. However, many relocations of both houses and the road would be required.

Third, current project specifications call for a continuous artificial beach (berm), but with a dune only at locations where it is deemed "necessary." Such a design seems unusual for a storm damage reduction project since the artificial dune at the back of the beach is the most effective feature on the shoreline for reducing storm damage (Pilkey et al. 1998, p. 101). "Necessary" may refer to placing the artificial dune between points where some remnants of the 1930s dune line still exist. However, Pilkey et al. (1998, p. 148) note that the old dune line in Kitty Hawk was lost by the late 1980s. The protective value of these 60-year-old dunes might be expected to be minimal. Any gaps left in the dune line would allow the passage of flood waters and hasten the erosion of the dune adjacent to the gap. Therefore, the Corps' development of alternatives should state the exact criterion for areas which would be given a dune and those that would not.

Fourth, the type of dredging equipment to be used and the manner in which the sediment would be moved to the beaches needs to be established. The basic option would probably involve either a hopper dredge or an ocean-certified pipeline dredge (NRC 1995, pp. 274-280). The nature of the equipment will influence the annual work schedule, the mode of transfer to the beach, and the need for any booster pumps. These factors would influence the environmental impacts of the project.

Modification of Development and Infrastructure

Table 11 gives several examples of measures which fall into this broad, third option for storm damage reduction. This category includes the many measures that would make structures better able to withstand coastal storms. A basic part of such measures is the improvement of building codes. Pilkey et al. (1980, p. 148) state that "It is possible to design buildings for survival in crashing storm surf. Many lighthouses, for example, have survived storm surge. But in the balanced-risk equation, it usually isn't economically feasible to build ordinary cottages to resist such forces."

Pilkey et al (1998, pp. 213-257) devote an entire chapter to construction regulations and techniques that would result in less storm damage. Their discussion covers such diverse topics as the type of house, strengthening the exterior envelope, structural integrity of buildings, and retrofitting an existing house (Figure 18). These authors also write that damage to water, sewage, electrical, telephone, and cable TV utilities can often be avoided be proper installation (Pilkey et al 1998, p. 221). The chapter notes that the best and most common method of minimizing flood damage due to waves or storm surge is to raise the lowest floor above the expected highest water level (Pilkey et al 1998, p. 234). A local LUP also states that "A widely used measure to avoid flood waters is simply to raise the structure above the expected level of flooding" (Kitty Hawk 1994, p. 76).

In addition to the advantages that better building codes and enforcement would provide to building owners, such measures would benefit the entire community be reducing missiling (flying debris), rafting (floating debris), and ramrodding (floating debris). Even entire houses that are not properly anchored may float off their foundations and become waterborne. In a

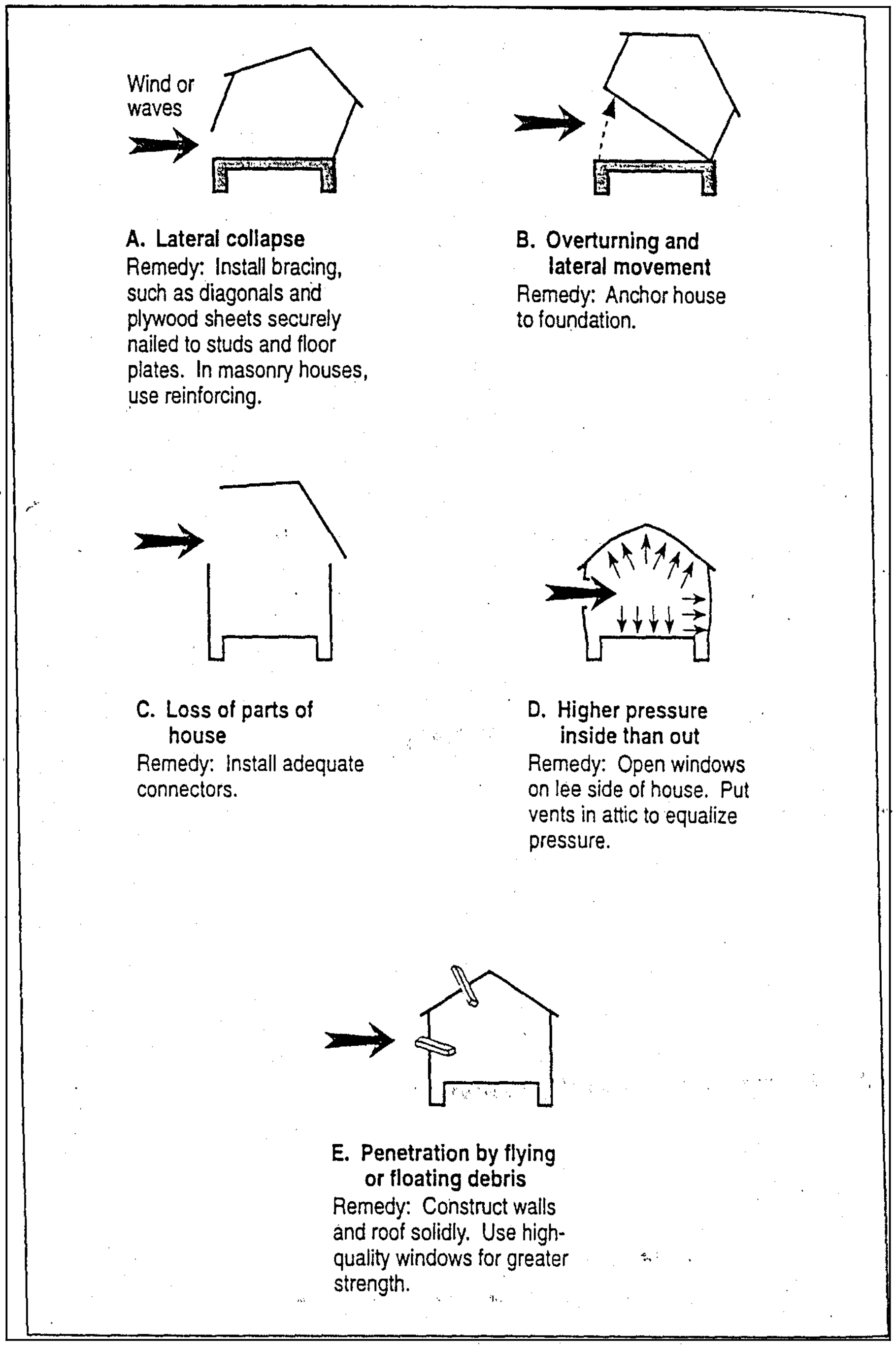

Figure 18. Examples of several construction techniques that would reduction storm damage to houses. Source: Pilkey et al. 1998. p. 99. Used with permission of Duke University Press.

coastal storm it is not enough to have your own property secure, the deficiencies of other buildings miles away can come by wind or water directly to your doorstep and then through your door.

Zoning and Land Use Planning

Table 11 gives several actions by which zoning and land use planning, a fourth major option, may be employed to reduce storm damage. Bush et al. (1996, pp. 137-143) discuss these measures, but the overriding message is to identify hazard areas and avoid developing them by proper planning. These authors note that the real world provides very few good examples of planned development on barrier islands, primarily because developers and communities do not stick with their plans.

However, certain measures could be employed. For example, multi-story commercial structures could be excluded from high hazard flood areas (the V-zone), lots in ocean erodible areas could have a long axes perpendicular to the ocean in order to allow for periodic pull backs, and development could be banned from potential inlet formation sites of overwash areas. The Town of Kitty Hawk recognizes that some lots fronting the ocean have or may become so shallow because of erosion, that they cannot be built on and that, wherever possible, the public may acquire though dedication or purchase land vacated by relocated structures (Kitty Hawk 1994, p. 75). The Town also expects that the environmentally sensitive land in Hazard Zone Four, an area that can expect flooding in even a minor hurricane, will develop as low density residential, if it is developed at all. These measures indicate an understanding that storm damage reduction can be achieved by zoning and land use regulations.

There are government actions that could reduce coastal storm damage. A group of individuals representing such diverse fields as coastal engineering, regional planning, coastal law, and economic geology met at the Second Skidaway Institute of Oceanography Conference on America's Eroding Shoreline in mid-1985. This group produce a "National Strategy for Beach Preservation" (Skidaway Institute of Oceanography 1985). A part of this strategy was a list of actions that could be taken at the federal (Appendix E), state (Appendix F), and local (Appendix G) levels to both minimize the economic losses of coastal stroms and preserve America's beaches.

Past Planning Within Dare County

Planning within the project area has clearly separated storm hazard mitigation from beach nourishment. The key method of storm hazard mitigation is the enforcement of base flood elevation standards designed to allow rising waters to flow freely under elevated structures (Dare County 1994, p. 94). The County also enforces the wind load requirements for hurricane zones established by the Southern Building Codes Council. Bush et al. (1996, p. 99) write that Nags Head has adopted building standards more restrictive than required by either FEMA or the North Carolina CAMA. Incentives are used to encourage the location of development as far back from the ocean as possible. The town has limited the development of oceanfront hotels and condominiums (Bush et al. 1996, p. 99).

Summary For the Development of Alternatives

As noted, there is no question that efforts should be made to reduce the damage of coastal storms. The major question is the proper method or methods to achieve this goal. This section has briefly discussed the framework which the Service believes should be used in deciding on a storm damage reduction program.

SECTION 8. SELECTION OF THE PREFERRED ALTERNATIVE

Neither the Notice of Intent to prepare an EIS nor the Corps' scoping letter discusses the process used to arrive at the preferred alternative. The selection among the alternatives discussed in the preceding section may be somewhat confused by the degree to which the purpose of storm damage reduction has been intertwined with the goal of erosion control/beach restoration. The Service hopes that the EIS will clearly separate the goals of storm damage reduction from those of erosion control/beach restoration prior to the development of alternatives. This distinction is very important because the options for erosion control/beach restoration have been clearly defined and the creation of artificial beach-dune systems is generally considered the least environmentally damaging. On the other hand, the goal of storm damage reduction can be achieved in many ways, and in this case the creation of an artificial beach-dune system has the greatest potential for environmental harm (Table 12).

After the development of alternatives, the EIS should clearly indicate the factors leading the selection of the preferred alternative. In general, the major factors, which may overlap to some extent, would be: (1) effectiveness; (2) sustainability; and, (3) the long-term impacts to other coastal features.

The issue of effectiveness is critically important. The EIS should clearly describe the level of storm for which protection is sought, types of storm damage for which the project would provide protection, and the geographic extent of this protection. As noted, an artificial beach-dune system would not protect against damage by strong wind, heavy rain, some flooding from the ocean, and all flooding by the storm surge ebb coming from the sound. Furthermore, surges associated with category 4 and 5 hurricanes would be expected to wash over the proposed artificial dune with a height of 13 feet above mean sea level. Hurricane Fran, a category 3 storm, produced a storm surge of 12-14 feet on Topsail Island in 1996 (Pilkey et al 1998, p. 29). The storm destroyed dunes, cut swash channels, and undercut buildings. The wind damage of Fran was extensive. The benefits of the proposed artificial beach-dune system would be generally limited to the weakest hurricanes. Conversely, alternatives which seek to remove structures from high risk zones can be completely effective for the storms used in the program's design.

The second factor in the selection process should address the issue of sustainability. This relates directly to the interrelated factors of durability and the periodic requirement for additional expenditures. While sustainability applies to all alternatives, this consideration is especially critical to the alternative for creating an artificial beach-dune system. The artificial beach-dune system would be under constant attack by both fair- and foul-weather waves of a rising sea. It would be dependent on funds to move a finite amount of offshore sand to the shore. Artificial beaches have a record of not lasting as long as original predictions. The Corps' predictions of sand requirements for renourishment at Wrightsville Beach, North Carolina, have been consistently exceeded (Figure 19). In some of the most extreme cases, expensively replenished beaches have vanished within months in a single, fierce storm. An Ocean City, New Jersey,

Table 12. Comparison of the degree of environmental impacts associated with the major options for two types of shoreline management project: beach stabilization/erosion control and storm damage reduction. As the table indications some options are available for both types of projects. The options given, but not the assessment of environmental impacts, are adapted, in part, from Land Use Plans (LUP) for governmental entities in the project area (Dare County 1994, Kitty Hawk 1994, and Kill Devil Hills 1993). While these LUPs do not consider an artificial beach-dune system in the context of storm damage reduction, the option is considered here for that goal based on the Corps' current planning effort.

Magnitude of Adverse Environmental Impacts	Beach Stabilization/ Erosion control	Storm Damage Reduction
Greater	Hard Structures: seawall, jetties, groins [a]	
	Artificial beach-dune system	Artificial beach-dune system
		Structure Relocations: Move back (retreat) from the shore [b]
		Zoning regulations: adequate ocean set-backs, prohibit building in high risk areas
Lesser		Higher construction standards

[a] While some seawalls have been built for storm damage reduction, hard structures in general are designed primarily for beach stabilization and erosion control.

[b] While structure relocation is often mentioned in connection with beach stabilization, this option in fact neither attempts to hold the beach in a given location nor control erosion.

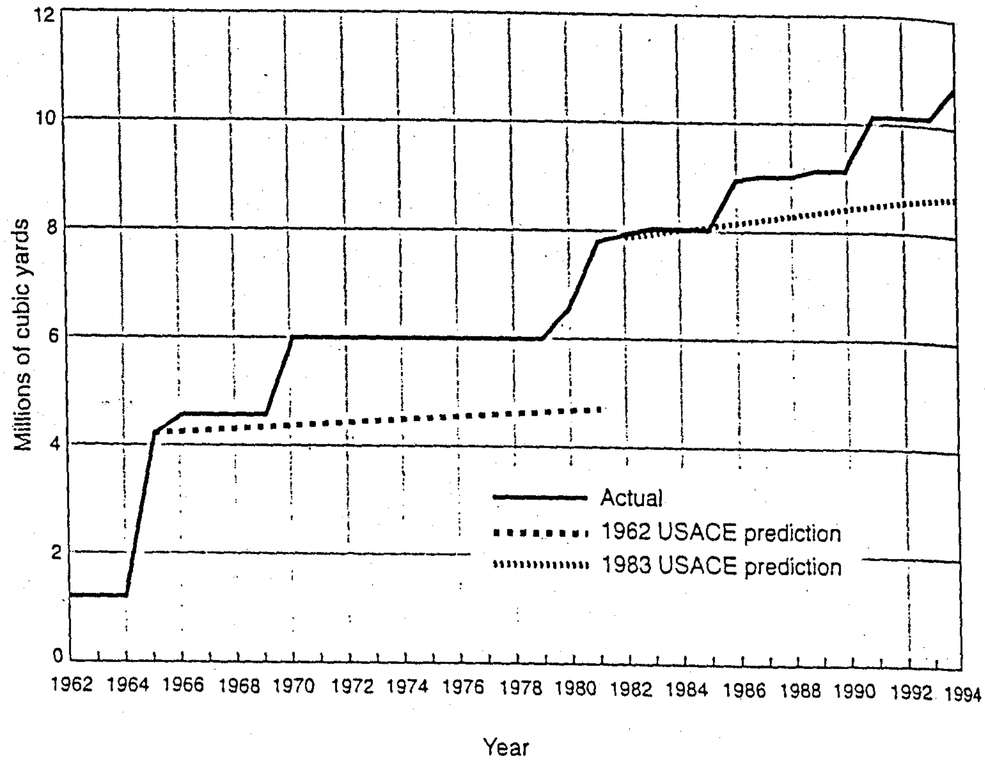

Figure 19. A comparison of the actual volume of sand required in the Wrightsville Beach, New Hanover County, Project with predictions of sand requirements in 1962 and 1983. In both cases the sand required exceeded predictions. Source: Pilkey et al. 1998. p. 98. Used with permission of Duke University Press.

beach rebuilt in 1982 at a cost of $5 million disappeared about 10 weeks later (Luoma, J. R. 1998). Folly Beach in South Carolina reached a depleted state approximately two years after nourishment and six years before the projected "next needed" renourishment (Pilkey et al. 1998, p. 98). The life span of a nourished beach cannot be accurately predicted because it is impossible to predict the frequency and magnitude of storms.

The selection of the preferred alternative should also consider the present erosion rate in the project area. A comprehensive report on beach nourishment (NRC 1995, p. 140) indicated that "Beach nourishment may not be technically or economically justified for some sites, particularly those with high rates of natural erosion." The decision making process in the EIS should discuss the data given in Table 1 and indicate whether areas with recorded erosion rates as high as 10-20 feet per year and suitable for sustaining an artificial beach-dune system for 50 years.

The issue of long-term impacts on other coastal features must be addressed in the EIS. Each alternative should be considered in light of its influence on: (1) future development; and, (2) long-term adverse impacts other coastal features (e.g. island migration, Oregon Inlet navigation channel). The issue of future development must be considered in selecting a preferred alternative. As noted, the impact of future development goes beyond its effects on the beach and includes important considerations of freshwater supplies and pollution resulting from wastewater disposal. The selection process should consider the natural process of island migration. An artificial dune does block island overwash and limits the natural ability of the ecosystem to transfer sand from the ocean beach to sound side marshes. Since the long-term existence of barrier islands is dependent on migrating landward, the selection process must consider the real long-term impact of the alternative developed.

Finally, the selection process must consider long-term impacts on other coastal features. The Service is particularly concerns that the predominant north-to-south longshore current would carry some of the sand used in an artificial beach-dune system south to the area of Oregon Inlet. If the Corps was not able to substantially increase the dredging effort at the inlet, the navigation channel would experience severe shoaling and could become unusable for larger vessels. Adequate passage through the Oregon Inlet navigation channel is at the heart of the 30-year debate over constructing a dual jetty system at the inlet. The Service opposes the dual jetty system which would require land from PINWR and CHNS. The jetties are very likely to produce severe impacts on the refuge for which acceptable mitigation is not possible. The Corps must address the Oregon Inlet navigation channel in selecting a preferred alternative. If the artificial beach-dune system is ultimately selected, the Corps should fully consider that additional funds may be required for dredging the navigation channel. The absence of a thorough consideration of this potential secondary impact would be a significant failure of NEPA planning process.

At this time the Service is not aware of the decision-making process which led to the project outlined in the NOI. We trust that the EIS will present a clear and orderly discussion of selection process with a thorough consideration of the factors mentioned above. Furthermore, we hope that the selection process remains focused on storm damage reduction and does not allow the process to become intertwined with the creation of a recreational beach.

The section process may want to consider the example of the Cape Hatteras Lighthouse presented by Pilkey et al. (1998, p. 6). This lighthouse, built in 1870 at a distance of 1,500 feet from the sea, became threaten by the encroaching ocean in the early 1900s. By 1980 the ocean was within 70 feet of the structure. Between the 1930s and 1981, the NPS spent approximately $15 million to protect the structure. Three beach renourishment projects during this period were unsuccessful. Finally, the NPS was directed by the Department of the Interior to find a method for protecting the lighthouse. The method had to meet three basic criteria: (1) the structure would be saved, i.e., the solution must be effective; (2) the method would be permanent, i.e, the solution must be durable; and, (3) there would be no recurring costs, i.e., the solution must be cost effective. An examination of all the facts in light of these criteria led to the conclusion that the only solution was to move the lighthouse back from the sea. In 1999 the lighthouse began its retreat from the sea.

SECTION 9. DESCRIPTION OF THE PREFERRED ALTERNATIVE

The Corps outlined a preferred alternative in the NOI in the Federal Register and a scoping letter, both released during July 1997. The reconnaissance level study supported additional investigation for providing storm damage reduction efforts on approximately 20 miles of ocean shoreline within Dare County north of the boundary of the CHNS. The method of storm damage reduction would be the placement of a sand berm and, where necessary, a berm and dune combination along various reaches of the shoreline. The final dimensions of the project and the actual reaches to be protected would be based on a maximization of net project benefits.

Material provided by the Corps in 1999 indicates that initial construction would occur on approximately 13.6 miles of beach. A northern project area would extend for 3.5 miles from near Bittern Street in Kitty Hawk south to near Tanya Drive in Kill Devil Hills. A disjunct southern project would extent approximately 10.1 miles from 600 feet south of Lillian Street in Nags Head southward to the boundary of the CHNS. Initial construction is estimated to require 14.6 million cubic yards (cy) of material. Project plans estimate that renourishment would occur on an average interval of three years. The estimated material for each renourishment would be 4.63 million cy. The total volume of sand for both initial construction and periodic renourishment during the 50-year life of the project is estimated to be 88.7 million cy.

Sand would be taken from five offshore borrow areas (Figure 20). Two borrow areas (N1 and N2) would be off the northern part of project area, Kitty Hawk and Kill Devil Hills. Three borrow areas (S1, S2, and S3) would be off the southern part of the project areas. Based on maps provided by the Corps, the borrow areas are approximately one-half to three miles offshore. The State of North Carolina owns the sand resources within three miles of the shoreline, while sand beyond three miles is owned by the federal government and managed by the Mineral Management Service. Borrow sites N1 and N2 are estimated to contain 5.19 and 2.35 million cy of sediment, respectively. Borrow sites S1, S2, and S3 are estimated to contain 104.45, 7.22, and 1.39 million cy of sediment, respectively. The total for the five sites is approximately 120.61 million cy, approximately 36% more than the estimated requirements for the 50-year project.

Initial construction is estimated to require a maximum of two years. The annual dredging schedule has not been determined. Current plans do not specify whether offshore sand removal would create deep holes in localized areas or attempt to skim off relatively thin layers of sand over a wide area.

A typical profile of the berm and dune has been developed (Figure 21). The top of the artificial dune would be at 13 feet above the national geodetic vertical datum (NGVD) which is roughly mean sea level. The top of the dune would be 25 feet wide. The back dune would have a slope of 5 feet horizontal to 1 foot vertical. The ocean side of the dune would slope down at 10 feet horizontal to 1 foot vertical to meet a berm at seven feet above the NGVD. The plan would attempt to maintain a 50-foot width for this berm. In order to account for erosion between renourishment, the berm would be initially constructed wider than 50 feet.

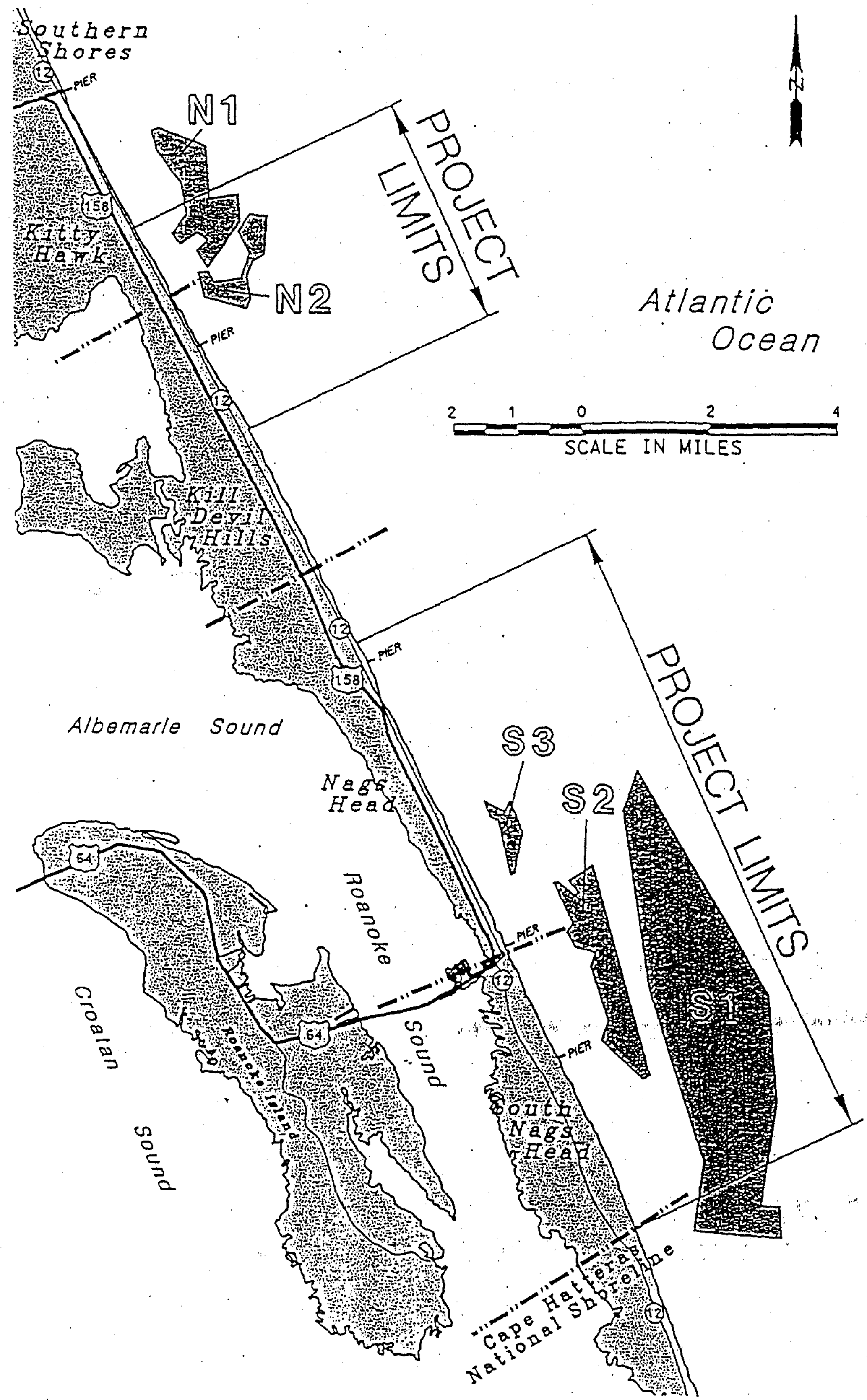

Figure 20. Map of the project area for the Northern Dare County Storm Damage Reduction Project, Dare County, North Carolina. Map shows the two northern offshore borrow sites (N1 and N2), the three southern offshore borrow sites (S1, S2, and S3), and the project limits for the northern and southern sediment placement areas. Source: Wilmington District, U. S. Army Corps of Engineers, Wilmington, North Carolina.

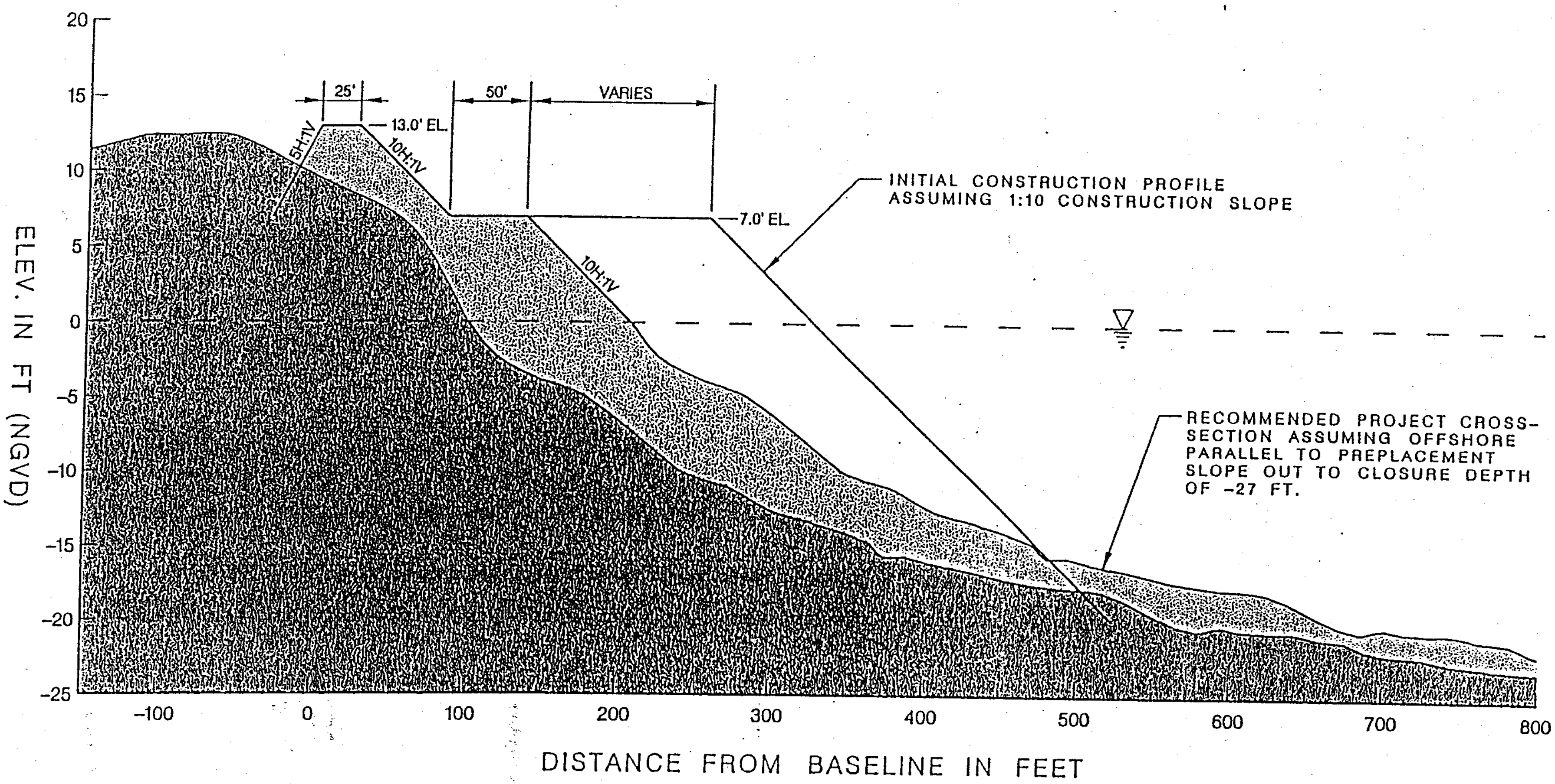

Figure 21. General profile for the artificial beach-dune system of the Northern Dare County Storm Damage Reduction Project, Dare County, North Carolina. NGVD refers to the National Geodetic Vertical Datum which is approximately equal to mean sea level. Source: Wilmington District, U. S. Army Corps of Engineers, Wilmington, North Carolina.

As noted in Section 7, several important design features and construction techniques have not been specified. These include:

1. The landward starting point for sediment placement;

2. The criterion for building a dune behind the beach; current plan only specify that a dune would be constructed where it is deemed "necessary;"

3. The type of dredging equipment to be used and the manner in which the sediment would be moved to the beaches; and,

4. The manner in which sand would be removed for offshore borrow area; either large volumes from localized areas or skimming sediment off in thinner layers over a large area

These important project aspects should be addresses in the EIS.

SECTION 10. IMPACTS OF THE PREFERRED ALTERNATIVE

As noted earlier, several critical design and construction aspects for this project have not been established. These features, such as the time of year for dredging/beach placement and the extent of dune construction, will profoundly affect the types and magnitude of project impacts. However, based on all available information from the Corps, project impacts will be described and evaluated. Two broad categories of project impacts will be considered: direct and indirect, or secondary, impacts. Finally, the long-term ramifications of initiating an artificial beach-dune system on a barrier island will be considered.

Direct Project Impacts

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 impacts. 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.

Dredging will kill the plants and animals within the sand removed from borrow sites. The NRC report states (1995, p. 118) that "The primary biological effect of dredging borrow sites is the removal of benthic assemblages inhabiting the surficial substrate."

The preferred alternative would increase turbidity during the dredging of sand at the offshore borrow sites. Silt and clay particles within the borrow material would become suspended by the dredge. The increased turbidity would be harmful to planktonic invertebrates, fish, and marine mammal. The suspended sediment would reduce light penetration beyond the actual area dredged and reduce primary production.

While increased turbidity *per se* is harmful, a closely related event, increased offshore sedimentation, also produces adverse impacts. The suspended particles are carried away from the actual dredging site and eventually settle to the bottom creating sedimentation. The settling of suspended particles is also referred to as siltation. Bush et al (1996, p. 83) state their belief that the dredging of sand off Boca Raton, Florida, for a new beach released mud that was responsible for killing coral heads more than 20 miles to the north. Hardbottom areas indicated by SEAMAP data (Appendix B, Map 12) could be destroyed by sedimentation. It is difficult to forecast the exact magnitude and areal extent of sedimentation produced by dredging. However, sediment with certain characteristics, e.g., high silt and clay content and currents, could cover hardbottom areas many miles from the dredging site with a damaging layer of sediment.

The nearshore waters off the northern portion of the North Carolina Outer Banks, north of Cape Hatteras, are important wintering areas for migratory fish populations (Appendix B). The mining of offshore sand in areas used for wintering by striped bass, summer flounder, and weakfish could adversely affect these species. The project could jeopardize the spawning stock biomass of these three interjurisdictional species which provide recruits for much of the mid-Atlantic coast. Fish in the area would be disturbed by the turbidity caused be initial construction and periodic dredging for replacement of sand. Dredging may remove habitat used by these species, such as underwater sand berms or mounds that provide shelter. Dredging would destroy benthic prey organisms and could cause mobile prey species to move out of the work area. Appendix B provides a detailed discussion of the importance of benthic or benthic-consuming prey for offshore fisheries.

A completely separate occurrence of turbidity would result from the placement of the sediment on the shoreline. While dredging turbidity may be high, it is generally a short-term phenomenon. However, turbidity resulting from fine material in the beach may occur for a long time after the sand has been deposited.

Turbidity may be measured in terms of nephelometric turbidity units (NTU). The State of Florida restricts the level of turbidity that can occur outside a predetermined mixing zone to 29 NTUs above corresponding background samples (NRC 1995, p. 114). A beach nourishment study by Saloman and Naughton (1984) revealed that turbidity was relatively low during nourishment with the exception of points where material with a high organic content was dredged and deposited on the beach. At one site where the dredge encountered mud, turbidities were as high as approximately 172 NTUs. At another site, where deposited material was nearly all clean sand, the turbidities immediately after dumping ranged from 2.6 to 15.4 NTUs. During a Hilton Head, South Carolina, beach nourishment project, limited surveys near the outfall pipe found turbidity levels of 50 to 150 NTUs above background levels in areas extending approximately 656 feet (200 meters) from the outfall (Van Dolah et al. 1992).

State water quality regulations require that in waters classified as SC (Saltwater, Class C), turbidity due to discharge must not exceed 25 NTUs (North Carolina Department of Environment Health, and Natural Resources 1991). Beach disposal of dredged material at Atlantic Beach, North Carolina, resulted in turbidities as high as 250 NTUs in the vicinity of the discharge pipe, but rapidly decreased with distance from the discharge pipe (USACOE, 1990). Reilly and Bellis (1978) found that after beach nourishment, the total suspended solids load in the nearshore waters adjacent to the beach nourishment project was much higher than the load of "normal sea water."

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.

The sedimentation resulting from finer grain material washing off the artificial beach-dune system is similar to, but distinct from, that produced by dredging. Nearshore reef habitats that lie within the depth of closure may be destroyed by sand burial resulting from the redistribution of beach fill material (NRC 1995, p. 113-114). Studies have indicated that sand placed on Wrightsville Beach has washed off the beach and buried extensive hardbottoms on the inner continental shelf (Riggs, 1994, p. 17). These hardbottoms were prime fishing locations, but are now out of production due to a covering of two to six inches of sand. Riggs (1994, p. 17) concludes that "The business of beach nourishment and hardbottoms represents a very serious conflict, and a problem that's going to get much bigger."

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.

Reilly and Bellis (1978) studied the effects of depositing 1.2 million cubic yards of sand on the beach at Bogue Banks North Carolina (Figure 2). Sediments were deposited at a depth of 6.6 feet (2 meters) and as a result of nourishment, the intertidal zone was moved 250 feet (75 meters) seaward in one day. Nourishment occurred between December 1977 and June 1978. The researchers sampled the intertidal organisms before and after sand placement at the nourished beach and at a nearby control beach. On the nourished beach they found complete mortality of mole crabs and coquina clams after sediment placement.

While species which move on and off the beaches during their life cycle may recolonize the new beach in time, species spending their entire life cycles in the intertidal regions of the beach may be more severely impacted by massive sand placement. *Haustorius* sp., an amphipod found on many beaches, recovered very slowly after beach nourishment on Bogue Banks (Reilly and Bellis 1978). After nourishment, no amphipods were found on the beach until late summer and recovery then was probably due to recruitment from nearby areas.

Reilly and Bellis (1978) indicated that numbers of migrating, invertebrate consumers such as the speckled crab (*Arenaeus cribarius*), lady crab (*Ovalipes ocellatus*), ghost crab (*Ocypode quadrata*) and blue crab (*Callinectes sapidus*) were drastically reduced after nourishment activities. This may be attributable to greater turbidity causing resident populations to move elsewhere, a change in beach slope and offshore bars making approach to the beach difficult, or more likely a reduction in the abundance of prey. Vertebrate consumers, such as fish and shorebirds, may also be adversely affected by a reduction in prey species.

Sediment placement during the sea turtle nesting and hatching season, May 1 through November 15, can lower reproductive success. Creation of the artificial beach-dune system during this season could result in the loss of sea turtles through disruption of adult nesting activity and by burial or crushing of nests or hatchlings. While a nest monitoring and egg relocation program would reduce these impacts, nests may be inadvertently missed or misidentified as false crawls during daily patrols. In addition, nests may be destroyed by operations at night prior to beach patrols being performed. Even under the best of conditions, about seven percent of the nests can be misidentified as false crawls by experienced sea turtle nest surveyors (Schroeder 1994).

Besides the potential for missing nests during a nest relocation program, there is a potential for eggs to be damaged by their movement or for unknown biological mechanisms to be affected. Nest relocation can have adverse impacts on incubation temperature (and hence sex ratios), gas exchange parameters, hydric environment of nests, hatching success, and hatchling emergence (Limpus et al. 1979, Ackerman 1980, Parmenter 1980, Spotila et al. 1983, McGehee 1990). Relocating nests into sands deficient in oxygen or moisture can result in mortality, morbidity, and reduced behavioral competence of hatchlings. Water availability is known to influence the incubation environment of the embryos and hatchlings of turtles with flexible-shelled eggs, which has been shown to affect nitrogen excretion (Packard et al. 1984), mobilization of calcium (Packard and Packard 1986), mobilization of yolk nutrients (Packard et al. 1985), hatchling size (Packard et al. 1981, McGehee 1990), energy reserves in the yolk at hatching (Packard et al. 1988), and locomotory ability of hatchlings (Miller *et al.* 1987).

Comparisons of hatching success between relocated and *in situ* nests have noted significant variation ranging from a 21 percent decrease to a 9 percent increase for relocated nests (Florida Department of Environmental Protection, unpubl. data). Comparisons of emergence success, moving up out of the nest onto the beach, between relocated and *in situ* nests have also noted significant variation ranging from a 23 percent decrease to a 5 percent increase for relocated nests (Florida Department of Environmental Protection, unpubl. data). A 1994 Florida Department of Environmental Protection study of hatching and emergence success of *in situ* and relocated nests at seven sites in Florida found that hatching success was lower for relocated nests in five of seven cases with an average decrease for all seven sites of 5.01 percent (range = 7.19 percent increase to 16.31 percent decrease). Emergence success was lower for relocated nests in all seven cases by an average of 11.67 percent (range = 3.6 to 23.36 percent) (A. Meylan, Florida Department of Environmental Protection, in litt., April 5, 1995).

A final concern about nest relocation is that it may concentrate eggs in an area resulting in a greater susceptibility to catastrophic events. Hatchlings released from concentrated areas also may be subject to greater predation rates from both land and marine predators, because the predators learn where to concentrate their efforts.

The placement of pipelines and the use of heavy machinery on the beach during a construction project may have adverse effects on sea turtles. This equipment can create barriers to nesting females emerging from the surf and crawling up the beach, causing a higher incidence of false crawls and unnecessary energy expenditure.

Another impact to sea turtles is disorientation (loss of bearings) and misorientation (incorrect orientation) of hatchlings from artificial lighting. Visual cues are the primary sea-finding mechanism for hatchlings (Mrosovsky and Carr 1967, Mrosovsky and Shettleworth 1968, Dickerson and Nelson 1989, Witherington and Bjorndal 1991). Artificial beachfront lighting is a well documented cause of hatchling disorientation and misorientation on nesting beaches (Philbosian 1976; Mann 1977; Florida Department of Environmental Protection, unpubl. data). In addition, research has also documented significant reduction in sea turtle nesting activity on beaches illuminated with artificial lights (Witherington 1992). Therefore, construction lights along a project beach and on the dredging vessel may deter females from coming ashore to nest, disorient females trying to return to the surf after a nesting event, and disorient and misorient emergent hatchlings from adjacent non-project beaches. Any source of bright lighting can profoundly affect the orientation of hatchlings, both during the crawl from the beach to the ocean and once they begin swimming offshore. Hatchlings attracted to light sources on dredging barges may not only suffer from interference in migration, but may also experience higher probabilities of predation to predatory fishes that are also attracted to the barge lights. This impact could be reduced by using the minimum amount of light necessary (may require shielding) or low pressure sodium lighting during project construction.

Depending on the time of year for sediment placement, work on the beach would disrupt feeding and roosting by shorebirds, including the piping plover. The elimination of beach infauna would remove a food source in the project area.

Marine mammals are highly mobile and range widely along the Atlantic coast. While dredging and beach disposal may be disruptive to normal travel routes and foraging patterns, these animals are likely to move to less disturbed areas. However, the dredging vessels must avoid hitting marine mammals and special observers may be necessary to watch for marine mammals.

Indirect Project Impacts

Removal of sand from the offshore borrow areas may permanently alter the physical characteristics of the areas and impact the benthic flora and fauna adapted to existing conditions. The long-term physical alterations produced by sand removal from marine habitats have not been well documented (NRC 1995, p. 118). The majority of follow up studies from offshore borrow sites have shown decreases in the mean grain size, including, in some cases, increases in the percentage of silts and clays in the borrow site (NRC 1995, p. 118). Offshore holes may fill with finer grain material (NRC 1995, p. 118). The finer material or other significant alterations in the physical characteristics of the substrate may not be suitable for the organisms that formerly occupied bottom sediment of the borrow area.

The recovery period for benthic communities that are lost to dredging is quite variable, ranging from a few months to several years (NRC 1995, p. 120). While the abundance and diversity of benthic fauna may return to pre-dredging values, several studies have documented changes in the species composition of the benthos that lasted more than a year, particularly in areas where bottom sediment composition was altered (Johnson and Nelson 1985, Bowen and Marsh 1988, Van Dolah et al. 1992, 1993, Wilber and Stern 1992). Benthic organisms inhabiting the potential offshore borrow areas serve as food for commercially important species and are essential in marine food chains (Figure 11). For example, adult spot are benthic feeders, primarily eating polychaetes and benthic copepods. Atlantic croaker are also bottom feeders, preying on polychaetes and bivalves. Pink and white penaeid shrimp also prefer benthos.

The cumulative effects of the project on offshore fisheries may be the transformation of formerly preferred habitat into unsuitable or unusable habitat (Appendix B). This change could occur as a result of altered substrate characteristics, depth, or other physical parameters. In addition to harming commercial and recreational fishermen, the loss or degradation of this important fish habitat would adversely impact marine birds, such as the northern gannet and eastern brown pelican, and marine mammals, such as the humpback whale.

In addition to changes in species composition and abundance, the removal of offshore sand may also reduce primary productivity. Reduced primary productivity could result from the greater depth in the borrow areas after sand removal. The greater depth would reduce solar energy reaching the new bottom. Furthermore, even minor sedimentation reaching distance hardbottom areas would reduce productivity.

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 nourishment 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.

When a beach is nourished, large volumes of sand are placed within the supralittoral and intertidal zones. Beach invertebrate populations are eliminated or greatly reduced. As noted, the direct, adverse impacts may be dramatic, but longer-term, indirect impacts related to altered beach characteristics and recruitment of a recovery population may have the greater impact on fish and wildlife resources that depend on beach invertebrates as a food source. Sand placement disturbs the indigenous biota inhabiting the subaerial habitats, which in turn affects the foraging patterns of the species that feed on those organisms (NRC 1995, p. 108). Dean (1999, p. 118-119) describes the artificial beach in Miami, Florida, as a quiet area without natural life.

Sand flowing onto the lower portion of the beach during the nourishment operation can increase the beach height in the intertidal zone from several centimeters to more than a meter (NRC 1995, p. 109). This significant change in the character of the intertidal zone can affect habitat suitability and feeding by beach invertebrates beyond the immediate impact of sediment placement.

Bottom habitats in the nearshore surf zone often support a diverse array of biota that are directly or indirectly affected by beach nourishment operations (NRC 1995, p. 112-113). This community may be affected by burial of the bottom habitats, increased sedimentation, changes in nearshore bathymetry and associated wave action, and elevated turbidity.

Studies have documented only limited or short-term alterations in abundance, diversity, and species composition of nearshore infaunal communities sampled off new beaches (NRC 1995, p. 115). However, several of these studies had inadequate sampling designs that may have precluded detection of significant alterations in the populations or community parameters measured (Nelson, W. G. 1991, 1993). The NRC (1995, p. 115) concluded that " . . . efforts should be directed toward obtaining a better understanding of functional changes in the trophic contribution of benthic assemblages to the fish and crustaceans species that rely on the benthos as a major food resource."

Reilly and Bellis (1978) state that species of beach infauna recruited from pelagic larval stocks, such as mole crabs and coquina clams, will recover if nourishment activity ends before larval recruitment begins in the spring. In the spring, recruitment begins with juveniles and adults approaching the beach. In the Bogue Banks project, nourishment extended from December until June, a time that included the March recruitment period of coquina clams. No increase in coquina clams occurred until July 29, approximately two months after cessation of nourishment, and populations failed to reach pre-nourishment numbers found during the winter. At the control site, coquina clams also decreased during the winter as they moved offshore. However, during March, numbers at the control site increased to high levels. This study indicated that adult coquina clams were probably killed in their offshore wintering environment, and beach nourishment effects, most likely high turbidity, prevented normal pelagic larvae recruitment. The individuals that eventually arrived were post metamorphic adults likely to have diffused from area beaches via littoral drift.

Reilly and Bellis (1978) found the complete absence of mole crabs within one week of the beginning of the nourishment project at Bogue Banks. Numbers were also reduced at the control site as adults moved offshore to spend the winter. Overwintering adult mole crabs returned to the control site in April, and the young of the year from pelagic larval stocks returned later in the spring. The return of mole crabs at Bogue Banks lagged one month behind that at the control site and then only young of the year mole crabs appeared at the nourished beach. The lack of adults at the nourished beach resulted in drastic reduction in overall biomass of mole crabs.

Goldberg (1985) (as reported in Goldberg (1988)) found that one year after a nourishment project in Broward County, Florida, was completed, infauna just offshore was regaining taxonomic diversity, but abundance was still as low as 62 percent below pre-nourishment numbers. Saloman and Naughton (1984) looked at the effects of a nourishment project at Panama City Beach, Florida. They found significant decreases in species abundance and diversity of organisms in the swash zone during a 5 to 6 week period after nourishment. On the other hand, Gorzelaney (1983) (as reported by Stauble and Nelson (1985)) examined the biological impacts of nourishment project on Indialantic and Melbourne Beach, Florida. Nourishment occurred between mid-October and January, and the researcher found no negative long term effects to nearshore fauna.

Each episode of dredging and sand placement over the 50 years of project life would create all the direct impacts considered above. Therefore, the Service is concerned about the renourishment frequency which will depend of the life of each placement. Any indirect impacts which reduce the life of the artificial beach-dune system and increase the renourishment frequency will adversely affect fish and wildlife resources.

The indirect impacts considered here relate to changes that would be produced by removing sand from offshore borrow areas. Offshore sand resources serve to protect existing development, and their removal may offer short-term protection in exchange for greater long-term damage. Offshore dredging may remove offshore sand bars and shoals that provide important protection to the beaches. Offshore holes produced by dredging may either increase wave energy or change refraction patterns, or both (Pilkey et al. 1983. p. 215). Wave energy and the stability of the beach may also be affected if the borrow site lies within the depth of closure (NRC 1995, p. 118).

Davis and Dolan (1993) state that "Because there is a close relationship between water depth and the height of waves in shallow water, any increase in water depth at the coast contributes to conditions that permit higher wave action closer to the shoreline, thus increasing the potential for damage." Kaufman and Pilkey (1983, p. 91) also point out that towns on Cape Cod are saved from the twenty-foot breakers of the North Atlantic by the annual formation of a large offshore bar made of sand eroded from the Cape. Offshore bars, small ridges of sand parallel to the shore, occur periodically offshore from most beaches. These bars dissipate the energy of breaking waves. The shallow water atop these offshore bars virtually trips incoming waves, forcing them to break (Pilkey and Dixon, 1996, p. 28).

Changes in offshore topography may alter the pattern of wave energy striking the beach through changes in wave refraction. Wave refraction is a physical phenomenon in which a part of a wave slows down while other parts continue to move at a different speed. The different speeds result in the bending of the wave, and the effect of wave refraction is to unevenly distribute wave energy along the shoreline (Thurman 1994, p. 236). Pilkey et al. (1983, p. 85) also note that if one part of a wave touches bottom first, friction causes that part of the wave to slow down. Different velocities in different parts of the wave will cause a bending, or refraction, in the wave crest. In regard to the life of an artificial beach, the point is that variations in bottom contours may weaken or intensify wave energy. Greater wave energy striking the shore carries the beach away faster.

Problems associated with waves striking the beach at different angles are closely related to the issue of greater wave energy striking the beach. Variations in the direction of wave attack are related to the physical phenomenon of wave diffraction. Wave diffraction can be considered the bending of waves around objects (Thurman 1994, p. 236). Diffraction occurs when wave energy is bent by passing an obstacle; it is not related to refraction. Diffraction results because any point on a wave can be a source from which energy can propagate in all directions.

The proposed, artificial beach-dune system will represent the introduction of a large mass of material into a very dynamic shoreline. Waves from many directions are constantly hitting the shoreline. The introduced material would alter the waves approaching the shore and, to some extent, serve to redirect wave energy. The continuing, serious erosion problems at Wrightsville Beach (immediately north of Masonboro Inlet, Figure 1) is associated with a seaward bulge in the shoreline (NRC 1995, p. 29). The bulge was created in 1966 when Moore Inlet was closed and filled by the Corps as part of a hurricane and shore protection project. The anomalous shape of Wrightsville Beach results in wave energy being concentrated along the bulge and wave breaker angles on the bulge transition that vary from normal breaker angles. These conditions alter the normal rates of sediment transport and cause increases in sediment transport away from the bulge in both the north and south directions.

While offshore sand sources offer environmental advantages over borrow areas in estuarine areas, dredging near the shore creates holes that may alter wave patterns on the adjacent shoreline. Altered wave patterns influence the location and extent of erosion for decades after initial sand placement. Pilkey et al. (1980. p. 40) write that:

> ". . . Dr. Victor Goldsmith of the Virginia Institute of Marine Science warns that when a hole is dug on the shelf for replenishment sand, wave patterns on the adjacent shoreline will likely be affected. Off the Connecticut coast, wave patterns changed by a dredged hole on the shelf quickly caused the replenished beach to disappear."

The alteration of offshore contours, or bathymetry, has the potential to shift wave patterns and may even focus waves to create erosional "hot spots", localized areas of excessive erosion. The USMMS (1999) notes that:

> "Wave energy tends to concentrate behind a shoal because of wave refraction and diffraction. The combination of wave length and shoal geometry controls the response of waves as they interact with a shoal. Shoal responses may also depend on the shoal size and ambient water depth as well as the wave conditions. The MMS-funded Virginia coast study has found that Sandbridge Shoal does have the effect of concentrating wave energy for the waves that comes from the north-northeast. . . . When a shoal is flattened (by dredging), the degree of wave energy concentration is likely to be reduced, resulting in greater wave energies hitting the coastal area. This may result in increased coastal erosion or unwanted, detrimental changes in longshore or nearshore current patterns. Significant coastal impacts could also be expected during storm events in that increased wave energies might potentially impact the coastal area."

While changes produced in the beach slope relate to changes in wave energy, the impacts considered here are separated from the discussion of wave energy changes related to offshore sand removal given earlier. The removal of offshore sand would primarily affect large waves approaching the shoreline. However, a significant change in beach slope may affect smaller waves immediately before they strike the beach. Kaufman and Pilkey et al. (1983, p. 216) state that:

> "The net effect of replenishing only the upper beach is to steepen the beach profile. The beach wants to return to its natural, more normal shape. The steeper profile of replenished beaches is the reason they erode more rapidly relative to a natural beach."

The slope of a nourished beach in the intertidal zone is generally steeper after nourishment until the beach reaches a more stable profile (NRC 1995, p. 108). Beach nourishment on Bogue Bank caused the beach slope in the intertidal zone to increase from three to five percent (Reilly and Bellis 1978).

The steeper slope of the artificial beaches allow waves of greater energy to strike the shoreline (Figure 22). As waves approach the shore and encounter water depths less than one-half a wave lenght, friction removes energy and the waves slows down (Thurman 1994, p. 235). A gentle offshore slope removes more energy than a steep slope before the wave strikes the beach. At Grand Isle in Louisiana the Corps began pumping sand on the beach in 1976. However, the Corps could not convince homeowners to move their house back and the new beach had to be place too far seaward (Kaufman and Pilkey 1983, pp. 99-100). The underwater slope of the new beach was too steep and after three months the new beach had washed away. Pilkey et al. (1998, p. 147) believe that the high wave energy in the area of Kitty Hawk, Kill Devil Hills, and Nags Head will cause any artificial beach to have a "relatively short life span and . . . be quite costly to the community."

In some respects, an artificial beach-dune system may be considered a seawall made from smaller particles, sand grains instead of giant boulders. Kaufman and Pilkey (1983, p. 213-214) state that:

> " Dr. Robert Dolan . . . finds [on the Outer Banks] that the dunes have acted much like a seawall. Because they are too high to permit overtopping and too continuous to allow inlets and breakthroughs, except under extreme conditions, the ocean's energy has been concentrated on the beaches . . . The beaches have narrowed and the offshore profile is growing steeper, creating stronger waves. . . . Waves strike this steep face with greater impact than a gentle slope, and storm erosion is fast and spectacular. The protection the dunes first offered seems to have lasted just long enough to attract enough development behind them for a major disaster."

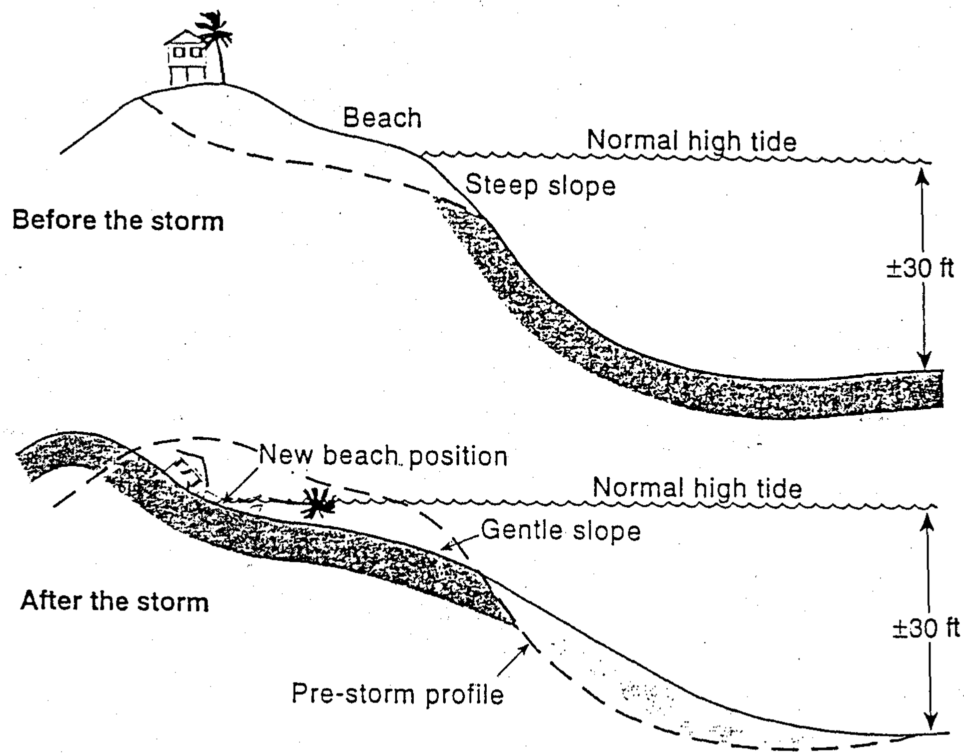

Figure 22. Diagram showing the storm-induced movement of beach sand with a steep offshore slope. A steeper offshore slope allows stronger waves to strike the beach as provides an area into which the dry beach sand can move. Source: Pilkey et al. 1998. p. 56. Used with permission of Duke University Press.

In this regard, it is interesting that seawalls composed of large stones are almost universally considered harmful to the beach, but that an artificial beach-dune system of almost the same dimensions, but made of sand, is often viewed as a more environmentally sound solution to a receding shoreline.

Beach fill adds to the coastal sediment budget (Davison et al. 1992). The material considered above strongly suggests that large quantities of sand will be washed out of the beach-dune system. Storms are especially likely to remove large quantities of sand from the artificial beach. While some of it will be washed out to sea, a large quantity of sand will undoubtedly be picked up in the longshore current. The predominant longshore current is from north to south. Sand carried south from the project area would move along Bodie Island and eventually reach Oregon Inlet (Figures 1, 2, and 9), approximately 5-6 miles south of the southern project limit. The Corps maintains an important navigation channel through Oregon Inlet. However, passage can be difficult at times and the Corps states (USACOE 1999, p. 2-2):

> "The intense wave action in the area also transports large amounts of sand toward Oregon Inlet. Much of this sand is trapped in the inlet environment, resulting in the development of massive shoals and concomitant severe erosion of the adjacent shoreline. The presence of the sand shoals, in combination with waves and tidal currents, creates an extremely hazardous zone for the passage of commercial and sport fishing craft."

Current estimates indicate that 4.63 million cubic yards of sediment would need to be added to the beach-dune system every three years for the 50-year life of the project. This is essentially an estimate of the amount of sediment that will be lost from the beaches and dunes. Some of these losses would occur as sediment is blown inland or washed out to sea. While losses to the longshore current will vary greatly from year to year, the simple average annual loss would be 1.54 million cubic yards. Estimates of the net amount of material carried in the longshore current at Oregon Inlet is 862,000 cubic yards moved to the south (USACOE 1999). The proposed project could more than double the amount of material carried to Oregon Inlet.

Dean (1999, p. 60-61) describes the movement of nourishment sand away from Hunting Island State Park, South Carolina. After a sand-pumping operation placed sand on the narrowing beaches of the park, the sand washed away and moved southward to the beaches of Fripp Island. In 1968 approximately 650,000 cubic yards of sand were placed on park beaches, but almost all this material was gone within 18 month (Dean 1999, p. 107-108). While this sand movement provided a brief respite for the beaches of Fripp Island, sand washed off any created beach may aggravate navigation through downdrift inlets.

Over the 50 years of the storm damage reduction project, the Corps would place approximately 88.7 million cubic yards of sand directly updrift from this navigation channel that is currently subject to "massive shoaling" that "creates an extremely hazardous zone for the passage of commercial and sport fishing craft" (USACOE 1999). Pilkey and Dixon (1996, p. 92) write that

"Based on comparisons before and after replenishment, the erosion rate of replenished beaches appears to be almost always greater than the natural beach's erosion rate. The assumption that pre- and post-replenishment erosion are the same is an important reason predictions of beach replenishment durability are optimistic more often than not." Down current drift of sediment may accelerate the filling of navigation channels in down current areas, which would increase the frequency of dredging required to maintain the channel (NRC 1995, p. 113). Sand placed on the beaches of Kitty Hawk, Kill Devil Hills, and Nags Head will be carried south to Oregon Inlet. Therefore, a potentially significant indirect impact of the preferred alternative is blockage of Oregon Inlet navigation channel.

Pilkey and Dixon (1996, p. 78) write that beach "replenishment frequently leads to more development in greater density within shorefront communities that are then left with a future of further replenishment or more drastic stabilization measures." Dean (1999, p. 106) also notes that the very existence of a beach nourishment project can encourage more development in coastal areas. In fact, the artificial dunes constructed in the 1930s are primarily responsible for the present state of development. Following completion of a beach nourishment project in Miami during 1982, investment in new and updated facilities substantially increased tourism there (NRC 1995, p. 31). Increased building density immediately adjacent to the beach often resulted as older buildings were replaced by much larger ones that accommodated more beach users. Such development is in itself an incentive to maintain the beach in order to sustain revenues derived from recreational activities and tourism and to protect the investment from erosion and storm damage or loss. Overall, shoreline management creates an upward spiral of initial protective measures resulting in more expensive development which leads to the need for more and larger protective measures.

However, the security offered by an artificial beach-dune system on a barrier island surrounded by a rising sea can only be temporary. Burgess (1994. p. 21) states that "Some contend that these blankets of shuttled sand are giving coastal residents a false sense of security and discouraging responsible building." Leatherman (1988, p. 90) also writes that:

> "Although man-made dunes can halt barrier migration in the short-term, barrier dunes will eventually be breached by overwashes and inlets during severe storms along an eroding shoreline. Dunes, therefore, have no long-term adverse effects on barrier island dynamics. Stabilized dunes have, however, encouraged development in highly hazardous areas by offering **a false sense of security** [emphasis added] to backbarrier environment."

Kaufman and Pilkey (1983, p. 213-214) indicate that:

> Dr.. Robert Dolan . . . finds [on the Outer Banks] that the dunes have acted much like a seawall. Because they are too high to permit overtopping and too continuous to allow inlets and breakthroughs, except under extreme conditions, the ocean's energy has been concentrated on the beaches . . . The beaches have

> narrowed and the offshore profile is growing steeper, creating stronger waves. . . . Waves strike this steep face with greater impact than a gentle slope, and storm erosion is fast and spectacular. **The protection the dunes first offered seems to have lasted just long enough to attract enough development behind them for a major disaster.**" [emphasis added]

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. Overpumping 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.

Additional development and population growth would also stress existing facilities for wastewater disposal. If adequate efforts are not made in a timely manner, ground water and estuarine water bodies may become contaminated. Such contamination would be harmful to a variety of fish and wildlife resources.

Increased development on the Outer Banks may have eliminated waterfowl habitat in the area. Cole and Turner (1992) note that waterfowl harvests from Cape Hatteras hunts declined in the preceding decade, but there was no similar decline for the Atlantic Flyway as a whole. They postulate that this difference might be explained by the

> ". . . decreasing amount of habitat available along the east coast in general, and adjacent to Cape Hatteras in particular. As additional wetlands are degraded or lost on and in the vicinity of Cape Hatteras, fewer number of birds may be available for harvest at Cape Hatteras. Habitat loss elsewhere in the Atlantic Flyway , though significant, is not likely as severe as in those resort areas immediately adjacent to the Atlantic Ocean, such as Nags Head and the Cape Hatteras National Seashore."

Impacts on Sea Turtles

Changes in the physical environment - Creation of an artificial beach-dune system may result in changes in sand density (compaction), beach shear resistance (hardness), beach moisture content, beach slope, sand color, sand grain size, sand grain shape, and sand grain mineral content if the placed sand is dissimilar from the original beach sand (Nelson and Dickerson 1988a). These changes could result in adverse impacts on nest site selection, digging behavior, clutch viability, and emergence by hatchlings (Nelson 1987, Nelson and Dickerson 1987).

Beach compaction and unnatural beach profiles that may result from beach nourishment activities could negatively impact sea turtles regardless of the timing of projects. Very fine sand and/or the use of heavy machinery can cause sand compaction on nourished beaches (Nelson et al. 1987, Nelson and Dickerson 1988a). Significant reductions in nesting success (i.e., false crawls occurred more frequently) have been documented on severely compacted nourished beaches (Fletemeyer 1980, Raymond 1984, Nelson and Dickerson 1987, Nelson et al. 1987), and increased false crawls may result in increased physiological stress to nesting females . Sand compaction may increase the length of time required for female sea turtles to excavate nests and also cause increased physiological stress to the animals (Nelson and Dickerson 1988c). Nelson and Dickerson (1988b) concluded that, in general, beaches nourished from offshore borrow sites are harder than natural beaches, and while some may soften over time through erosion and accretion of sand, others may remain hard for 10 years or more.

These impacts can be minimized by using suitable sand and by tilling the beach after nourishment if the sand becomes compacted. The level of compaction of a beach can be assessed by measuring sand compaction using a cone penetrometer (Nelson 1987). Tilling of a nourished beach may reduce the sand compaction to levels comparable to unnourished beaches. However, a pilot study by Nelson and Dickerson (1988c) showed that a tilled nourished beach will remain uncompacted for up to 1 year. Therefore, the Service requires multi-year beach compaction monitoring and, if necessary, tilling to ensure that project impacts on sea turtles are minimized. A root rake with tines at least 42 inches long and less than 36 inches apart pulled through the sand is recommended for compacted beaches. Service policy calls for beaches to be tilled if compaction levels exceed 500 pounds per square inch (psi).

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

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

Impacts on Piping Plovers

Factors contributing to the decline of the piping plover are: (1) habitat loss and degradation due to development and shoreline stabilization; (2) disturbance by humans and pets; and, (3) predation (USFWS 1996, p. 33). Much of the plover's historic habitat along the Atlantic Coast has already been destroyed or permanently degraded by development and human use. The construction of houses and commercial buildings on and adjacent to barrier beaches directly removes plover habitat and results in increased human disturbance. While legal restrictions on coastal development may slow the future pace of physical habitat destruction, the trend in habitat availability for this species is inexorably downward. The decrease in habitat availability, especially with regard to the dynamic nature of these coastal areas, may force birds to nest in suboptimal habitats which could be detrimental to future reproductive efforts.

A more subtle, but equally ominous, threat to the plover is the decrease in the functional suitability of the plover's habitat due to accelerating recreational activity on the Atlantic Coast. Functional habitat loss occurs when suitable nesting sites are made unusable because high human and/or animal use precludes the birds from successfully nesting. Population growth along both the United States and Canadian coasts fosters an ever increasing demand for beach recreation. In 1993 only 32% of the U. S. Atlantic Coast population of piping plovers nested on federally owned beaches where at least some protection can be afforded under the ESA. The remaining 68% nested on state, town, or privately-owned beaches where they face increasing disturbance from humans, domestic animals, and development.

Barrier island beaches preferred by piping plovers are dynamic, storm-maintained ecosystems. Natural coastal processes, such as overwash fans and accreting spits, are important for creating piping plover habitat. The construction and maintenance of artificial dune systems along with efforts to prevent the closure of barrier island inlets appear to lead to a reduction in piping plover nesting habitat. Dune maintenance conducted to protect an access road on Island Beach State Park in New Jersey may be one of several factors contributing to very low density of piping plovers (USFWS 1996, p. 35). On Cape Lookout National Seashore, a roadless area, piping plovers have nested at several closed inlets, a habitat type that is not present on Hatteras Island which is traversed by a state highway protected by an artificial dune system (USFWS 1996, p. 35).

<u>Ramifications of the Preferred Alternative</u>

While it is comforting to view the preferred alternative in the relatively short term of only a few decades, many very disturbing problems arise when the time frame is expanded outward to 50, 100, or more years. Pilkey et al. (1998, p. 107) summarized the ultimate paradox of using artificial beach-dune systems in order to protect structures by noting that "You can have buildings or you can have beaches; in the long run you cannot have both." This is the fundamental issue: barrier islands are areas of shifting sand which must move in the face of a rising sea in order to continue their existence. Efforts to fix the location of the islands will ultimately lead to their destruction, or at the least the destruction of the natural characteristics upon which important fish and wildlife resources depend.

There should be a fundamental difference in the perspective toward beach stabilization on barrier islands and beaches directly tied to the mainland. Mainland beaches may be renourished for decades without posing a threat to long-term viability of inland ecosystems. In contrast, on barrier islands a commitment to protect structures in their current location will keep the island from transgressing landward. The line of dunes will prevent cross island overwashes. By preventing overwash, the frontal dunes on the island's ocean side precludes new marsh growth and increases the soundside erosion rate (Pilkey et al. 1980, p. 29). Eventually erosion of sound side marshes will also become a threat to structures and addition efforts will be required to protect development from the sound. The combined effects of a rising sea and protective structures will eliminate the estuarine marshes that are such a valuable nursery habitat for fish.

Aside from the impacts considered above, the initiation of a program to create and maintain an artificial beach-dune system has serious ramifications for the entire barrier island ecosystem. First, this program represents a commitment to protect structures in their present location despite a rising sea level that would, under natural conditions, force the island to move landward. Second, this commitment will be extremely difficult to reverse. Pilkey et al. (1998, p. 107) note that once shoreline engineering is started, it can't be stopped. Third, maintaining structures in their present location will become increasingly expensive. Current plans for renourishment at three year intervals may shrink to a two year cycle and after several decades annual sediment placement could be required. However, renourishment at any interval depends on an economical source of sand and at some point the cost of moving sand will become prohibitive. At this point, the value of the structures behind the artificial beach-dune system will have increased many times over. Where a phased-in program of relocation and retreat from the beaches would cause serious social and economic hardships in the late 1990s, by the middle of the next century such a program could be out of the question and seawalls may be the only politically acceptable solution to preserve development. Seawalls, on both the beaches and sound side marshes, would eventually eliminate existing habitat values at the margins of the barrier island.

SECTION 11. COMPARISON OF ALTERNATIVES

Section 7 discussed the range of alternatives that can contribute to reducing the damage caused by coastal storms. In general these options may be divided in two broad categories. First, artificial barriers may be thrown up in an attempt to keep out the ocean. These options do nothing to prevent wind damage and unless they are extremely high and very water tight do little to prevent flooding and storm surge damage in major storms. Second, there can be a combination of land use polices and construction standards which attempt to move buildings out of harm's way and fortify them when, not if, high wind, waves, and wave reach them. These options apply to storm damage reduction and not directly to problems associated with shoreline recession which are not within the scope of the stated objective for this project.

From these options the Corps has proposed the creation of an artificial beach-dune system and the impacts associated with that option have been considered in Section 10 that divides project impacts into direct and indirect categories. Table 13 presents a comparison of the environmental impacts associated with the two broad options for storm damage reduction. The table shows that the creation of the artificial beach-dune system is much more harmful to the environment than a combined program of higher construction standards and land use planning. In fact, the latter produces none of the adverse impacts associated with the former.

Table 14 compares the indirect impacts of the two options. In this comparison it is assumed that both options will allow development to continue. Therefore, the indirect impacts associated with future development would be the same for both options. However, nine of the 11 impacts discussed would only occur with the creation of an artificial beach-dune system. One impact of special interest to the Service is the exacerbation of navigation problems at Oregon Inlet. The predominant north-to-south longshore current may carried sediment placed on the beach into the navigation channel. If dredging were increased, the channel could become impassible for commercial fishing vessels. Such a situation would lead to calls for construction of a dual jetty system, a project which the Service opposes.

The Service acknowledges that these yes-no dichotomies simplify very complex impacts and do not address the efficacy of the two approaches. However, these assessments do not fully consider the very long-term problems that can occur with a perpetual commitment of maintaining an artificial beach-dune system, such as exhausting the supply of sand near the project area and the ever rising cost of each sand placement. Despite any over simplification and omissions, these tables indicate that the artificial beach-dune system would produce greater adverse impacts on the natural resources of the project area.

Table 13. Comparison of direct project impacts for the Dare County Storm Damage Reduction Project, Dare 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	Creation of Artificial Beach-Dune System	Combination of Building Restrictions, Zoning, Selective Removal, 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 14. Comparison of indirect project impacts for the Dare County Storm Damage Reduction Project, Dare County, North Carolina, among the preferred alternative (an artificial beach-dune system) and a combination of building restrictions, zoning regulations, selective removal of structures, and improved construction standards.

	Major options for storm damage reduction	
Indirect Impact	Creation of Artificial Beach-Dune System	Combination of Building Restrictions, Zoning, Selective Removal, Improved Construction Standards
Alter bottom characteristics that influence flora and fauna	yes	no
Reduce offshore primary productivity by increasing depth	yes	no
Produce long-term turbidity and sedimentation from the beach	yes	no
Reduce invertebrate populations on beach	yes	no
Create greater demand for more shoreline erosion control by increasing wave energy striking the beach	yes	no
Create greater demand for more shoreline erosion control by altering wave patterns that may influence erosion	yes	no
Create greater demand for more shoreline erosion control by producing a steeper beach profile that influences erosion	yes	no
Create navigation problems at Oregon Inlet	yes	no
Increase development that threatens upland, estuarine habitats, and water quality	yes	yes
Create long-term reduction in sea turtles reproduction	yes	no
Create long-term decline in habitat quality for piping plovers	yes	yes

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.

SECTION 12. 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.

The stated purpose of this project is the reduction of storm damage. The Service supports this goal. However, the 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.

In seeking to reduce storm damage, it is only logical to require buildings to be separated from destructive forces. However, complications arise when the distance between structures and destructive forces does not remain the same from year to year and actually decreases over time. When the landscape can shift significantly in a matter of days, the risk of destruction for a given building may change from low to high very quickly. With regard to the ocean shoreline approaching buildings that were once far from the sea, there are basically two choices (Table 12). There can be a comprehensive program of selective removal, improved construction standards, tighter zoning regulations, and retrofitting existing structures. On the other hand, an artificial

barrier may be constructed between the structures and the sea, an effort to leave the structures in place and hold back the ocean. The former alternative provides a pattern for the long-term accommodation of limited development on barrier islands and the latter sets the stage for expensive, repetitive efforts that are most likely to fail over the long term.

The Service believes the creation of an artificial beach-dune system on a thin barrier island or barrier spit poses concerns that are fundamentally different from the same procedure directly on the mainland. On the mainland, sand can be added for decades in the face of a rising sea level without significant harm to adjacent uplands. However, a barrier island, or even a barrier spit in the present case, is surrounded by water which is currently rising and may rise at an increased rate in the future. Even a water tight barrier on only one side of an island is a futile gesture; the water will come in from all the unprotected sides. Furthermore, engineered structures which hinder the natural, landward transgression of barrier islands in the face of a rising sea set the stage for the eventual destruction of the islands. In the distant future, development must either accommodate the movement of the islands or permanent development will survive on isolated slivers of sand completely ringed by dikes dozens of feet high; there would be no beaches or estuarine marshes as we know them now. The latter scenario would be devastating to the fish and wildlife resources that depend on habitats associated with natural barrier islands.

The Service believes that conservation measures associated with any storm damage reduction endeavors on the Outer Banks fall into three categories. First, the NEPA planning process must be employed to clearly define the project purpose and develop the widest range of alternatives. Second, specific measures to minimize adverse direct impacts of the preferred alternative must be developed. Finally, measures to eliminate or reduce the serious, long-term indirect impacts of the preferred alternative must be considered. The Service position on these three aspects is given below.

<u>**Conservation Measures Related to NEPA and Selection of a Preferred Alternative**</u>

The Corps has presented a preferred alternative, the creation of an artificial beach-dune system. The only alternatives mentioned to date have been the "no action" course and modifications to the design and construction of the proposed system. In light of the serious long-term consequences of creating and maintaining an artificial beach-dune system, compliance with the NEPA planning process is important. The initial stage of the NEPA process is the purpose and need statement. These two aspects of a project are often viewed as inseparable, but in fact they are distinct aspects of the planning process. In this case, the need is clear and undisputed. The Outer Banks are extremely vulnerable to both tropical hurricanes and northeasters. There is a need to reduce storm damage.

The project purpose arises from the stated need, and establishes the extent to which the project hopes to satisfy this need. It is impossible to eliminate all damage from coastal storms on the Outer Banks. Therefore, certain parameters must be developed that set clear boundaries on what the project can and cannot be expected to accomplish. The Service sees three important factors in defining the project purpose. First, the level, or category, of storm for which the project is intended to provide protection must be defined. There is enough general data on hurricanes and northeasters to define the level of storm, based on storm surge characteristics, to provide this criterion. The range of options would vary considerably between protecting against hurricanes in categories one and two as opposed to a category five hurricane such as Camille (1969) which was more powerful than Hugo (1989) or Andrew (1992). Second, the actual type of storm damage to be reduced should be specified. Third, the area to be protected should be defined based on the first two criteria discussed. These three factors form the purpose of the project.

Development of Alternatives

The key issue from a NEPA standpoint will be the extent to which various alternatives are developed and evaluated. Based on the project purpose, the widest possible range of alternatives must be developed. In this regard the Corps should not be limited to measures for which it has jurisdiction. It is within the scope of the NEPA planning process to determine that the best alternative is a measure or series of measures that must be undertaken by others.

The development of alternatives should not be overly influenced by economic or political considerations at this stage of planning. The factors of cost and the desires of the local community may come into play during the evaluation of alternatives, but not in the creation of alternatives. For example, the project purpose may be defined as the protection of structures in the ocean erodible zone (area) from ocean storm waves (type of damage) of hurricanes up to category 3 (level of storm). In this instance, a possible alternative would be to remove all structures in this precise area that were susceptible to ocean storm wave damage from the specified hurricanes. Not all structures in the specified area would need to be removed. Structures elevated well above the expected level of storm waves associated with a category 3 hurricane would require no action. Other houses below the expected level of wave attack could be retrofitted to withstand the attack of the specified storm category. The relocation of threatened, beachfront structures in conjunction with improved building standards must be considered a viable alternative for damage reduction from hurricanes below the major categories, 4 and 5, in which case no form of human intervention, either artificial beaches or strict building codes, would probably be of much benefit.

Evaluation of Alternatives and Selection of Preferred Alternative

After alternatives are developed, the Corps should explain the evaluation of each alternative and the process leading to the selection of a preferred alternative. The selection of the preferred alternative should be based on an overall consideration of cost, social impacts, and environmental impacts. While the first two categories are more measurable, they should not be allowed to completely override environmental concerns.

At this stage, the planning process should consider the durability of each alternative. For example, the Corps should consider that maintaining an artificial beach may not work in areas of high natural erosion. In this regard, the Corps should examine the combined effects of sea level rise and natural shoreline recession at 30, 40, and 50 years of project life. Such an examination may show that maintenance of the artificial beach-dune system may become untenable due to costs or dwindling sand supplies over many decades.

With a clearly defined purpose, the costs and social disruptions of alternatives to the artificial beach-dune system may be quite low. The alternatives evaluation should always remain focused on the specific project purpose, i.e, the area, the type of damage, and the level of storm. It would be clearly inappropriate to imply that the artificial beach-dune system would significantly reduce all forms of storm damage in all categories of storms. A tightly focused evaluation may show that the proposed artificial beach-dune system provides protection for such low intensity storms that only a relatively few structures directly on the shoreline would be protected while other structures, conforming to established set backs and building codes would not benefit from the new beach-dune system.

The stated goal of storm damage may have a greater chance of success if smaller scale sediment placements were coupled with improved zoning and construction standards (NRC 1995, p. 31). For example, if the project purpose is to protect structures in the ocean erodible area from storm waves of hurricanes in categories 1-3, then a combination of selective structure removal, retrofitting existing structures, increased standards for new structures, and repairing of the 1930s dune line could prove to be the best combination of cost and environmental protection.

<u>Conservation Measures for the Direct Impacts of the Artificial Beach-Dune System</u>

If the NEPA planning process should lead to the selection of the artificial beach-dune system that the Corps has already indicated to be the preferred alternative, there should be plans to minimize the direct impacts of the project. Table 13 lists ten direct impacts of creating the artificial beach-dune system with sediment taken from offshore borrow areas. The first impact, elimination of the offshore benthic community, can be minimized, but this community will be lost in the areas in the areas used for borrow material. The other nine impacts can be mitigated by measures that fall into two broad categories. These are ensuring that the offshore sand is very compatible with existing beach sand and selecting the work season. For some direct impacts, such as disrupting offshore fish, conservation measures may involve both sediment compatibility and seasonal work schedule.

Measures for the Offshore Benthic Community

No studies concerning the effects of dredging sand from borrow sites off the North Carolina coast have been conducted. Therefore, impacts associated with offshore sand mining are unknown, and mitigation requirements are difficult to predict. Hurme and Pullen (1988) recommend pre-project, baseline surveys in all potential borrow sites. Offshore monitoring is needed in order to determine the effects offshore sand mining has on marine communities in and adjacent to borrow areas and the shoreline. Special attention should be given to identifying hardbottoms and to monitoring the effects on hardbottom habitats which may be near proposed borrow areas. Stender et al. (1991) and Maier et al. (1991) used side scan sonar and underwater television cameras to identify live bottom sites near potential offshore sand borrow sites in South Carolina. The purpose of these surveys would be to avoid important benthic resources such as clam beds or active spawning areas.

Measures Related to Sand Compatibility

Four of the ten direct impacts given in Table 13 relate to the issue of sediment compatibility. These impacts are offshore turbidity and sedimentation (caused by dredging) along with nearshore turbidity and sedimentation (caused by beach disposal). The Corps should ensure that all material placed on the beach is compatible with natural beach material. The dredging of material with a high percentage of silt and clay would produce increased turbidity and sedimentation (NRC 1995, p. 108).

The best conservation measure for reducing turbidity and subsequent sedimentation is to avoid using any material with silt and clay particles. At the very least, the project should not dredge material that consists of more than ten percent silt and clay (particle diameter > 0.05 mm).

However, even among particles that are technically sand size, there is a natural range from very fine sand to very coarse sand. According to Brady (1990, p. 92) the U. S. Department of Agriculture recognizes five grades of sand based on particle diameter: very fine (particle diameter 0.05 to 0.10 mm), fine (0.10 to 0.25 mm), medium (0.25 to 0.5 mm), coarse (0.5 to 1.0 mm), and very coarse (1.0 to 2.0 mm). Many of the most significant adverse environmental impacts would be minimized by avoiding the use of the two lowest grades, very fine and fine sand. The use of sediment with particle diameters greater than 0.25 mm would also prolong the life of the deposited sand and thereby increase the time between subsequent dredging and placement operations.

Measures Related to the Annual Work Schedule

Four of the ten direct impacts given in Table 13 are best addressed by determining an annual work schedule. These impacts are: (1) mortality of beach invertebrates; (2) reduced sea turtle nesting success; (3) disturbance of shorebirds; and, (4) disturbance of offshore marine mammals. An overview of the seasonal occurrence, or specific period of vulnerability, of major species or groups of species is given in Table 15.

Table 15 indicates that there is no single month, or even a single season, when all adverse impacts to important fish and wildlife resources could be avoided. As might be expected, overall biological activity for these resources is less during the colder months. From a strictly biological point of view, the least harmful six-month period would be the months of October through March. However, this period coincides with rough seas in the ocean off the project area and the need to frequently mobilize and demobilize dredging equipment adds to the project cost.

Table 15. Fish and wildlife seasonal considerations in establishing the schedule for offshore dredging and sediment placement in the Dare County (North Carolina) Storm Damage. Reduction Project. Shaded months represent periods when dredging and/or beach placement could be harmful.

Resource of Concern	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Offshore Fish												
Spawning	■ (partial)	■	■	■	■	■						
Striped bass	■	■	■								■	■
Sea Turtle												
Nesting					■	■	■	■	■	■	■ (partial)	
In the Water	■	■	■	■	■	■	■	■	■	■	■	■
Piping Plover												
Nesting			■	■	■	■	■	■				
Migrating			■ (partial)	■ (partial)				■	■	■ (partial)		
Marine Mammals												
Baleen whales	■	■	■									
Dolphin				■	■	■	■	■	■	■	■	
Beach Invertebrates												
Emerita spp.					■	■	■	■	■			
Donax spp.				■	■	■	■	■	■	■	■	
Digger amphipods	■	■	■	■	■	■	■	■	■	■	■	■
Recruitment period					■	■	■	■	■			

It is very difficult to assign relative importance to the various fish and wildlife resources in the project area. The value of undisturbed wintering habitat for offshore striped bass is difficult to weigh against the value of an undisturbed summer beach for sea turtles and beach invertebrates. However, strictly based on a consideration of area utilized by the various resources of concern, there is more offshore fisheries habitat than beach. While overwintering fish may be able to move several miles away from the dredging vessel, the thin strip of beach used by sea turtles, mole crabs, and coquina clams is very limited. Therefore, from a conservation point of view the least damaging time for dredging and beach disposal is the colder months of the year.

Throughout the 50-year project life, work schedules must be addressed for both initial construction and sediment replacement operations. Current plans indicate that 14.66 million cubic yards would be involved in initial construction and each replacement operation would move 4.63 million cubic yards. The Service realizes that the rough seas during the winter months can limit actual work time. In fact, production during the winter may only equal 25% of that which can be accomplished during the summer. However, winter dredging offers clear advantages to the fish and wildlife resources. Therefore, the Service proposes that initial construction be accomplished by using at least two dredging vessels that commence work on or after October 1. These vessels would work as weather allows through the winter and attempt to finish initial construction by March 31. If some work remained after March 31, these vessels would continue work into the spring until work was completed.

Sediment replacement operations should follow a similar pattern, but with a reduced work period. Replacement operations should be limited to the period from November 1 through the end of February. The use of one or two vessels would depend on the volume of material to be moved. Since bad weather could limit winter production, the dredge vessel(s) could continue until the end of March. If a single vessel is used, the Corps should be able to forecast a production rate by the end of December. If it is apparent by the end of December that a single vessel may not be able to complete sediment movements by the end of February, a second dredge should be added in order to ensure completion of the sediment replacement operation by the end of March at the latest.

Measures for Direct Impacts to Specific Fish and Wildlife Resources

Appendix B by Laney et al. notes that the most effective strategy for avoiding impacts to fish, and fisheries, in and near the proposed borrow sites is not to construct the project. They also state that fisheries resources would be protected by relocating structures jeopardized by the retreating beachfront, rather than providing artificial protection against natural processes. Finally, they state that a third option is to seek alternative sources of material for constructing the proposed project other than offshore deposits which lie within significant wintering grounds for major stocks of highly important ecological, commercial and recreational fishery resources. This could include upland sites, as well as alternative ocean or estuary sites, if they can be located, where resource values may be less and where Esseantial Habitat (EH) or Essential Fish Habitat (EFH) has not been designated.

Direct impacts to nearshore and offshore fisheries would be minimized by ensuring strict compatibility of dredged sediment with existing beach sand and working during a period of low biological activity. The nearshore and offshore areas are important spawning, feeding, and migratory areas for a variety of species. It is possible that some marine areas will be designated as "essential fish habitat." The Corps should consider the possibility of such a designation and develop a policy regarding dredging in areas of essential fish habitat. The outline of this policy should be included in the project EIS.

If sediment placement extends into the sea turtle nesting season, May 1 through November 15, the Corps must ensure that a program of nest monitoring and relocation is initiated with adequate funding. Such programs are a routine part of sediment placement on nesting beaches. However, if there is any chance that beach sediment placement may occur during the sea turtle nesting season, Section 7 of the Endangered Species Act requires that the Corps prepare a Biological Assessment and initiate formal consultation with the Service.

As a specific measure to benefit sea turtles in the project area, the Corps should recommend to all local governments that individuals working on state-sanctioned sea turtle conservation projects be exempted from local regulations which hinder their work. For example, the state's effort to record sea turtle nests on the beach could be facilitated by allowing volunteer monitors to use motorized vehicles on the beach during their monitoring work. If such access is prohibited by local laws, exceptions should be granted for sea turtle patrols. A request for a particular exemptions should be made in writing from a state employee of the NCWRC and not from individual volunteers.

While marine mammals are highly mobile and range over wide areas, there must be measures to ensure that whales and porpoises are not directly harmed by the dredging and transport of sediment. Such measures may include observers on the dredging vessels. The Corps should initiate informal consultation with the NMFS which has jurisdiction under the Endangered Species Act for marine mammals. If early consultation determines that the project may adversely affect any protected species, the Corps must initiate formal consultation with the NMFS.

Conservation of beach invertebrates is directly linked to the annual scheduling of work. If species such as the beach digger, mole crab, and coquina clam are on the beach during sediment placement, these individuals will be killed. While some invertebrates remain on the beach the entire year, others such as the mole crab and coquina clam move off the beaches during the colder months. The Corps should develop a monitoring program to quantify the impact of the project on beach invertebrates; ranging from the nearshore subtidal zone, through the intertidal zone and subaerial beach, to the toe of the dune.

Conservation Measures for the Indirect Impacts of the Artificial Beach-Dune System

Measures Related to Bottom Characteristics that Influence Flora and Fauna

Certain construction techniques can minimize long-term harm to offshore organisms. The ability of a benthic community to repopulate a borrow area is influenced by the size and configuration of the borrow area, its exposure to waves and currents, the similarity of sediment surrounding the area, the new sediment-water interface, and possible changes in water quality (Hurme and Pullen 1988). Shallow dredging over an extensive area may cause less environmental harm than deep pit dredging (Thompson 1973 as cited in Hurme and Pullen 1988). Shallow dredging may minimize the possibility of deep holes filling with finer grain sand and thereby changing the nature of the bottom substrate.

Offshore shoals and underwater ridges are desirable habitats for many species of fish, and Hurme and Pullen (1988) write that " . . . little is known about the potential effects of modifying the general offshore bathymetry on fisheries." These authors suggest that long-term adverse impacts can be minimized by:

1. Leaving a sufficient layer of sediment that matches as closely as possible the original surface layer to avoid exposing a dissimilar sediment unless exposing a new substratum is desired; and,

2. Taking borrow material from broad, shallow pits in deeper water with an actively shifting bottom.

In order to fully assess the impacts to offshore borrow areas, the Corps should sponsor a long-term monitoring program to evaluate the recolonization of these borrow areas. Such a program was recommended by the NMFS in a scoping letter on the project dated July 15, 1997. It may be possible to do a comparison of wide, shallow dredging and localized deep dredging in the early years of the project. If statistically valid data indicates that there have been no long-term adverse impacts from localized deep dredging, then that method could be adopted for the remainder of the 50-year life of the project.

The Corps should also undertake a program to ensure that hardbottom areas are not impacted by sedimentation. SEAMAP data (Appendix B, Map 12) indicate that hardbottoms may exist in or near the proposed borrow areas. Fine sediment in the dredged material can be carried over considerable distances and blanket these areas. In order to monitor impacts on hardbottoms the Corps should fund a program to measure sedimentation and biological productivity in selected hardbottoms in all areas surrounding the borrow areas. This program could select the nearest hardbottom in each octant (one-eighth of a circle or an arc of 45°) around both the northern and southern borrow areas. The limit of the area should not be restricted to only those area considered "near" the borrow site, but should extend out to at least 25-30 miles. The area of exposed hard substrate would be compared from year to year and some measure of biological productivity made. After initial construction, the annual changes in exposed substrate and productivity between years with dredging and years of no dredging should provide evidence as to whether dredging, or even sediment coming off the beaches, is adversely affecting these important habitats.

Measures Related to Offshore Primary Productivity

Any reduction in offshore primary productivity may also be avoided by shallow dredging over wide areas to reduce a depth increase, i.e., sand should be taken off in thin layers rather than creating a series of deep holes. If the Corps finds it necessary to take sand form only limited areas, there should be an effort to assess the impact on primary productivity. Such a program could be based on procedures used in Onslow Bay off the southern coast of North Carolina (Cahoon et al. 1990; Cahoon 1992; and Cahoon and Cooke 1992).

Measures Related to Long-term Turbidity and Sedimentation from the Beach

While turbidity coming directly from the beach and the resulting sedimentation is generally considered to be a short-term phenomenon, the use of sediment with a high content of silt and clay as well as a high percentage of very fine and fine sand allows these problems to become chronic. This problem can only be minimized by ensuring that sediment with silt, clay, and fine sand are not placed on the beaches. The conservation measures mentioned above to reduce short-term problems would be applicable to this potential long-term environmental impact.

Measures Related to Invertebrate Populations on the Beach

The direct impacts of placing large quantities of sediment on beach invertebrates was discussed earlier in this section. However, such placements can also have long-term adverse impacts if the populations are not given time to recover. Species which annually move offshore and then return to the beaches in the spring, e.g., mole crabs and coquina clams, are much more likely to recolonize a nourished beach at the first recruitment period after sand placement. Hackney et al. (1996, p. 109) conclude that accomplishing renourishment before larval recruitment will ensure rapid recovery of these species. However, more sedentary species, such as digger amphipods of the genus *Haustorius*, have much slower rates of recolonization. In the North Carolina beach nourishment study of Reilly and Bellis (1978, p. 67), the authors concluded that the life history and behavior of *H. canadensis* did "... not favor its return to the nourished area quickly." The point of these concerns is that shorter intervals between new sediment placements may reach the point where a given species never returns to the placement area.

The ability for invertebrates to return to the sediment placement area is also influenced by the length of the project. Since surviving populations on the edges of the placement area may supply the colonists for the placement area and dispersal may be limited, the shorter the placement area, the greater the opportunity for adjacent populations to reach the entire length of new beach. In this regard, a series of small projects spaced over several years may be more beneficial to beach invertebrates than a single large project which covers many miles of beach. Such a procedure would allow beach invertebrates to colonize the impacted zone from nearby, unaffected beaches.

A solution to the long-term impacts of beach sediment placement on beach infauna is difficult. From the timing perspective, longer intervals between beach placements is preferred. This would seem to favor larger projects at greater intervals. From a space perspective, shorter projects are favored, and this would seem to favor smaller projects that may require a shorter interval between placements. Overall, beach invertebrates would appear to benefit from smaller placements that a spaced several years apart. This could be accomplished by constructing a large project in a series of small stages. The key to this effort would be to avoid the temptation to move linearly down a given beach. If a given beach could be divided into nine sections, a sequence of work might involve placing sediment on section 1, 4, and 7 during year one. In year two, sections 2, 5, and 8 would receive sediment and the final sections, 3, 6, and 9 would be done during the third year. After three years the process could begin again with new placements on the first sections used. This process would space unaffected beaches between those receiving sediment.

The concept of nourishing a large beach in stages separated by shorter intervals rather large, intensive efforts at longer interval has been considered. Hackney et al. (1996, p. 109-110) state that this procedure would minimize impacts. Pilkey and Dixon (1996, p. 83) cite a 1972 study from Virginia Beach, Virginia, that determined that small, annual nourishments were superior to large nourishments spaced several years apart. This conclusion was due in part to the fact that larger volumes of sand disappeared more rapidly than smaller volumes. While such a scheme would produce more frequent sand placement, each placement would be smaller and allow for unimpacted sections between impacted sections. On balance such a procedure is likely to benefit the long-term viability of beach invertebrate populations.

Measures Related to the Frequency of Sand Dredging and Placement

As noted in Table 14, several indirect project impacts could lead to greater erosion in the project area. These impacts were associated with an altered offshore and nearshore bathymetry that can produce increased wave energy striking the beach, altered wave patterns, and a steeper beach profile that also allowed greater wave energy to strike the beach. These factors, either together or especially in combination, can increase the removal of the new sediment. The Service's concern about increased sediment removal stems from the fact that such removal would decrease the time between sediment additions. More frequent sediment additions increase all the direct impacts of dredging and sediment placement.

Hurme and Pullen (1988) state that "... any mining which would substantially change the form of the existing bathymetry should be undertaken with caution." As part of the recommended caution, several measures may minimize the risk of increasing the rate of loss for the new sediment. These measures are:

1. Sand should be dredged in thin layers over a wide area rather than creating deep holes;
2. Existing offshore sand shoals should not be removed;
3. Borrow areas should be seaward of the active shoreface of the beach; and,
4. The best source of sand may be on the Outer Continental Shelf

Pilkey et al. (1998, p. 97) write that it is generally best to take marine sand from a location as far from the beach as possible in order to reduce the impact of sea floor changes on wave patterns. The Corps should study the changes that would occur in the offshore bathymetry and present a conclusion about the effects of creating deeper water will have on wave energy reaching the beaches and the possibility for even greater rates of shoreline recession.

If cost becomes the overriding factor in determining the borrow areas and these borrow areas are within the active shoreface of the beach, it is likely that current predictions about the survival of the created beach and thus the time between required sediment additions are overly optimistic. If the conservation measures to minimize future erosion given above are deemed to be too costly, there is a possibility that increased erosion rates and the need to add sand more frequently may, over several decades, eliminate any cost savings made by selecting borrow areas close to the beach.

Measures Related to Navigation Through Oregon Inlet

The Service has always supported maintaining the Oregon Inlet navigation channel through dredging. However, a single severe storm season could wash thousands of cubic yards of new sand off the Dare County beaches southward to the Oregon Inlet navigation channel in a relatively short time. Without adequate planning and resources for additional dredging the channel would become blocked to commercial fishing vessels. There is no reason for not establishing specific procedures within the storm damage reduction project to avoid a crisis situation at this important passageway.

In order ensure that an artificial beach-dune system does not lead directly to closing the navigation channel, a legally binding Memorandum of Agreement (MOA) must be established between the Service, the National Park Service, the Corps, the Dare County Government, and the State of North Carolina. This MOA would formally recognize the potential threat that sediment placement on Dare County beaches presents to the navigation channel, specify that additional, annual funding will be secured for dredging the navigation channel prior to initiating the storm damage reduction project, include the additional funding as a cost of the storm damage reduction project, and clearly state that failure to keep the inlet open will automatically terminate the storm damage reduction project. The amount of the additional annual funding will be a percent of the current funding and will be determined by the parties to the MOA. If funding is not adequate and the navigation channel becomes blocked, it would be possible to divert funds from storm damage reduction project to the dredging effort at the inlet.

If the current dredging can keep the channel open, the plan would not need to be implemented. On the other hand, it would seem unwise to totally ignore this potential problem and allow a crisis to develop without a clear plan of action.

Measures Related to Increased Development

The creation of an artificial beach-dune system is likely to lead to greater development, the increased withdrawal of freshwater, and the generation of additional wastewater. These events would be the result of a greater sense of security which leads to the construction of more and larger tourist facilities. The new artificial beach would also serve to draw additional tourists to the project area. Dare County stated (1994, p. 18) that "Residential development will continue to proliferate with pressure for increased development density adjacent to the shorelines."

There are no conservation measures which can be associated with the current project to address these future impacts. While current LUPs stress the need for controlled development and the orderly provision of both adequate water and wastewater treatment, there are no guarantees that policies will not change in the future. The Town of Kitty Hawk has stated (1994, p. 37) that:

> "The Town supports the guidelines of the Coastal Area Management Act and the associated policies of the Coastal Resources Commission but reserves the right to review and oppose sections of the CAMA or its implementation that may be deemed contrary to the Town's land use policies and development preferences."

In addition to the habitat losses associated with future development, there is a concern for a spiraling cycle of increased development and ever greater efforts to protect increasingly valuable property. If the current project conveys the idea that a firm commitment has been made to halt beach recession, increased development will occur near the beach. As the artificial beach-dune system washes away, the value of structures at risk from storm damage will be much greater than today. Therefore, a future benefit-cost analysis will justify greater expenditures to create the next beach-dune system which will in turn generate additional development in the ever enlarging shadow of the constructed dune.

With a constantly rising sea level, the cost of the beach-dune system (which will slowly evolve toward an all encompassing dike) will simply become too expensive in spite of the value of the structures it protects. Simple economics will force a decision between extremely costly relocations or allowing costly destruction. This is the same decision that could be made today at a much lower overall cost. During the years that the decision is deferred, the quality and quantity of fish and wildlife habitat is likely to decline significantly.

At the present time, the issue of reducing storm damage can be addressed best through the NEPA planning process. For this reason the Service has stressed the need for a thorough development and analysis of alternatives to initiating the artificial beach-dune system.

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. Recommendations will be presented in the same three broad categories introduced in the preceding section, but a single number sequence will be followed for the entire section.

A clear presentation of the steps taken in the NEPA planning process is essential. In the first step, the statement of purpose and need, the need for storm damage reduction is clear. However, the purpose of this specific project requires greater attention. A clear statement of purpose would serve to disentangle the goals of storm damage reduction and restoration of a lost recreational beach. While these goals are often viewed as two sides of the same coin, the options for each goal are different. Table 12 indicates that the alternatives for beach replacement and storm damage reduction projects have, with some overlap, a different array of alternatives. For example, creating an artificial beach is the least environmentally damaging alternative for beach stabilization, but the most environmentally damaging alternative for storm damage reduction. To fully explain the NEPA planning process, the Service recommends the following measures:

1. The EIS should define the level of storm for which protection is sought; the type(s) of storm damage which would be reduced; and, those locations within the project area for which protection is desired.

2. The EIS should present the entire range of alternatives that achieve the desired storm damage reduction without regard for cost, social impacts, or the jurisdictional authority of the Corps. Two excellent references (Bush et al. 1996 and Pilkey et al. 1998) should be consulted.

3. Once all alternatives have been developed, the Corps should balance the desired level of storm damage reduction against social and environmental impacts in the selection of the preferred alternative. The EIS should discuss the factors that lead to the preferred alternative. Important questions that the EIS should answer regarding the artificial beach-dune alternative are:

    a. Would a series of smaller sediment placements, perhaps on an annual basis, be more cost efficient in achieving the desired level of storm damage reduction?

    b. Would the proposed artificial beach-dune system provide protection against such low intensity storms (e.g., hurricane categories 1 and 2) and to such a limited area of structures that a program of selective relocation, strict zoning/setback requirement, retrofitting existing buildings, and stricter building codes for new buildings is more cost efficient?

Current plans call for the construction of an artificial beach-dune system. This alternative would produce direct, adverse impacts on fish and wildlife resources. The Service offers the following recommendations to avoid, minimize, or mitigate these direct impacts:

4. The Corps should establish a program to monitor dredging impacts on primary productivity and benthic invertebrate community composition. The program should assess the biomass and species composition of organisms that recolonize borrow areas. The program should include pre-project baseline data and post-project data at one-, three-, five-, and ten-years after dredging. The program should use at least one area among the two northern and three southern borrow area groups. At three, five, and ten years after sediment removal, data collected should be compared with offshore fisheries data (e.g., species composition, diversity, food habits, landings, catch per unit effort, and other appropriate information) in order to produce an overall evaluation of dredging impacts on offshore fisheries. If these comprehensive evaluations indicate that fisheries resources have been adversely affected, the Corps should work with the Service and National Marine Fisheries Service to develop a mitigation program for the remaining decades of the project.

5. The Corps should ensure that no 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 borrow sites and the review of data provided by the Southeast Monitoring and Assessment Program (SEAMAP). If hardbottoms are adversely affected, the project should include specific measures to mitigate any adverse impacts.

6. In order to minimize both the direct and indirect impacts of turbidity and subsequent sedimentation, the Corps should ensure that: (1) the project does not use any sediment which consists of more than ten percent silt and clay particles; and, (2) the project should use only the three coarsest grades of sand (medium, coarse, and very coarse). These construction restrictions would not only reduce turbidity, but would also prolong the life of the artificial beach-dune system and thereby increase the time between beach-dune reconstruction. The project EIS should contain a Sand Suitability Analysis in accordance with procedures of the Corps' Coastal Engineering Research Center.

7. Since there is no single period of the year when work could be scheduled to avoid adverse impacts to all the fish and wildlife resources in the project area, the best way to minimize adverse impacts is to reduce the duration of construction. Reduced construction time can be achieved by the simultaneous use of more than one dredge. On balance, the most limited resources, e.g., an undisturbed beach, would benefit from dredging during the winter months. Therefore, the Service recommends that initial construction be

accomplished by using at least two dredging vessels that commence work on or after October 1. These vessels would work as weather allows through the winter and attempt to finish initial construction by March 31. If some work remained after March 31, these vessels would continue work into the spring until work was completed. Sediment replacement operations should follow a similar pattern, but with a reduced work period. Replacement operations should be limited to the period from November 1 through the end of February. Scheduling beach disposal outside the larval recruitment period of beach invertebrates will ensure better recovery of these species.

Beyond the broad measures given above, the Service recommends the following measures to benefit specific resources:

8. If sediment placement extends into the sea turtle nesting and hatching season, May 1 through November 15 of any year, the Corps must initiate formal consultation in accordance with Section 7 of the Endangered Species Act. Sediment placement during this period will require a program of sea turtle nest monitoring and relocation. Furthermore, the Corps should incorporate measures designed to help state-approved sea turtle monitoring programs into formal project plans.

9. The Corps should coordinate with the National Marine Fisheries Service to develop procedures to avoid adverse impacts to marine mammals that may occur in the area of the offshore borrow sites.

10. The project should include a monitoring program on beach and subtidal invertebrates that form an important food resource for shorebirds. 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 the CHNS just south of the project area. There should be an additional requirement to quantify changes in biomass and community composition at one-. three-, five-, and ten years after initial construction. 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.

11. The Magnuson-Stevens Fishery Conservation and Management Act and Sustainable Fisheries Act of 1996 (Public Law 104-297) requires that essential fish habitat (EFH) be identified. The Service believes that over the 50-year life of the project, some or all of both nearshore or offshore areas impacted by this project may be designated as EFH. The Corps must consult with the National Marine Fisheries Service regarding the impact of the proposed project on those species for which the proposed borrow sites and adjacent areas have been determined to constitute Essential Fish Habitat (see references, Appendix B, Table 1). Although the study area has not been formally designated as EFH for anadromous species, management councils are mandated to comment to the Corps regarding the impact of the proposed project on those species; therefore, the New

England, Mid-Atlantic and South Atlantic Fishery Management Councils, as well as the Atlantic States Marine Fisheries Commission, should be contacted and provided with an opportunity to review the Corps' draft environmental document for the proposed project.

The consultation process in the Southeast Region of the NMFS is addressed in NMFS (1999). As noted in the Introduction and Table 1 of Appendix B, the study area has been designated as EFH for species other than those addressed herein through the analysis of data from Cooperative Winter Tagging Cruises. NMFS (1999) contains a list of the species managed by the SAFMC and NMFS, their EFH, and the geographically defined Habitat Areas of Particular Concern (HAPC) identified in Council Fishery Management Plans. In North Carolina, the SAFMC identified the sandy shoals of Cape Hatteras, not too distant from the study area, as an HAPC.

Consultation requirements in the Magnuson-Stevens Fishery Conservation and Management Act direct federal agencies to consult with NMFS when any of their activities may have an adverse effect on EFH (NMFS 1999; see also NOAA 1999 for information on the NMFS northeast region). The EFH rules define an **adverse effect** as "any impact which reduces quality and/or quantity of EFH...[and] may include direct (e.g., contamination or physical disruption), indirect (e.g., loss of prey, reduction in species' fecundity), site-specific or habitat wide impacts, including individual, cumulative, or synergistic consequences of actions." Since the proposed project would result in the removal from the study area of an estimated 88.7 million cy of substrate during the course of the proposed 50-year project life, it would appear that it meets the criteria for constituting an adverse effect and that the Southeast Region of NMFS should be contacted by the Corps for that purpose.

The most significant environmental impacts of the proposed 50-year effort of sand relocation will be indirect. In this regard, it is necessary to look beyond the impacts of the initial construction and consider the many reconstruction operations that are currently scheduled at three year intervals, but over the decades are likely to become more frequent.

The loss of the offshore benthic community during dredging is a direct project impact. However, the more serious issue regarding this community is its ability to recover from dredging and continue to provide the primary production to support consumers at higher trophic levels in offshore waters. The avoidance of any significant increase in depth along with maintenance of the sediment characteristics of offshore bottoms would help maintain primary productivity. While the assessments in Recommendation 4 would seek to quantify impacts on the benthic community, the Service recommends the following measures to minimize the long-term impacts on all offshore benthic organisms:

12. Dredging should leave a sufficient layer of sediment that matches as closely as possible the original surface layer to avoid exposing a dissimilar sediment; and,

13. Borrow material should be removed in thin layers over a wide area rather than from localized areas that would create numerous deep pits that are likely to refill with much finer material and permanently alter the nature of the substrate.

Beach invertebrates would appear to benefit from series of small projects as opposed to a single large project which covers many miles of beach. Such a procedure would allow beach invertebrates to recolonize the impacted zone from nearby, unaffected beaches. Therefore, the Service recommends that:

14. The Corps consider dividing the entire target beach into nine sections and establishing a sequence of work for placing sediment of one-third of the sections each year. Year one would use sections 1, 4, and 7; year two would use sections 2, 5, and 8; and year three would use sections 3, 6, and 9. After three years the process would be repeated.

Fish and wildlife resources will benefit by prolonging the life of the artificial beach-dune system. Measures which prolong the life of the beach-dune system will minimize all the direct impacts discussed in Section 10 as well as minimize the cumulative impacts by allowing time for impacted population to recover. Therefore, the Service recommends that:

15. Borrow areas should be located seaward of the active shoreface of the beach and sand sources on the Outer Continental Shelf should be considered in order to avoid any significant changes in the bathymetry over which waves approach project area beaches.

16. Existing offshore sand shoals or sand bars should not be removed for use in creating the beach-dune system.

17. The project EIS should include an analysis of changes in wave patterns and wave energy striking the shoreline that would occur as a result of removing sand from offshore borrow pits. The analysis should present a determination on the impacts that changes in the offshore bathymetry would have on wave energy reaching the beaches and the possibility for even greater rates of sediment removal and shoreline recession. This analysis should specifically discuss wave energy impacts that would exist in the 50th year of the project when depths in some offshore areas may be increased by as much as 30 feet.

Based on present calculations, approximately 1.5 million cubic yards of sand would disappear from the project area beaches every year of the 50-year project. Some of this sand will be carried by the predominant north-to-south longshore current to Oregon Inlet where the Corps has had difficulty maintaining the authorized navigation channel. In order to ensure that this project does not exacerbate maintenance of the Oregon Inlet navigation channel, the Service recommends:

18. The EIS should fully discuss: (1) the potential rates of sediment losses from the beach fill based on grain size data (the Sand Suitability Analysis); (2) the likely pathways that may carry as much as 1.5 million cubic yards of sand per year for 50 years away from the

beach; and, (3) the likely locations that would ultimately receive the sediment carried away from the beach.

19. In light of the serious difficulties that the Corps has had in maintaining the important navigation channel at Oregon Inlet, the EIS should present a plan for dredging the additional sand that will be carried to the Oregon Inlet navigation channel. This plan should consider the feasibility of adding the additional dredging costs to the storm damage reduction project. In order to avoid delays in responding to any closure of the navigation channel, a Memorandum of Agreement (MOA) should be signed by the Corps, Service, NPS, and the Dare County government that clearly establishes the procedures to be used and the methods of funding for both increased maintenance and emergency dredging. An EIS without such a plan and a MOA to ensure its implementation would be inadequate.

The Service has serious concerns about the ability of an artificial beach-dune system to provide long-term protection for structures on a barrier island, or barrier spit, surrounded by a rising sea. The measures given in this section should help to avoid or minimize some of the adverse environmental impacts. While some measures may add to project costs, any additional costs should be weighed against the gains in environmental quality. Some of these gains, such as protecting offshore fisheries, would have a measurable economic benefit that should be considered in the alternative selection process. Other recommendations seek to extend the period between reconstruction and such measures would reduce overall costs. Therefore, the Service requests that these recommendations be incorporated into the NEPA planning process for storm damage reduction in Northern Dare County.

SECTION 14. SUMMARY OF FINDINGS AND SERVICE POSITION

The data and analysis presented in this report have led the Service to a number of findings and conclusions. These findings have been thoroughly considered in the development of our position on the proposed alternative for storm damage reduction in the project area.

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 full force of both tropical hurricanes and northeasters. Early residents recognized this fact of life and built their homes as far from the ocean as possible. The faith in modern technology, government sponsored insurance that the private sector finds too risky, and a recent absence of major storms have resulted in expensive development on an ocean shoreline that is retreating in the face of a rising sea. As the ocean moves closer to fixed structures the risk of storm damage increases. The Service recognizes the increasing risk of storm damage and supports the goal of reducing such damage.

The key question is not whether to seek storm damage reduction, but the best method to achieve this goal on a barrier island. The Corps, with the support of local interests, has proposed the creation of an artificial beach-dune system between the ocean and structures on the shoreline. Current planning documents do not fully explain the alternatives that were considered or the reasoning leading to the selection of this alternative. The Service finds that this decision requires greater support than has been made available to date.

Our desire for greater justification is based on three points. First, the creation of an artificial beach-dune system from sand dredged offshore is not the innocuous procedure that it may once have been considered. The material presented in Section 10 clearly indicates that some direct impacts may be serious, but they are usually short-lived and localized. The more serious impacts are the secondary, indirect impacts which may seem inconsequential on a year to year basis, but which accumulate over the years and decades without ever allowing the affected resources to return to pre-project levels. Within the 1990s new data have been presented on the serious impacts of these projects to natural beach communities, offshore communities, nesting sea turtles, and even commercially important fisheries. Unfortunately, these findings have usually been based on only a few years of study, and the longer-term, cumulative impacts have yet to be reported. The selection of a preferred alternative should be based on thorough evaluation of impacts over a period of at least 50 years.

Second, there is a fundamental difference in the long-term ramifications between constructing beaches and dunes on a mainland shoreline and the same construction on a barrier island. Sand may be added to a beach that is a part on the mainland without a threat to the long-term existence of the uplands behind the beach. However, a barrier island or spit is surrounded by the sea that is rising and may soon rise at an accelerating rate. Barrier islands must move landward in order to stay above the rising sea. An artificial barrier along only one side of an island cannot provide real long-term protection. Such a barrier signifies a commitment to hold back the sea and protect structures in their present location. In time, an artificial beach-dune system will prove inadequate as damaging seas sweep around the edges and come in from the sound. Sea level rise combined with the natural reaction of the barrier islands to move landward makes the long-term maintenance of structures in a fixed location impossible. If the original commitment remains unchanged, the barrier island eventually must be ringed by a continuous dike that will destroy both the beach and the estuarine wetlands on the sound margin. This is a basic concern of the Service.

Third, there are proven alternatives to constructing beaches and dunes for storm damage reduction that have not been adequately considered. As noted, constructed beaches are less harmful than hard structures for controlling shoreline recession. However, constructed beaches are the most environmentally damaging alternative for storm damage reduction. A combined program of selective removal and relocation of structures, strict zoning laws that fully consider the natural rate of shoreline recession, and improved building standards may actually be more economical and efficient over the long term. Current planning has not adequately considered alternatives to beach-dune construction. This appears to be the result of a poorly defined purpose for the project. The NEPA document should state the level of storm for which protect would be provided, the types of storm processes for which protection would be provided, and the area to be protected. With a clearly defined purpose the widest possible range of alternatives could be developed and evaluated.

The Service finds that current planning for storm damage reduction in northern Dare County has not presented evidence that all direct and indirect environmental impacts of constructing an artificial beach-dune system were fully considered in the selection of the beach-dune system. The construction and maintenance of such a system would have profound impacts on the barrier island ecosystem over the 50 years of official project life. The project EIS should demonstrate an understanding of these impacts in the selection of best means to reduce storm damage in the project area.

Position of the Service

Overall, the Service supports the goal of storm damage reduction. The Service also supports the planning process of the NEPA. However, at the current time the Corps has not clearly defined either the type of damage to be reduced or the area to be protected. Such definitions are necessary to fully develop and evaluate the widest possible range of alternatives. Furthermore, current planning has not adequately considered the unique nature and geological forces acting on a barrier island. These considerations are critical in fully describing the long range, secondary impacts of the project. In regard to a very serious, potential project impact, the Corps and the Service must work together to ensure that the placement of millions of cubic yards of sand on project area beaches is not allowed to close the Oregon Inlet navigation channel without a specific, adequately funded plan in place before the start of any sand placement.

While the Service has serious reservations about the long-term efficacy of an artificial beach-dune system to protect existing structures on a barrier island, the decision to postpone the day of reckoning ultimately lies with the citizens of the project area and their elected representatives. If the thorough evaluation of all social and environmental factors required by the NEPA planning process should confirm that an artificial beach-dune system is the best overall alternative, we believe that the incorporation of the Service's recommendations given in this report into the design and construction of the project will avoid or minimize many of the most serious adverse impacts on the fish and wildlife resources in the project area.

SECTION 15. LITERATURE CITED

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APPENDICES

APPENDIX A

Acronyms Used

CAMA	Coastal Areas Management Act
CHNS	Cape Hatteras National Seashore
EH	essential habitat
EFH	essential fish habitat
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FWCA	Fish and Wildlife Coordination Act
LUP	land use plan
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
NCCRC	North Carolina Coastal Resources Commission
NCDOT	North Carolina Department of Transportation
NCWRC	North Carolina Wildlife Resources Commission
NGVD	National Geodetic Vertical Datum, approximately = mean sea level
NOI	Notice of Intent
NMFS	National Marine Fisheries Service (U. S. Dept. of Commerce)
NPS	National Park Service (U. S. Dept. of the Interior)
NRC	National Research Council
NTU	nephelometric turbidity units
PAR	planning aid report

PINWR	Pea Island National Wildlife Refuge
SAV	submerged aquatic vegetation
SEAMAP	Southeast Monitoring and Assessment Program
USACOE	U. S. Army Corps of Engineers
USFWS	U. S. Fish and Wildlife Service (U. S. Department of the Interior)
USMMS	U. S. Mineral Management Service

APPENDIX B

Draft Report

Impact Assessment of Proposed Corps of Engineers Dredging Associated with the Dare County Beaches Project Upon Fisheries Resources

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Collection of the data upon which this assessment is based would have been impossible without the expertise and assistance of the numerous staff personnel of the cooperating agencies as well as the officers and crew of the National Oceanic and Atmospheric Administration (NOAA) research vessels used as sampling platforms. The authors express their most grateful appreciation to all those staff of the following agencies which have participated in the Southeast Monitoring and Assessment Program (SEAMAP) Cooperative Winter Tagging Cruises: Atlantic States Marine Fisheries Commission (ASMFC), Interjurisdictional Fisheries Management and Research and Statistics Programs; Canada Ministry of Hunting and Fishing; East Carolina University (NC); Maryland Department of Natural Resources, Fisheries Service; Massachusetts Department of Natural Resources, Division of Marine Fisheries; National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center; New York Department of Environmental Conservation, Division of Marine Fisheries; North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries (DMF); North Carolina Wildlife Resources Commission (NCWRC), Division of Inland Fisheries; U.S. Fish and Wildlife Service (USFWS), Maryland Fisheries Resources Office, Northeast Regional Office Fisheries Program and South Atlantic Fisheries Resources Coordination Office; University of Massachusetts-Amherst; and Virginia Marine Resources Commission. Removal of digestive tracts from striped bass mortalities or sacrificed for other sampling was performed by Harold F. Upton, Sara E. Winslow and others during the course of the cruises, and analysis was conducted with the assistance of technical personnel at the NMFS SEFSC. The sampling and tagging operations would have been impossible without the support of the officers and crew of the NOAA Research Vessels ALBATROSS IV (Woods Hole, MA), CHAPMAN (Pascagoula, MS) and OREGON II (also Pascagoula, MS, based). Particular appreciation is expressed to Mr. W.W. "Bill" Cole, Jr., who has coordinated the cruise annually since its inception in 1988.

The authors express their sincere appreciation to Ms. Cynthia Goshorn, Maryland Department of Natural Resources, Fisheries Service, and Ms. Tina McCrobie and Mr. Mike Mangold, U.S. Fish and Wildlife Service, Maryland Fisheries Resources Office, for providing the data for striped bass and Atlantic sturgeon in a format useable for analysis with the geographic information system (GIS) located in the Raleigh, NC, U.S. Fish and Wildlife Ecological Services Field Office. Ms. Dianne Stephan, Habitat Coordinator for the Atlantic States Marine Fisheries Commission, graciously reviewed the initial version of Table 1 and provided valuable editorial additions, as well as promptly providing additional information on the status of EFH for many species under the jurisdiction of NMFS and the New England and Mid-Atlantic Fishery Management Councils.

Funding for the SEAMAP Cooperative Winter Tagging Cruises was provided by the SEAMAP program and the cooperating agencies noted in the preceding text. Funding for the present analysis was provided by the U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC.

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INTRODUCTION

Purpose

Transfer funding was provided to the Raleigh, NC, Ecological Services Field Office by the U.S. Army Corps of Engineers, Wilmington District, to cover costs of selected analysis and interpretation of data collected during the course of Southeast Area Monitoring and Assessment Program (SEAMAP) Cooperative Winter Tagging Cruises for the period 1988-1998. Data on striped bass, Atlantic sturgeon, spiny dogfish and other species have been collected by the Service's South Atlantic Fisheries Resources Coordination Office and cooperating partner agencies in the vicinity of sand mining sites proposed for excavation by the Corps as a source of sand to artificially widen Dare County, NC, beaches. The USFWS has conducted a preliminary analysis of data in the database (Doug Newcomb, Coastal Program and Wilson Laney, Fisheries Program, both in Raleigh, NC) with a view toward assessing the potential impacts of the proposed mining activities on Atlantic sturgeon, striped bass and other species.

The purpose of this analysis is to assess the presence and abundance of striped bass, Atlantic sturgeon, and other species as available data permit, in and near the vicinity of the proposed borrow sites; to characterize the habitat in which striped bass and other species were captured, from a seasonal as well as physical perspective; to evaluate the degree of dependency by striped bass on the benthic habitats proposed for removal/disturbance as reflected by their food habits; to determine to where striped bass tagged in and near the proposed borrow sites traveled; to compare the attributes of striped bass in and near the proposed borrow sites to those outside the borrow sites; and to make recommendations for avoiding or minimizing impacts to the fish and fisheries dependent upon them.

Project Description

The U.S. Army Corps of Engineers, Wilmington District, proposes to place a sand berm, and where necessary, sand berm and dune combination along approximately 13.6 miles of Atlantic Ocean beach in Dare County, North Carolina, adjacent to this important wintering ground, and to excavate the required sand from within the wintering grounds. A detailed description of the project is provided in Hall (1999). A northern project area would extend for 3.5 miles from Kitty Hawk south to Kill Devil Hills. A disjunct southern portion of the project would extend 10.1 miles from Nags Head southward to the northern boundary of Cape Hatteras National Seashore. Initial construction is estimated to require 14.6 million cubic yards (cy) of sand. Renourishment is planned to occur on an average interval of three years. Estimated material required for each deposition would be 4.63 million cy. The total volume of sand required for initial construction and periodic re-deposition during the proposed project's 50-year life is estimated to be 88.7 million cy. At the present time, the type of dredging equipment has not been specified, although options include an ocean-certified pipeline dredge and hopper dredge.

Initial construction is estimated to require two years. The annual dredging schedule has not yet been determined. Current plans do not specify whether sand removal from the proposed offshore borrow sites would create deep holes in localized areas, or would attempt to skim off relatively thin layers of sand over wider areas (Hall 1999). However, analysis conducted by Dr. Robert Dolan (University of Virginia, Charlottesville, personal communication) suggests that establishment of a large excavation hole in borrow site S1 is unavoidable, based on the estimated amounts of sand proposed for removal for initial construction and subsequent maintenance. Dolan also advises that, because of the level of fine sediments present in the borrow sites, and the degree of incompatibility between the borrow site sediments and the existing beach sediments, the potential for long-term disruption of the ecosystem is high (R. Dolan, personal communication and Hall, 1999).

The proposed project has the potential to adversely affect Atlantic sturgeon, spiny dogfish, striped bass and weakfish, among many other species, as a result of: disturbance during construction and maintenance; removal of habitat used by the species, such as underwater sand berms or mounds which may provide shelter; direct removal and destruction of benthic prey; and alteration of formerly preferred habitat to unsuitable or unusable habitat, through alteration of substrate, depth or other physical parameters. Consumptive human users of these species, specifically commercial and recreational fishermen, as well as nonhuman predators such as northern gannets, eastern brown pelicans and humpback whales, could in turn be adversely affected if actions undertaken by the Corps or their contractors result in the temporary or permanent displacement of species which are targeted for recreational use, personal consumption, sale or predation.

Study Area

For the purpose of this report, the study area is considered to be the Atlantic Ocean in and within a 5 kilometer radius of the Corps of Engineers, Wilmington District, proposed borrow sites N1 and N2 and S1-S3 as depicted in Hall (1999), or other radius which may be impacted by turbidity plumes resulting from dredging and deposition activities, oil or fuel spills during construction, or other similar activities. It should be noted that the effective extent of impact may include areas as far away as the spawning grounds or natal estuaries of species which winter in the vicinity of the proposed borrow sites, but migrate elsewhere to spawn, as well as areas to which inappropriately-sized sediments mined and placed on the beaches may drift, subsequent to deposition by the Corps.

Study Area Value to Fisheries

Nearshore waters off the northern portion of the North Carolina Outer Banks, north of Cape Hatteras, have long been documented as an important wintering area for migratory fish populations, including Atlantic Coast migratory Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus;* USFWS et al., unpublished data), spiny dogfish (*Squalus acanthias*) (Mid-Atlantic Fishery Management Council et al. 1998), striped bass (*Morone saxatilis*), and weakfish

(*Cynoscion regalis*) (Pearson 1932; Parr 1933; Taylor 1951; M. Street, NC Division of Marine Fisheries, personal communication). Taylor (1951) reported that the Hatteras region "...is also a wintering area for migratory populations, and even, to some extent, a center of dispersal [p. 21]." Parr (1933) theorized that regions with moderate seasonal temperature change, which he termed "homothermous regions", serve as centers of concentration and dispersal. Taylor (1951, p. 32) noted that some species using NC coastal waters "...thrive in the extensive sounds during the long warm season, retreat to the warm offshore waters in the fall, and in part at least, migrate elsewhere in spring and summer as mature or advanced immature fish." He cited weakfish (a.k.a. gray sea trout) and striped bass (a.k.a. rock) as examples of species which exhibit this general life history pattern. Pearson (1932) confirmed that there were 55 species of fish taken by trawling in the area, a list which included most of the important species of the middle and south Atlantic states.

Recent Fishery Management Plans prepared by the Atlantic States Marine Fisheries Commission (ASMFC), which acts on behalf of the coastal states to develop management regulations for inland waters out to three miles oceanward, and the federal Fishery Management Councils (New England (NEFMC), Mid-Atlantic (MAFMC) and South Atlantic (SAFMC)), which develop management regulations for ocean waters from 3-200 miles offshore (Exclusive Economic Zone, or EEZ), confirm the significance of the habitat present in or near the Corps' proposed borrow sites for highly important fisheries. Habitats in or near the proposed borrow sites are identified as important for Atlantic sturgeon (ASMFC Atlantic Sturgeon Plan Development Team 1998, ASMFC 1998, Atlantic Sturgeon Status Review Team 1998); spiny dogfish (MAFMC et al. 1998); striped bass (ASMFC Striped Bass Plan Development Team 1995); and weakfish (Lockhart et al. 1996), among other species. Portions of the habitat present in or near the proposed borrow sites have been formally designated by either the ASMFC or one or more federal Fishery Management Councils as habitats essential for these species of fish and others to spawn, breed, feed and/or grow to maturity as discussed below.

The area in and near the proposed borrow sites is also of high value to both commercial and recreational fisheries for spiny dogfish, striped bass and weakfish, and will likely be for Atlantic sturgeon in the future, once that fishery is restored.

Commercial landings of spiny dogfish in NC, for the period 1988-1997, ranged from 41,000 (1990) to 13.2 million pounds (1996) (MAFMC et al. 1998, Table 20, p. 174). North Carolina averaged 16 percent of the coastwide commercial landings during 1988-1997 (MAFMC et al. 1998, Table 21, p. 175). Most landings occurred during the months of November through April (MAFMC et al. 1998, Table 25, p. 179). Landings of dogfish in Other Dare County ports constituted 30 percent by weight of the total landings and 11 percent of the total value (MAFMC et al. 1998, Table 35, p. 189). Recreational catch and landings of dogfish are also significant, but North Carolina data were not readily available for reference in this report.

Commercial landings of striped bass in NC, from 1980-1992, constituted 14 percent of the coastwide total. Since the severe harvest restrictions of the 1980s, North Carolina landings have dropped to 7 percent of the total. Commercial landings of striped bass are currently controlled by harvest quotas as determined by the ASMFC Striped Bass Management Board (see ASMFC Striped Bass Plan Development Team 1995 and subsequent Addenda). The recreational fishery for striped bass in and near the proposed borrow sites has recently improved significantly. Historically, it was believed by many recreational anglers that Albemarle and Pamlico Sounds were the wintering grounds for many of the largest striped bass found on the coast (Rosko 1966). Tremendous schools of striped bass were reported to enter the sounds through Oregon, Hatteras and Ocracoke Inlets and move through the sounds into the Neuse, Pamlico, Pungo, Chowan and other rivers, and were felt to offer potential for "...virgin fishing in this vast expanse of wilderness." Capture of striped bass by recreational anglers in the surf was apparently an uncommon event (Rosko 1966, p. 224) since it was reported that "...a few [are] taken by surf casters fishing for other species...." Currently, as a result of the recovery of the striped bass fishery and expansion of the population, anglers in the vicinity of the proposed borrow sites target striped bass and encounter them frequently (Sara Winslow, NC Division of Marine Fisheries, Elizabeth City, NC, personal communication).

Weakfish landings in North Carolina are also highly significant (Lockhart et al. 1996). Historically, greatest landings were in the mid-Atlantic and Chesapeake Bay, and North Carolina landed the most weakfish on the Atlantic Coast consistently from 1957-1975. Since 1976, North Carolina landings have generally constituted approximately 33-66 percent of the coastwide total (Lockhart et al. 1996). For the period 1984-1994, commercial landings in NC ranged from as low as 58 to as high as 74 percent of the total. Recreational landings in NC are also high and economically significant. Values reported as associated with the recreational fishery for weakfish in NC (1990 dollars) were: sales of $12,907,533; value-added of $6,144,400 and capital expenditures of $699,100, with an additional income of $2,630,800 associated with 75 jobs directly associated with weakfish (Lockhart et al. 1996, p. 20).

Atlantic sturgeon landings were historically significant in NC. Analysis of the entire time series of landings from 1849 through 1995 inclusive indicates that NC landed approximately 5.8 percent of the total (ASMFC Atlantic Sturgeon Plan Development Team 1998). Recreational catches of Atlantic sturgeon have been limited to incidental capture of the species during fishing using hook and line for other species. Currently, all states have banned possession and any directed take of all Atlantic sturgeon, and the National Marine Fisheries Service is implementing complementary regulations for the waters of the EEZ. Juvenile Atlantic sturgeon have been captured in the vicinity of the study area during SEAMAP Cooperative Winter Tagging Cruises (USFWS et al., unpublished data).

Other species of fish and invertebrates with highly significant ecological and economic value occur in or near the proposed borrow sites either seasonally or as residents. These include alewife (*Alosa pseudoharengus*), American ell (*Anguilla rostrata*), American shad (*Alosa sapidissima*), Atlantic croaker (*Micropogonias undulatus*), Atlantic menhaden (*Brevoortia tyrannus*), Atlantic sea herring (*Clupea harengus*), Atlantic sharpnose shark (*Rhizoprionodon terranovae*), black sea bass (*Centropristis striatus*), blueback herring (*Alosa aestivalis*), bluefin tuna (*Thunnus thynnus*), bluefish (*Pomatomus saltatrix*), butterfish (*Peprilus triacanthus*), cobia (*Rachycentron canadum*), dusky shark (*Charcharhinus obscurus*), hickory shad (*Alosa mediocris*), horseshoe crab (*Limulus polyphemus*), king mackerel (*Scomberomorus cavalla*), monkfish (*Lophias americanus*), red drum (*Scianops ocellatus*), red hake (*Urophycis chuss*), sandbar shark (*Charcharhinus plumbeus*), sand tiger shark (*Odontaspis taurus*), scalloped hammerhead shark (*Sphyrna lewini*), scup (*Stenotomus chrysops*), Spanish mackerel (*Scomberomorus maculata*), spot (*Leiostomus xanthurus*), spotted seatrout (*Cynoscion nebulosus*), summer flounder (*Paralicthyes lethostigma*), tautog (*Tautoga onitis*), tiger shark (*Galeocerdo cuvier*), windowpane flounder (*Scophthalmus aquosus*), and witch flounder (*Glyptocephalus cynoglossus*). All of these species are the subject of management plans prepared by either ASMFC, MAFMC, NEFMC, NMFS, SAFMC or a combination of these management institutions, and most of them have been captured in or near the proposed borrow sites during SEAMAP Cooperative Winter Tagging cruise operations (USFWS et al., unpublished data).

<u>Essential and Essential Fish Habitat Designations</u>

All fish species addressed in this report for which current management plans are in implementation also have their habitats designated in some fashion to facilitate the review of proposed federal or state projects within such habitats and to secure additional protection of them through the imposition of measures to avoid adverse impacts. Habitats so identified for those species managed by the states exclusively through the ASMFC, formerly as Essential Habitats (EH, e.g., Atlantic sturgeon, striped bass), are not the subject of Congressionally-mandated protection measures. The ASMFC has ceased use of the term "essential habitat" to avoid confusion regarding the consultation requirements for federally-designated Essential Fish Habitats (EFH); however, the term will be used in this report because published ASMFC amendments still employ it. Those species for which EFH has been identified by the appropriate federal Fishery Management Council(s), sometimes in cooperation or jointly with ASMFC, (e.g., black sea bass, scup and summer flounder among others) or the National Marine Fisheries Service, are subject to the protective measures established by the provisions of the Magnuson-Stevens Fishery Conservation and Management Act and associated rules of the National Marine Fisheries Service (Public Law 94-265; 16 U.S.C. 1801 et seq.; see U.S. Department of Commerce 1996). Many other species which occupy habitats in or near the proposed borrow sites are the subject of management plans, as noted above, and also have designated EFH which may include the proposed borrow sites. To the extent possible, we have reviewed plans for all species for which EFH has been designated at this time, and have noted in this report those cases in which the proposed borrow sites appear to have been designated EFH for particular species. A list of species, the responsible management entity, and habitat designations, is provided in Table 1, along with the appropriate references.

The anadromous species (alewife, American shad, Atlantic sturgeon, blueback herring, hickory shad and striped bass for the purpose of this report) represent a special case. The Councils are required to comment on and make recommendations to the Secretary of Commerce and any federal or state agency concerning any such activity that, in the view of the Council, is likely to substantially affect the habitat, including EFH, of an anadromous fishery resource under its authority. For the purposes of commenting, "under its authority" is defined as any anadromous species which spends any part of its life history in waters of the EEZ, therefore all east coast anadromous species, with the possible exception of shortnose sturgeon for which occurrence in the EEZ is presently undocumented, are under the authority of one or more of the Councils. Since there are no Council management plans for anadromous species, however, no formal EFH amendments were prepared for these species. The South Atlantic Fishery Management Council did include written descriptions of what it believed would constitute EFH for anadromous species, if Council plans existed to amend (SAFMC 1998), to provide a basis for the Council to comment as required by law. The other two councils did not address EFH for east coast anadromous species other than Atlantic salmon. The ASMFC has described essential habitats for anadromous species in the management plans prepared for them; however, such designation by the ASMFC does not require any action on the part of federal or state agencies or Councils, since the Atlantic Coastal Fisheries Cooperative Management Act does not contain any provision for EFH consultation. The habitats which were designated by either the Council or ASMFC for the species addressed by this report are described in the paragraphs which follow.

Alewife (ASMFC, Councils): Description of EH will be added to the final version of this report.

American eel (ASMFC): Description of habitats deemed essential will be added to the final version of this report.

American shad (ASMFC, Councils): Description of EH will be added to the final version of this report.

Atlantic croaker (ASMFC): Description of any habitats deemed essential by the ASMFC will be added to the final version of this report.

Atlantic menhaden (ASMFC): Description of EH will be added to the final version of this report.

Atlantic sea herring (ASMFC, NEFMC): Description of EFH will be added to the final version of this report.

Atlantic sharpnose shark (ASMFC, NMFS): Description of EFH will be added to the final version of this report.

Table 1. Species in/near proposed borrow sites for which habitat designations have/have not been made with designation (EH = Essential Habitat designation by ASMFC; EFH = Essential Fish Habitat designation by federal Fishery Management Council or NMFS), management institution (ASMFC, MAFMC, NEFMC, NMFS or SAFMC), life stages for which habitat was so designated, and documentation (A ? in a given field indicates FWS uncertainty, based on materials available for review, NMFS should be contacted for clarification).

SPECIES	DESIGNATION	LIFE STAGE(S)	INSTITUTION	DOCUMENT(S)
Alewife	EH	juveniles, adults	ASMFC	ASMFC (1999a)
American eel	In preparation	larvae, mature adults present	ASMFC	ASMFC (in preparation-a)
American shad	EH	juveniles, adults	ASMFC	ASMFC (1999a)
Atlantic croaker	None-but present	larvae, juveniles, adults	ASMFC	Mercer (1987)
Atlantic menhaden	EH	larvae, juveniles, adults	ASMFC	AMAC (1992)
Atlantic sea herring	EFH	adults	ASMFC, NEFMC	ASMFC (1999b), NOAA (1999)
Atlantic sharpnose shark	EFH	adults	ASMFC, NMFS	NOAA (1999)
Atlantic sturgeon	EH	juveniles, adults?	ASMFC	Taub (1990), ASMFC-ASPDT (1998)
Black sea bass	EFH	juveniles?, adults?	ASMFC, MAFMC, SAFMC**	NOAA (1999)
Blueback herring	EH	juveniles, adults	ASMFC	ASMFC (1999a)
Bluefin tuna	None-but present near	juveniles, adults	NMFS	NOAA (1999)
Bluefish	EFH	young-of-year, adults	ASMFC, NEFMC, MAFMC, SAFMC**	NOAA (1999)
Butterfish	EFH	juveniles, adults	MAFMC***	NOAA (1999)

SPECIES	DESIGNATION	LIFE STAGE(S)	INSTITUTION	DOCUMENT(S)
Cobia	EFH	adults	SAFMC	SAFMC (1998)
Dusky shark	EFH	neonate/early juveniles, late juveniles/subadults	ASMFC, NMFS	NOAA (1999)
Hickory shad	EH	juveniles, adults	ASMFC	ASMFC (1999a)
Horseshoe crab	In preparation	juveniles?, adults present	ASMFC	ASMFC (In preparation-b)
King mackerel	EFH	adults	SAFMC	SAFMC (1998)
Monkfish	EFH	eggs, larvae	NEFMC, MAFMC	NOAA (1999)
Red drum	EFH	adults	ASMFC, SAFMC	Mercer (1984a), NOAA (1999), SAFMC (1998)
Red hake	EFH	eggs, larvae, juveniles	NEFMC	NOAA (1999)
Sandbar shark	EFH	neonate/early juvenile, late juvenile/subadults, adults	ASMFC, NMFS	NOAA (1999)
Sand tiger shark	EFH	neonate/early juvenile, adult	ASMFC, NMFS	NOAA (1999)
Scalloped hammerhead	EFH	late juvenile/subadults	ASMFC, NMFS	NOAA (1999)
Scup	EFH	juveniles?, adults	ASMFC, MAFMC, NEFMC**	NOAA (1999)
Spanish mackerel	EFH	adults	ASMFC, SAFMC	SAFMC (1998)
Spiny dogfish	EFH	juvenile and adult females	ASMFC, MAFMC***	MAFMC et al. (1998)
Spot	None, but present	larvae, juveniles, adults	ASMFC	
Spotted seatrout	None, but present	adults	ASMFC	Mercer (1984b)
Striped bass	EH	juveniles, adults	ASMFC	ASMFC-SBPDT (1995)

SPECIES	DESIGNATION	LIFE STAGE(S)	INSTITUTION	DOCUMENT(S)
Summer flounder	EFH	juveniles, adults	ASMFC, MAFMC, NEFMC**	NOAA (1999)
Tautog	EH		ASMFC	ASMFC (1996)
Tiger shark	EFH	neonate/early juvenile, late juvenile/subadult, adult	ASMFC, NMFS	NOAA (1999)
Weakfish	EH	larvae, juveniles, adults	ASMFC	Lockhart et al. (1996)
Windowpane flounder	EFH	juveniles	NEMFC	NOAA (1999)
Witch flounder	EFH?	eggs?	NEFMC	NOAA (1999)

** Plan prepared by ASMFC and MAFMC in cooperation with NEFMC and SAFMC
*** Plan prepared by MAFMC, in cooperation with NEFMC and SAFMC

Atlantic Sturgeon (ASMFC): Identification and distribution of essential habitats for Atlantic sturgeon are described in ASMFC Atlantic Sturgeon Plan Development Team (1998) and Atlantic Sturgeon Status Review Team (1998). The ASMFC considers all presently identified spawning, nursery, migration and wintering habitats, both historical and currently used by Atlantic sturgeon, as summarized in the plan and described in detail in ASMFC (1998), essential habitats for the purposes of restoration and recovery of the species. Habitat within and adjacent to the proposed borrow sites is used by juvenile Atlantic sturgeon and is considered nursery, migratory and wintering habitat.

Black Sea Bass (ASMFC, MAFMC and SAFMC): Description of EFH will be added to the final version of this report.

Blueback herring (ASMFC): Description of EH will be added to the final version of this report.

Bluefin Tuna (NMFS): Description of EFH will be added to the final version of this report.

Bluefish (ASMFC, NEFMC, MAFMC, and SAFMC; MAFMC lead): Description of EFH will be added to the final version of this report.

Butterfish (MAFMC): Description of EFH will be added to the final version of this report.

Cobia (SAFMC): Description of EFH will be added to the final version of this report.

Dusky shark (ASMFC, NMFS): Description of EFH will be added to the final version of this report.

Hickory shad (ASMFC, Councils): Description of EH will be added to the final version of this report.

Horseshoe crab (ASMFC): Description of habitats determined essential by the ASMFC will be added to the final report.

King mackerel (SAFMC): Description of EFH will be added to the final version of this report.

Monkfish (NEFMC and MAFMC): Description of EFH will be added to the final version of this report.

Red drum (ASMFC, SAFMC): Description of EFH will be added to the final version of this report.

Red hake (NEFMC): Description of EFH will be added to the final version of this report.

Sandbar shark (ASMFC, NMFS): Description of EFH will be added to the final version of this report.

Sand tiger shark (ASMFC, NMFS): Description of EFH will be added to the final version of this report.

Scalloped hammerhead shark (ASMFC, NMFS): Description of EFH will be added to the final version of this report.

Scup (ASMFC, NEFMC and MAFMC): Description of EFH will be added to the final version of this report.

Spanish mackerel (ASMFC, SAFMC): Description of EFH will be added to the final version of this report.

Spiny Dogfish (MAFMC): EFH for spiny dogfish is described in MAFMC et al. (1998). **Final EFH designation by the MAFMC and NMFS was not available during preparation of this report. Information regarding the final EFH designation will be provided in the final version. The information which follows is the preferred alternative which was presented to the public during plan deliberations.** The Council described EFH for spiny dogfish separately for juveniles and adults. Preferred EFH for juveniles as described by the Council in the public hearing draft of the plan was:

> **Juveniles:** EFH ranges from the Gulf of Maine through Cape Hatteras, North Carolina across the Continental Shelf in areas that encompass the highest 90% of the area where juvenile dogfish were collected in the NEFSC [Northeast Fishery Science Center] trawl surveys. South of Cape Hatteras, North Carolina through Florida, EFH is the Continental Shelf waters with the same habitat parameters as north of Cape Hatteras. Generally, dogfish are collected in depths between 33 ft and 1,280 ft and temperatures between 37 F and 66 F. EFH is also the "seawater" portions of all the estuaries where dogfish are common or abundant on the Atlantic coast, from Passamaquaddy Bay, Maine to Cape Cod Bay, Massachusetts, generally in water temperatures ranging between 37 F and 82 F.

Preferred EFH for adults as described by the Council in the public hearing draft of the plan was:

> **Adults:** EFH ranges from the Gulf of Maine through Cape Hatteras, North Carolina across the Continental Shelf in areas that encompass the highest 90% of the area where adult dogfish were collected in the NEFSC trawl surveys. South of Cape Hatteras, North Carolina through Florida, EFH is the Continental Shelf waters with the same habitat parameters as north of Cape Hatteras. Generally, dogfish are collected in depths between 33 ft and 1,476 ft and temperatures between 37 F and 66 F. EFH is also the "seawater" portions of all the estuaries

where dogfish are common or abundant on the Atlantic coast, from Passamaquaddy Bay, Maine to Cape Cod Bay, Massachusetts, generally in water temperatures ranging between 37 F and 82 F.

Figures depicting the Council's preferred EFH designation are provided in the draft plan (MAFMC et al. 1998, pp. 218-219). Although the quality of the figures is poor and the scale is small, it appears that the proposed borrow sites were included for designation as EFH for both juvenile and adult female spiny dogfish. It is unclear from the figures whether EFH designated for males includes the proposed borrow sites. **This uncertainty will be resolved in the final version of this report.**

Spot (ASMFC): Description of habitats deemed essential by ASMFC will be added to the final version of this report.

Spotted seatrout (ASMFC): Description of habitats deemed essential will be added to the final version of this report.

Striped Bass (ASMFC): Essential habitat for migratory striped bass is described in ASMFC Striped Bass Plan Development Team (1995). The ASMFC considers all spawning and nursery areas as well as adult resident and migratory habitats, essential to the continued sustainability of the Atlantic Coast migratory stock of striped bass. The study area is included in the description of adult resident, migratory and wintering habitats. The essential habitats for Atlantic Coast migratory striped bass are depicted in the plan amendment in Figure 1 (ASMFC Striped Bass Plan Development Team 1995, p. 12).

Summer Flounder (ASMFC and MAFMC; joint plan): Description of EFH will be added to the final report.

Tautog (ASMFC): Description of habitats deemed essential will be added to the final version of this report.

Tiger shark (ASMFC, NMFS): Description of EFH will be added to the final version of this report.

Weakfish (ASMFC): Essential habitat for weakfish as defined by ASMFC includes all habitats described in the fishery management plan for the species (Lockhart et al. 1996), which includes spawning sites in coastal bays, sounds and the nearshore Atlantic Ocean and nursery areas that include the lower portions of the rivers and their associated bays and estuaries, and resident and migration habitat in the Atlantic Ocean. The principal spawning area is identified as from North Carolina to Montauk, NY. Adult weakfish reside in both estuarine and oceanic habitat. The Continental Shelf from Chesapeake Bay to Cape Lookout, NC, appears to be the major wintering ground (Lockhart et al. 1996). Habitat within and near the proposed borrow sites is likely to constitute spawning, nursery, resident, wintering and migratory habitat. Lockhart et al. (1996)

contains maps which depict adult weakfish abundance and distribution in the vicinity of the proposed borrow sites during spring and fall (Lockhart et al. 1996, Figures 1A, 1B, pp. 5 and 6). While catches depicted on the maps appear to indicate that weakfish are sparse in the study area vicinity, it should be noted that heaviest weakfish concentrations in the study area occur during winter, when sampling was not conducted.

Windowpane flounder (NEMFC): Description of EFH will be added to the final version of this report.

Witch flounder (NEFMC): Description of EFH will be added to the final version of this report.

It is abundantly clear from both historical studies (i.e., Pearson 1932) and current management plan documents (Table 1) that the proposed borrow sites constitute highly significant habitat for a great variety of species as well as those for which specific analysis is conducted within this report. The proposed borrow sites are within areas designated as essential habitats for Atlantic sturgeon, striped bass and weakfish. The proposed borrow sites were included in the area proposed for designation as EFH for female juvenile and adult spiny dogfish, and may be included in the EFH designation for males.

METHODS AND MATERIALS

Historic and current literature was surveyed for information regarding the distribution and abundance, habitat preferences and use, and food habits of Atlantic sturgeon, striped bass, and spiny dogfish of all life stages in or near the study area. Some of this information is included in the Introduction, while the remainder is referenced in the Discussion or Recommendation Sections. Data collected during the SEAMAP Cooperative Winter Tagging Cruises conducted during 1988 through 1998 inclusive were analyzed to determine the presence and abundance of Atlantic sturgeon and striped bass in or near the proposed borrow sites; depth and temperature characteristics of capture localities, and destination of Atlantic sturgeon and striped bass tagged in or near the sites which were later recaptured. Striped bass stomach contents collected during the years 1994-1999 were analyzed to assess the overall composition and the percent of prey with benthic affiliations, as an indication of the degree of dependency of striped bass on the substrate which is proposed for removal. **The same analyses are currently being conducted for spiny dogfish data, and will be provided in the final version of this report.**

Data collected by the SEAMAP program which indicate the presence of hard bottom habitats (SEAMAP-SA 1999) were also overlaid and juxtaposed with the proposed borrow site boundaries in order to assess the potential for presence of hard bottom within the borrow sites.

SEAMAP Cooperative Winter Tagging Cruise Protocol

SEAMAP Cooperative Winter Tagging Cruises (hereafter called Cruise) were initiated in 1988 by the USFWS, Southeast Region Fisheries Program in Cooperation with the ASMFC, the NMFS, and other state, university and occasional international partners. The purpose of the Cruises was to reconfirm the presence of wintering concentrations of migratory striped bass and to establish a tag and release monitoring program for mixed stocks to estimate total mortality, determine coastwide migration patterns, and monitor length and age composition. Principal state partners have included the marine fisheries agencies of the states of North Carolina, Virginia and Maryland. The Cruise is conducted annually during the winter months in the nearshore waters of the Atlantic Ocean from the vicinity of Cape Lookout, NC, to Cape Charles, VA. While the principal target species is striped bass, Atlantic sturgeon have been tagged from the beginning as well. Red drum and summer flounder have been tagged in cooperation with the NC DMF in some years. Spiny dogfish have been tagged in cooperation with the NMFS Northeast Region, East Carolina University, Dalhousie University in Canada, and the NC DMF beginning in 1996.

Sampling platforms for the Cruises have included the NOAA Research Vessels ALBATROSS IV, CHAPMAN and OREGON II. Details of Cruise sampling gears and protocols are provided in Benton (1992), but a brief summary is provided herein. The general study area for the Cruises is usually from Cape Hatteras, NC, north to Cape Charles, VA, but in recent years has been expanded to include the area from Cape Lookout north in an attempt to assess whether the winter range of migratory striped bass is expanding due to the recovery of the population. Fish are captured with trawls from either a side (OREGON II) or stern trawler (ALBATROSS IV, CHAPMAN). Nets used have varied in size from 65-ft (19.8 m) two-seam bottom trawls (standard on the OREGON II) to a 116-foot (35.4 m) high-opening bottom trawl (used in 1990 and 1992 on the CHAPMAN and ALBATROSS IV, respectively). Tows were conducted in depths ranging from 30-60 ft (10-20 m), with duration from 5-30 minutes depending on catch rate and bycatch. Tow time, starting and ending position, depth, surface temperature, surface salinity and total number of striped bass, Atlantic sturgeon and spiny dogfish (1996-1999 only) were recorded for each tow.

All target species were placed in 1,000 gallon (3,785 l) tanks with either circulating seawater or fresh seawater from the ships' fire suppression systems. All live, healthy fish were measured to the nearest cm, scale samples taken from selected striped bass and pectoral spine sections taken from Atlantic sturgeon and dorsal spines removed from selected spiny dogfish for aging, tags inserted, and fish released. Striped bass received internal anchor tags placed posterior of the pectoral fin on the left side. Atlantic sturgeon received various combinations of tags, but always at a minimum t-bar tags placed in the left pectoral fin and beneath the dorsal fin. In some years, passive integrated transponder (PIT) tags as well as dart tags were also employed. Spiny dogfish received a single dart tag inserted with a canula into the dorsal musculature beneath the first dorsal fin.

Food Habits

Beginning in 1994, striped bass captured which contained coded wire tags (CWT) indicating that they were hatchery-reared fish were retained and sacrificed for retrieval of information on their origin and release date. Entire digestive tracts were removed from these fish, as well as from any incidental mortalities, for food habits analysis. The entire digestive tract was placed in a labeled plastic bag and frozen for later analysis. Digestive tracts were transported to the National Marine Fisheries Service, Southeast Fisheries Science Center, Beaufort, NC, Laboratory, where their contents were removed and analyzed. All contents were identified to species where possible. For fish prey, length (TL, mm) and sex were determined where possible. For the purposes of this study, an attempt was made to categorize the percent of prey which are either benthic, or which feed primarily upon benthic prey.

Database Management and Data Analysis

All release and recapture data are maintained on computer systems housed at the USFWS Maryland Fisheries Resources Office located in Annapolis, MD; at the Maryland Department of Natural Resources, Fisheries Service, also in Annapolis, MD; and at the U.S. Geological Service-Biological Resources Division, Leetown, WV, Science Center. Hard copies of all data are maintained by the USFWS South Atlantic Fisheries Resources Coordination Office, Raleigh suboffice. For the purposes of this report, electronic data files were provided by the Maryland Department of Natural Resources, Fisheries Service and the Service's Maryland Fisheries Resources Office, to the Service's Raleigh, NC, Ecological Services Field Office, where they were entered into a geographic information system (GIS). Subsequent analysis of the data was conducted using the GIS to determine the location and abundance, measured as catch per unit effort (CPUE) in numbers of fish per thousand cubic meters, of striped bass captured in and within 1 and 5-kilometer radius of the proposed borrow sites. CPUE was derived by dividing the number of fish per tow by the volume of water sampled in thousands of cubic meters. Cubic meters for each sample were derived by multiplying distance swept by trawl times net mouth area. Numbers of fish per tow were adjusted to reflect the proportion of the tow that was actually in the site border or buffer area. Numbers of fish versus depth and temperature were also plotted using GIS.

Recapture locations of fish released in and near the proposed borrow sites were determined from recapture data provided by the Maryland Fisheries Resources Office, as reported by commercial and recreational fishermen.

Food habits data were analyzed by NMFS, SEFSC, Beaufort Laboratory, personnel. Prey species which were definitively benthic species, or which feed preferentially on benthic species, were enumerated in the contents of each digestive tract. Percent benthic or benthic-dependent prey was then calculated.

PRELIMINARY RESULTS

Results of striped bass data analysis are presented in Maps 1-1 through 10-3, Figures 1-2 and Tables 2-5. Striped bass food habits data are presented in Tables 6-13. Atlantic sturgeon occurrence data are depicted on Maps 11-1 through 11-3. Potential occurrence of hard bottom relative to the proposed borrow sites is depicted on Map 12.

Maps 1-1 through 10-3 depict the tows conducted during each year in relation to proposed borrow site boundaries and within 1 and 5 kilometer radii of the site boundaries. The initial map for each year depicts the proposed sites with tow tracks in and near the site boundaries. CPUE (number of striped bass per thousand cubic meters) is presented adjacent to each tow track. The second and third maps for each year depict the same information, but include tows within 1 and 5 km radii around the site boundaries. Table 2 presents numbers of tows conducted within each proposed borrow site and within 1- and 5-kilometer radius zones around each site. Due to tow overlap and the fact that the 5-km radius zone results in merger of proposed borrow sites located close together, difficulty was encountered in determining exactly which tows transected which sites. Tables 3a-b present CPUE values and mean striped bass CPUE for each site by year, and for all sites by year. Table 4 presents the rank of CPUE from each proposed borrow site, as determined from tows in and near the sites, by year. Table 5 presents numbers of tagged striped bass recovered by year, by state. **Additional analyses of the data are ongoing to further refine information which pertains specifically to each of the proposed borrow sites (i.e., analysis of recaptures of striped bass tagged/released within each site). Additionally, analysis of stomach content data specific to borrow sites is presently incomplete and has not been included in this draft. Analysis of data for Atlantic sturgeon and spiny dogfish was beyond the scope of the transfer funding provided; however, preliminary Atlantic sturgeon capture data are included in this draft report. Spiny dogfish data analysis is ongoing and results will be provided in the final version of this report.**

Presence of Striped Bass in/near Proposed Borrow Areas

For 1988 through 1997, tows were conducted in or near (within a kilometer) of most of the proposed borrow sites. Exceptions were: 1988, when no tows were taken in or near S1; no tows in/near S1 in 1990; no tows in/near N2 and S3 in 1993; none in 1994 in/near S2; and 1997 when no tows were conducted in or near sites N1 and N2 (Maps 1-1 through 10-3; Tables 2, 3a-b). In all years, striped bass were captured in or adjacent to the proposed borrow sites.

Striped Bass Catch Per Unit Effort (CPUE) in/near Proposed Borrow Areas

CPUE in and near the proposed borrow sites ranged from a low value of 0.13 fish per thousand cubic meters at Site S2 in 1992, to a high of 35.35 fish at Site N2 in 1994. Mean values for individual sites and for all sites combined, by year, are presented in Tables 3a-b. **Additional analyses of these data are planned to investigate whether there are significant trends in abundance of fish at particular sites, and how the catch rates for the proposed borrow sites compare to rates outside the sites.** In the interim, sites were ranked from highest to lowest mean CPUE, by year, to determine if any obvious trend was evident (Table 4). An obvious trend is evident, with Sites N1 and N2 having the highest CPUE for 8 of the 10 years for which data are compiled. There is some bias to the data, since not all sites were sampled in all years. Also, in most years, more tows were conducted in or near Sites N1 and N2 than near sites to the south, with the exception of 1997.

Characteristics of Areas Used by Striped Bass

Cumulative numbers of fish captured at various depths and sea surface water temperatures were plotted versus depth (Figure 1) and versus temperature (Figure 2) to provide a visual indication of any evident trends. There is no readily apparent correlation of fish numbers versus depth; however, depths in and around the proposed borrow sites are relatively uniform. There does appear to be a correlation between numbers of fish and temperature, with higher numbers of striped bass captured at lower water temperatures. **Additional data analysis is being conducted using regression to assess whether statistically significant relationships exist between CPUE and depth, CPUE and temperature, or both.**

As requested by Corps personnel (Chuck Wilson, Environmental Branch, U.S. Army Corps of Engineers, Wilmington District, personal communication to RWL), boundaries of the proposed borrow sites were plotted over data from the SEAMAP South Atlantic Bight Hard bottom Mapping project to assess the potential for the presence of hard bottom within the proposed borrow site boundaries (Map 12). The SEAMAP data indicate the potential exists for hard bottom to occur in or near proposed borrow sites S2 and S3.

Destinations of Striped Bass Tagged in/near the Study Area

Data for returns of striped bass released in or near the proposed borrow sites are being requested. In the interim, returns for all fish tagged and released from 1988 through 1998 are presented in Table 5. Returns of tagged striped bass have come from Nova Scotia, Canada, and from every coastal state from Maine to North Carolina. Highest percentage of returns came from Maryland, followed by Virginia and Massachusetts. Only 3.5 percent of the tagged fish were recaptured in North Carolina.

PRELIMINARY RESULTS

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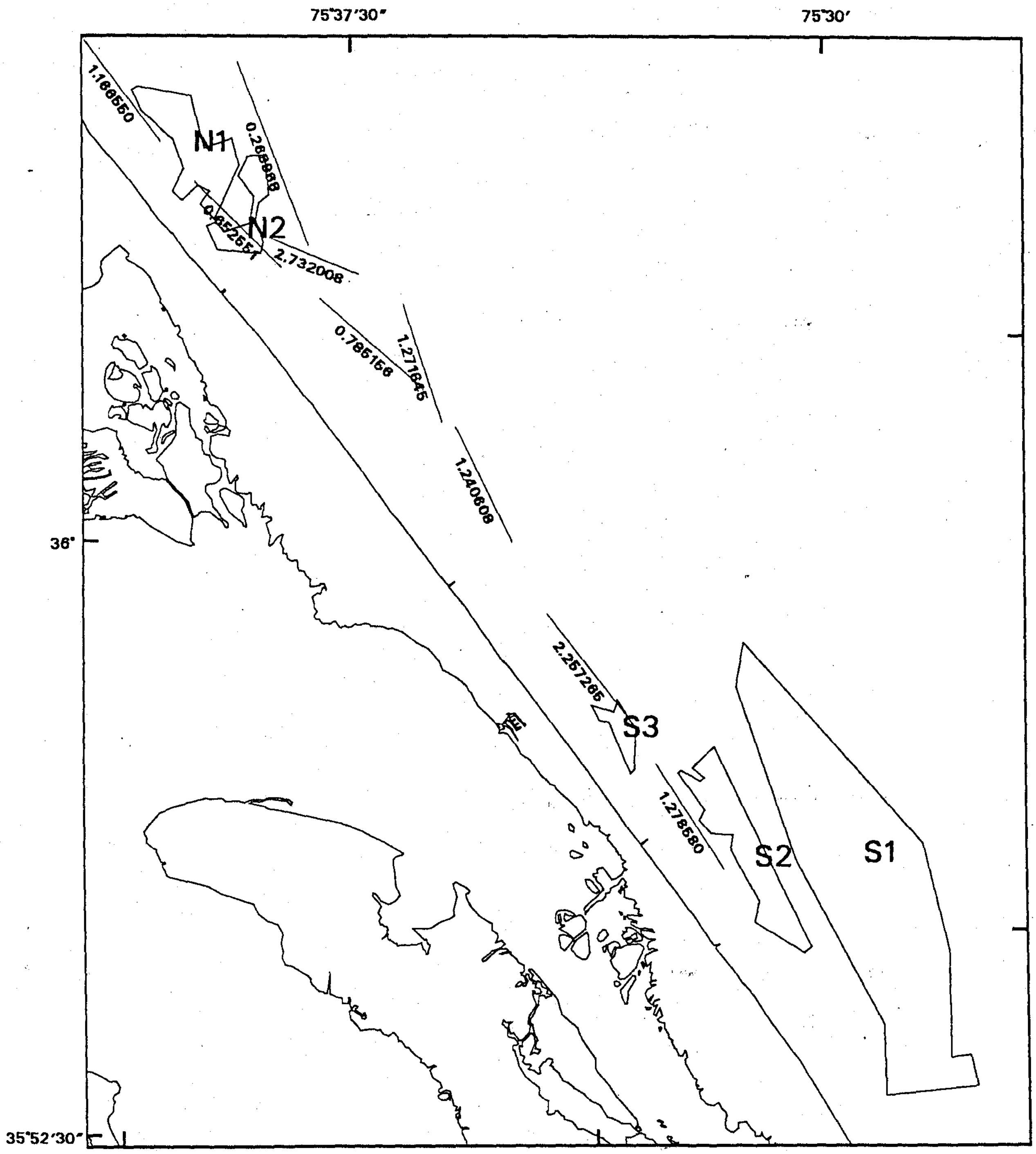
MAP 1 - 1 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1988



Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas

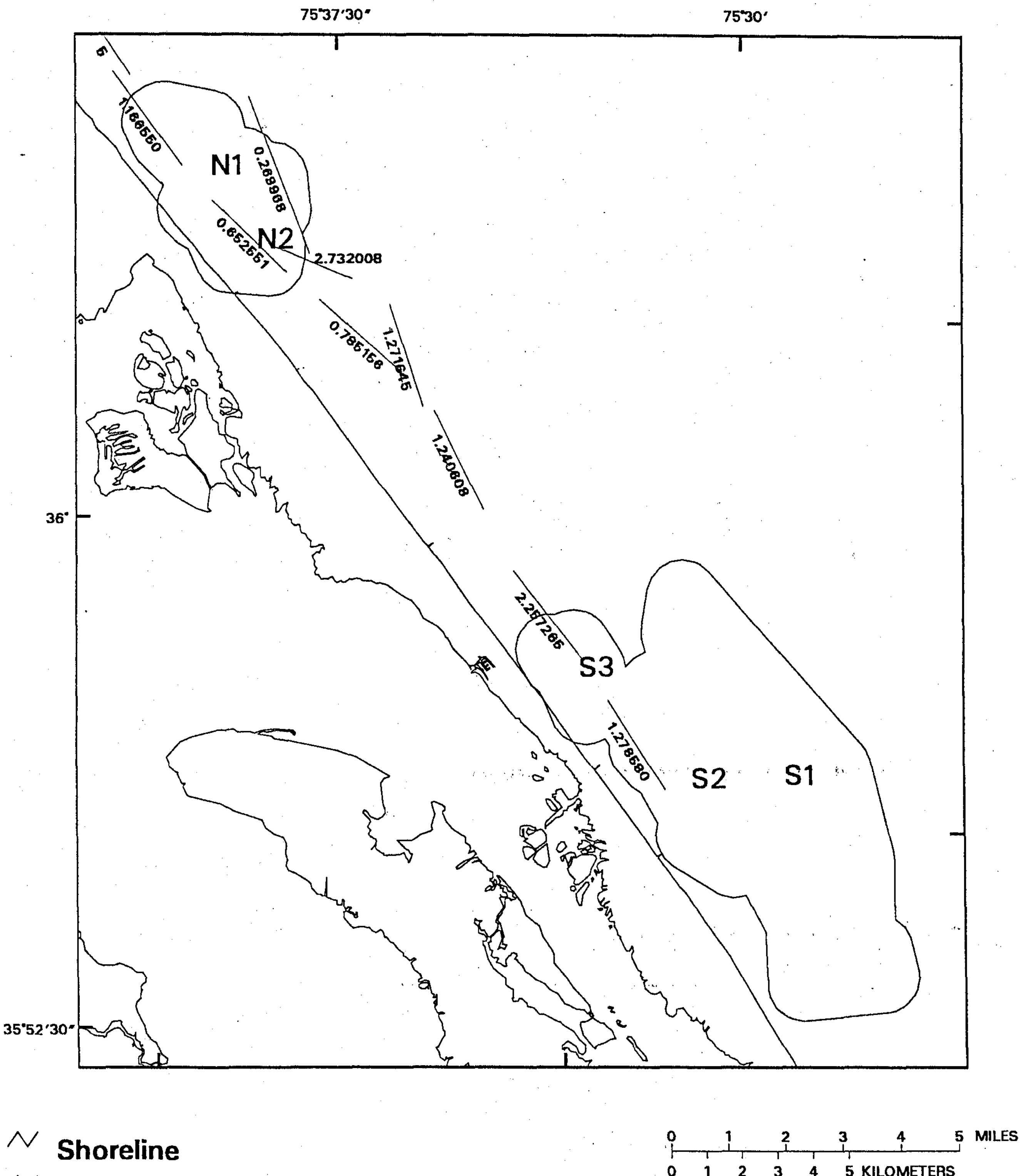
0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS

USFWS - D. Newcomb, 5/11/99

MAP 1 - 2 STRIPED BASS COLLECTION CRUISES

NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS

1988



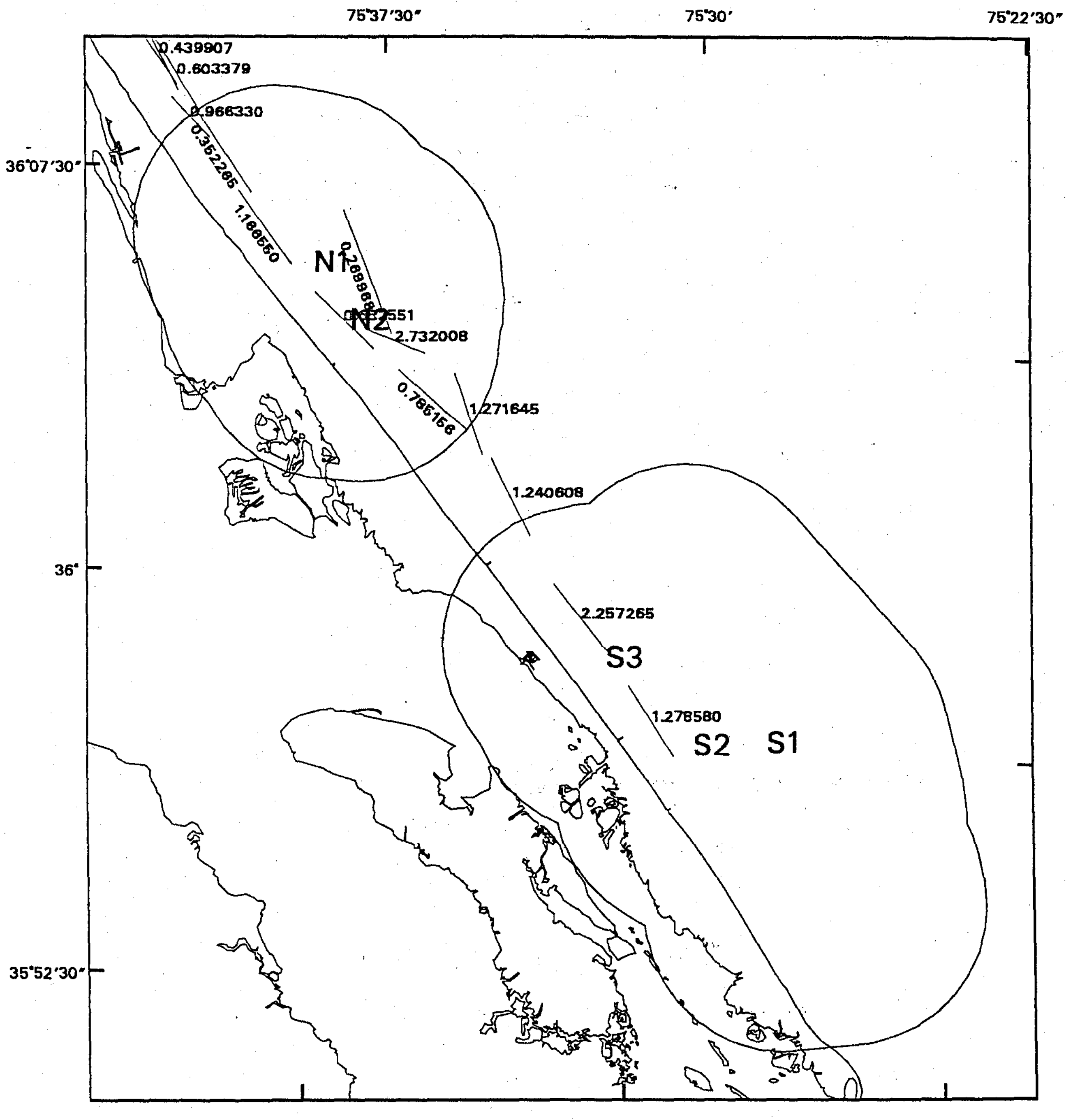
Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas + 1 Km buffer

USFWS - D. Newcomb, 5/11/99

MAP 1 - 3 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1988



Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

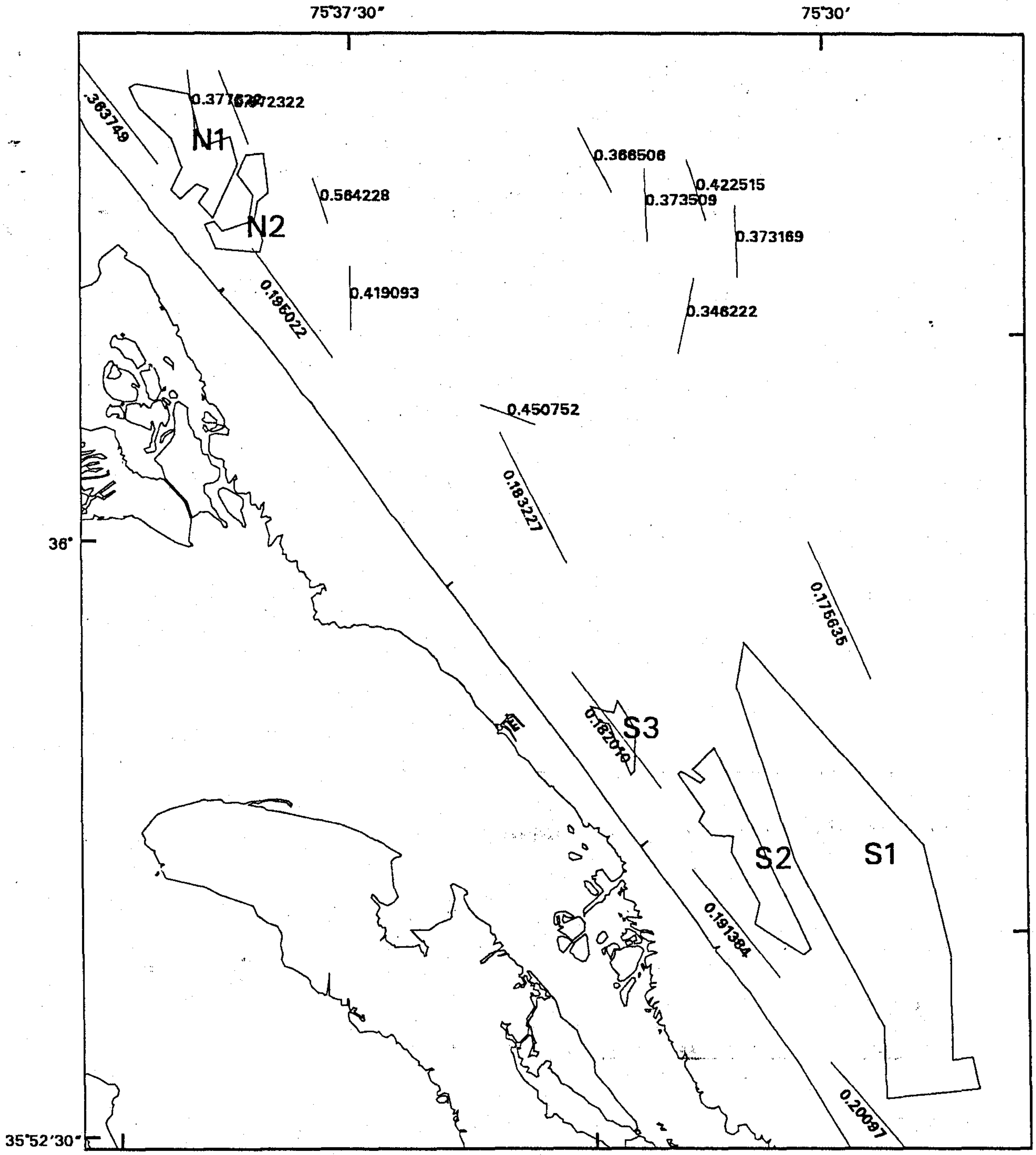
Sand Borrow Areas + 5 Km buffer

0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

USFWS - D. Newcomb, 5/11/99

MAP 2 - 1 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1989



Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

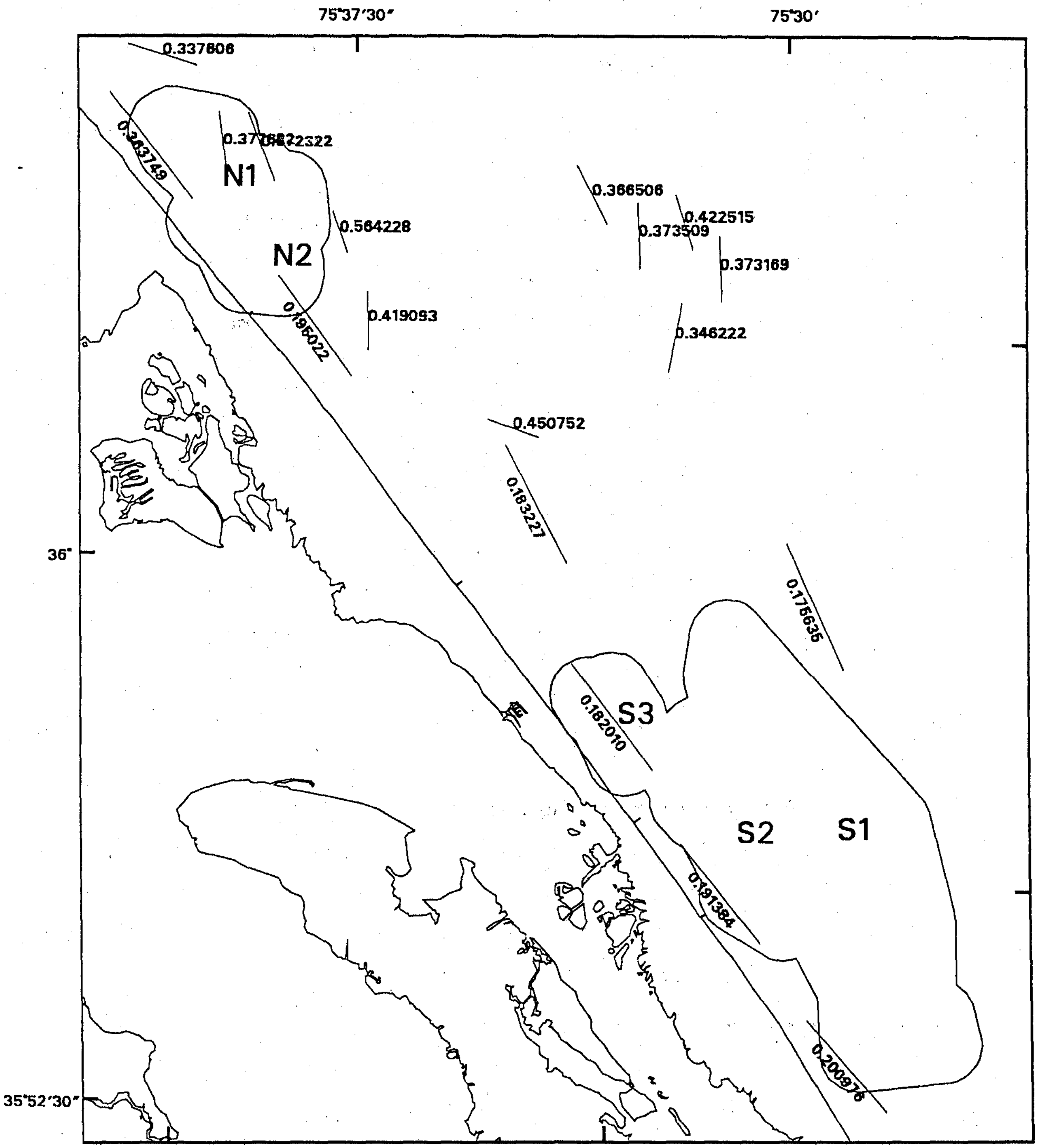
Sand Borrow Areas

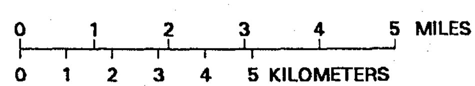
0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

USFWS - D. Newcomb, 5/11/99

MAP 2 - 2 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1989





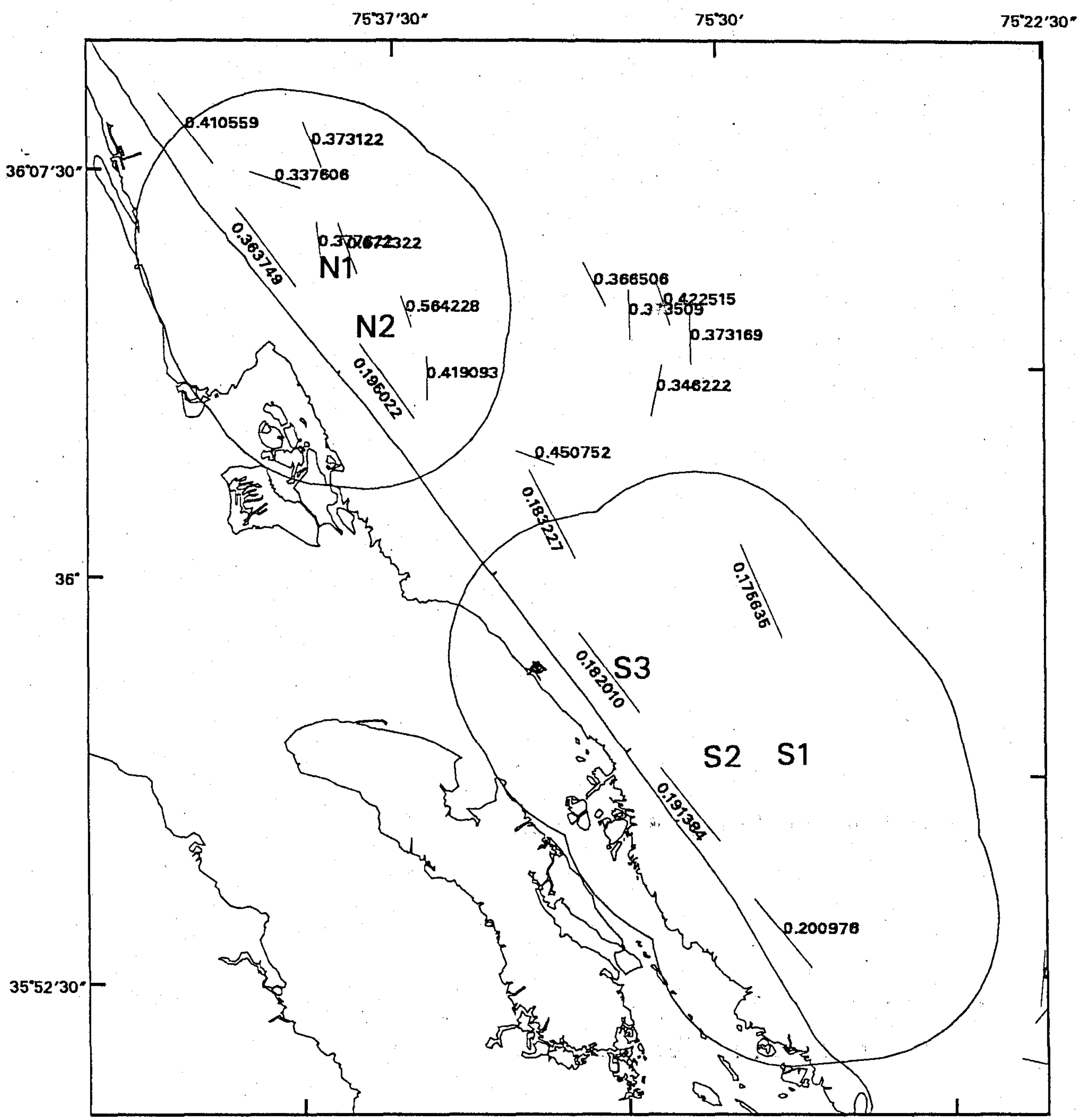
Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas + 1 Km buffer

USFWS - D. Newcomb, 5/11/99

MAP 2 - 3 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1989



0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS

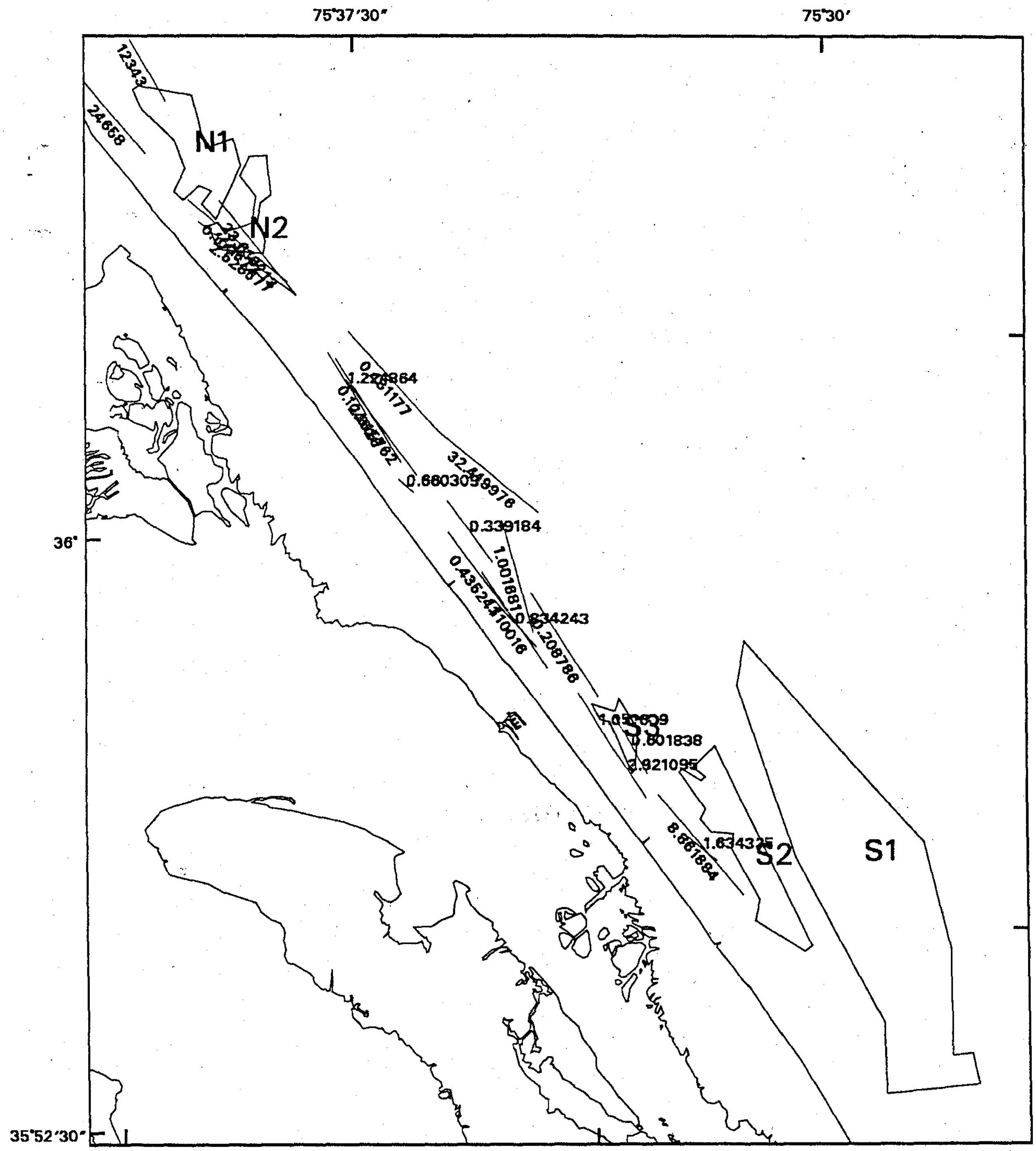
Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas + 5 Km buffer

USFWS - D. Newcomb, 5/11/99

MAP 3 - 1 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1990



Shoreline

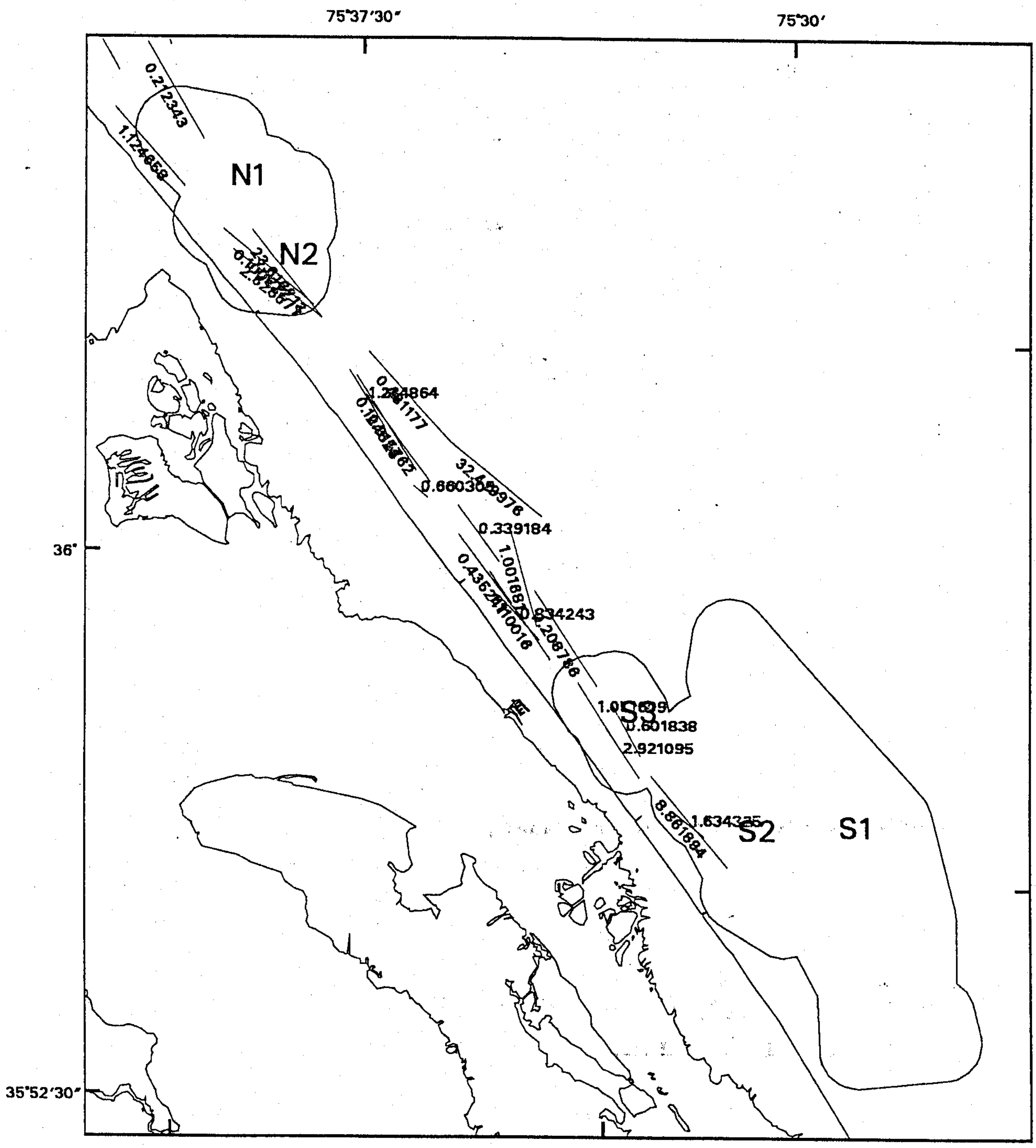
Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas

0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS

USFWS - D. Newcomb, 5/11/99

MAP 3 - 2 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1990



Shoreline

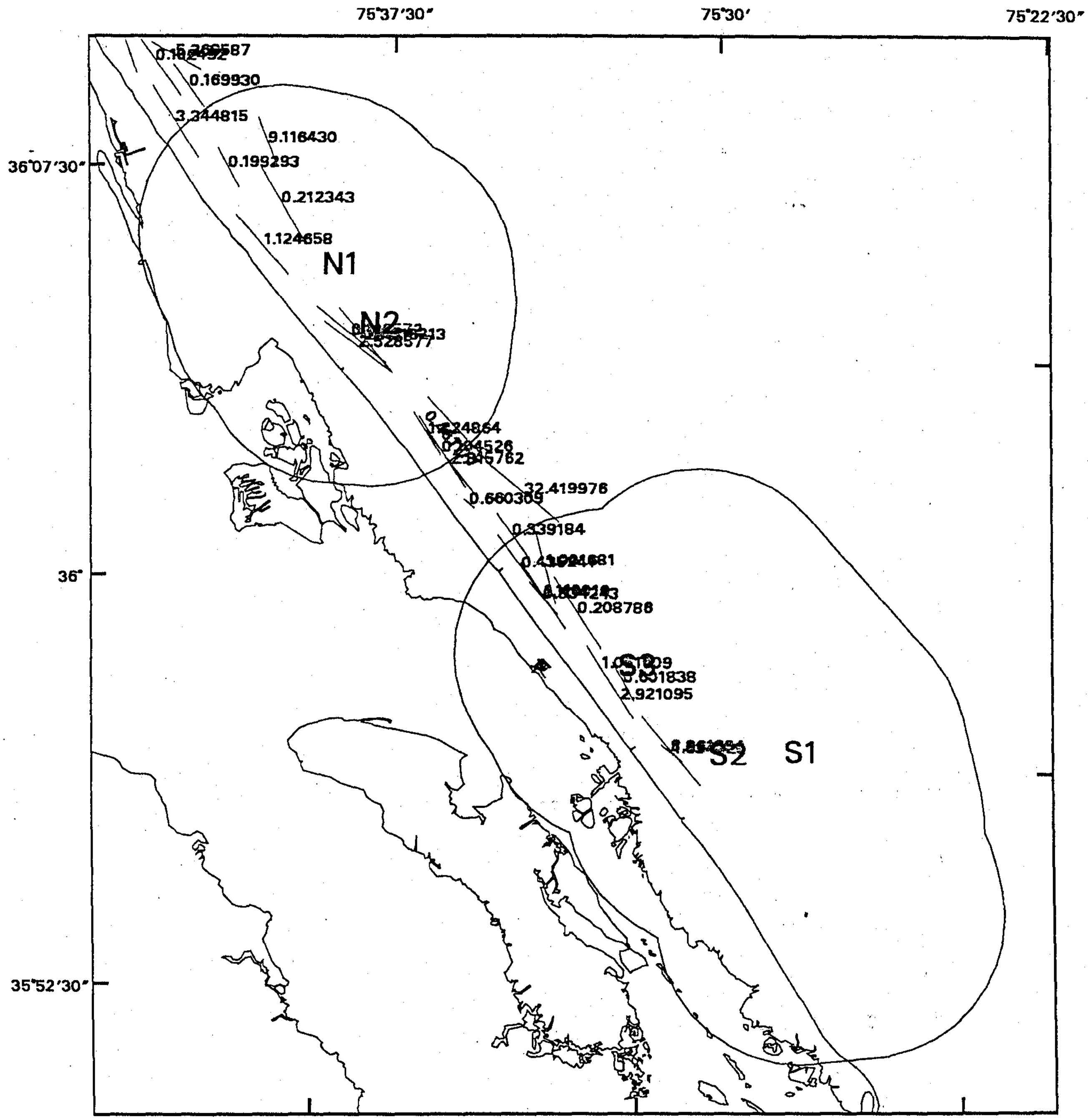
Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas + 1 Km buffer

0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS

USFWS - D. Newcomb, 5/11/99

MAP 3 - 3 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1990



Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

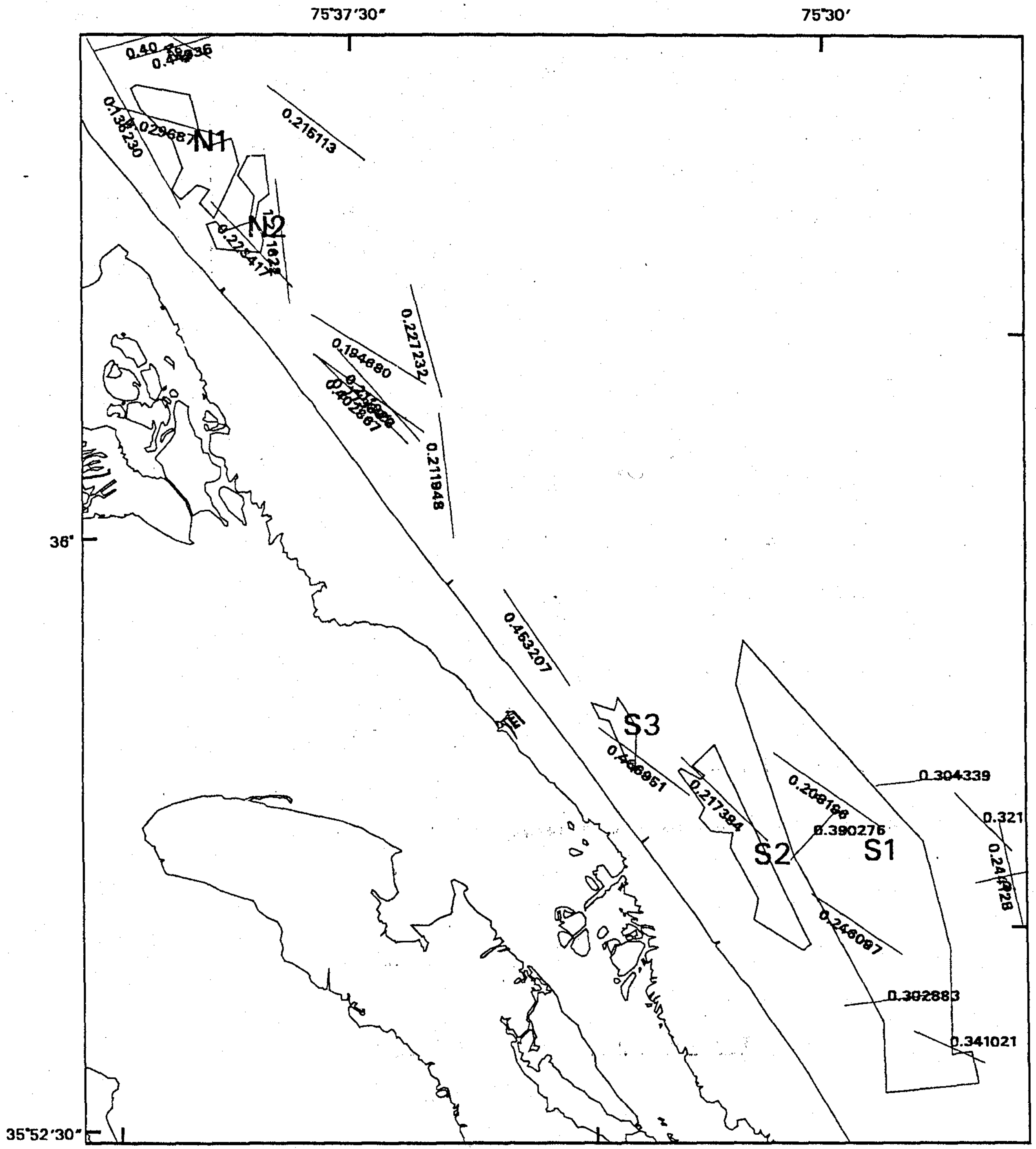
Sand Borrow Areas + 5 Km buffer

0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

USFWS - D. Newcomb, 5/11/99

MAP 4 - 1 STRIPED BASS COLLECTION CRUISES
NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS
1991



Shoreline

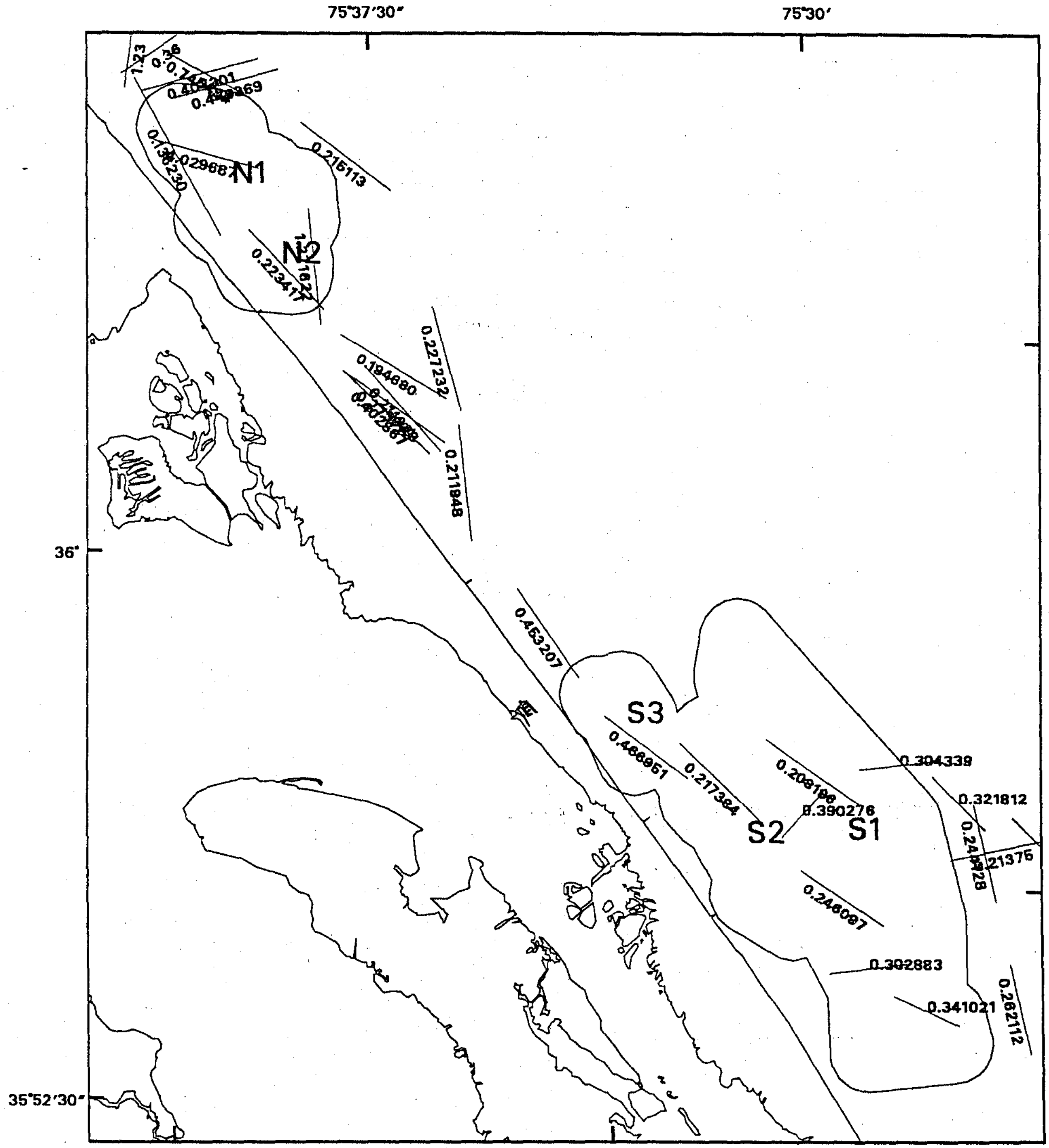
Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas

0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS

USFWS - D. Newcomb, 5/11/99

MAP 4 - 2 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1991



0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

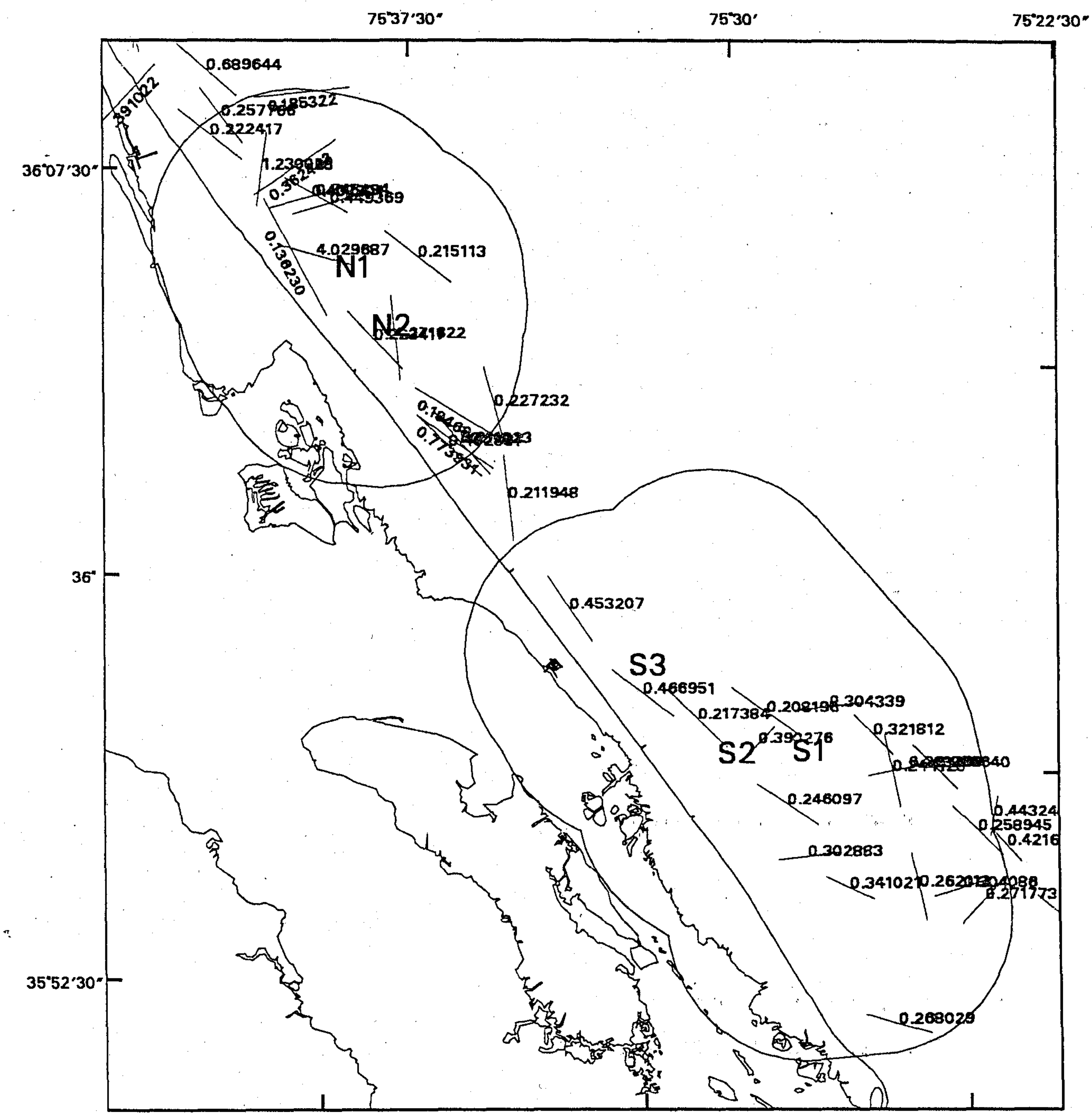
Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas + 1 Km buffer

USFWS - D. Newcomb, 5/11/99

MAP 4 - 3 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1991



0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

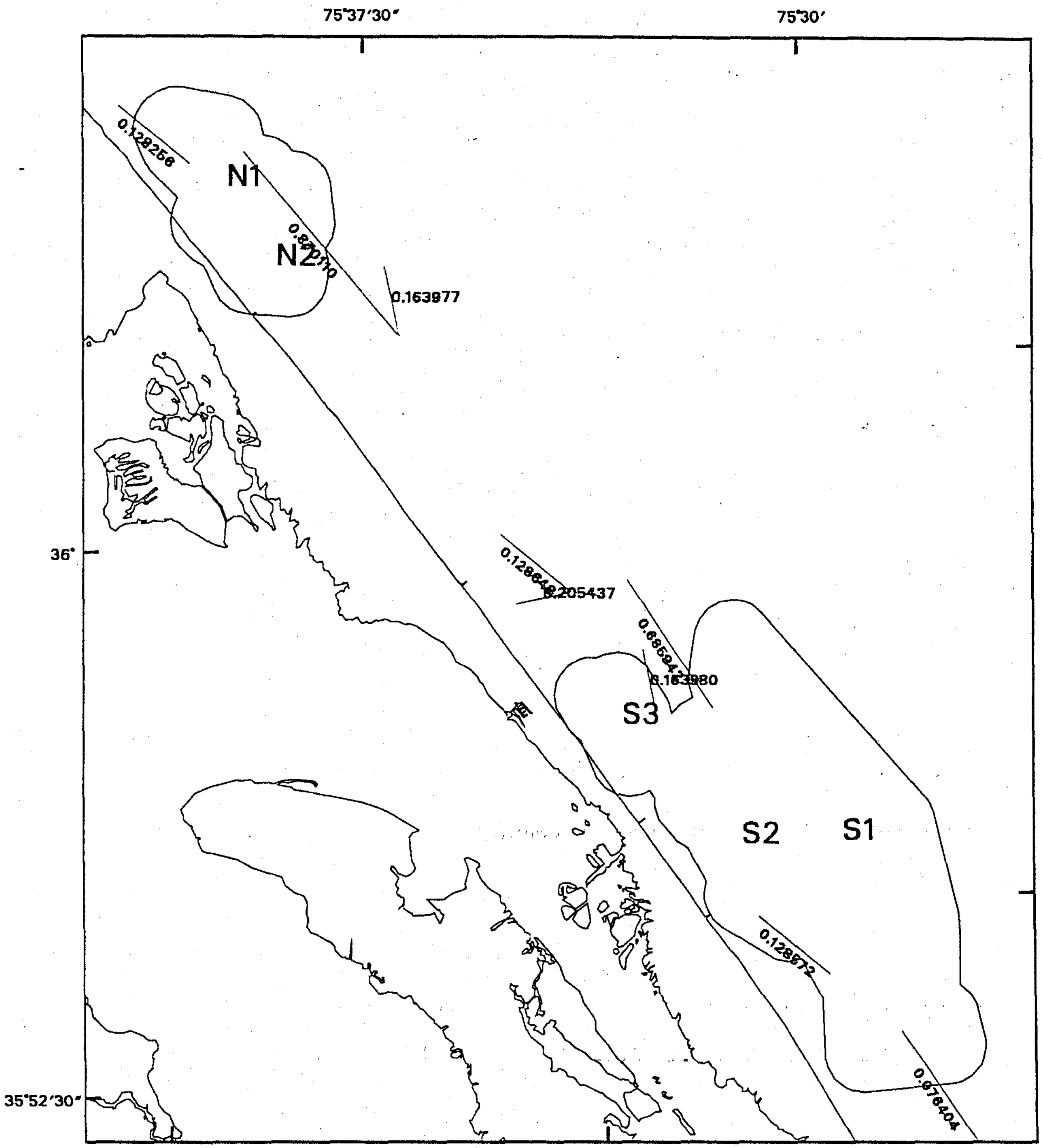
Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas + 5 Km buffer

USFWS - D. Newcomb, 5/11/99

MAP 5 - 2 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1992



Shoreline

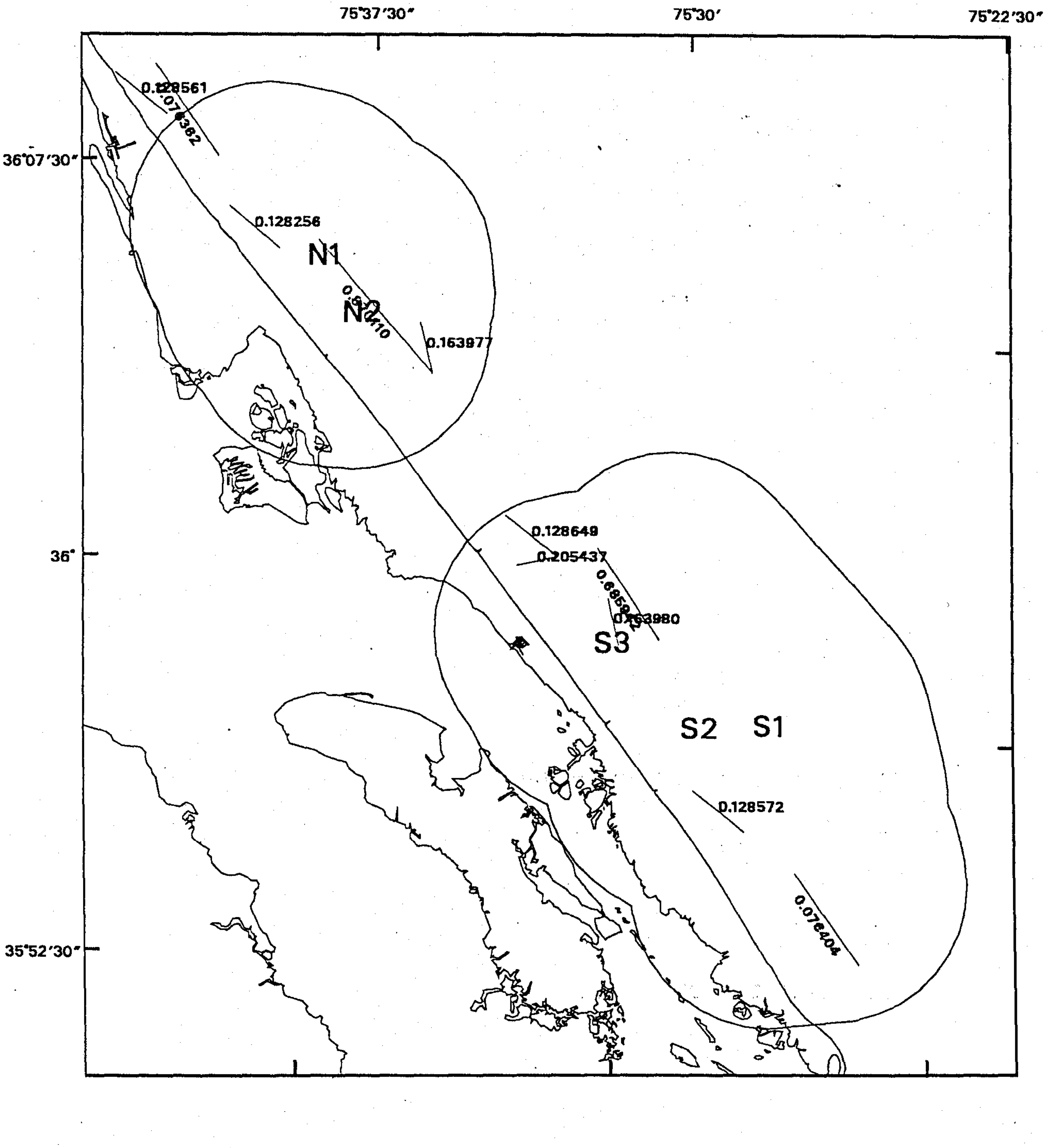
Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas + 1 Km buffer

0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS

USFWS - D. Newcomb, 5/11/99

MAP 5 - 3 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1992



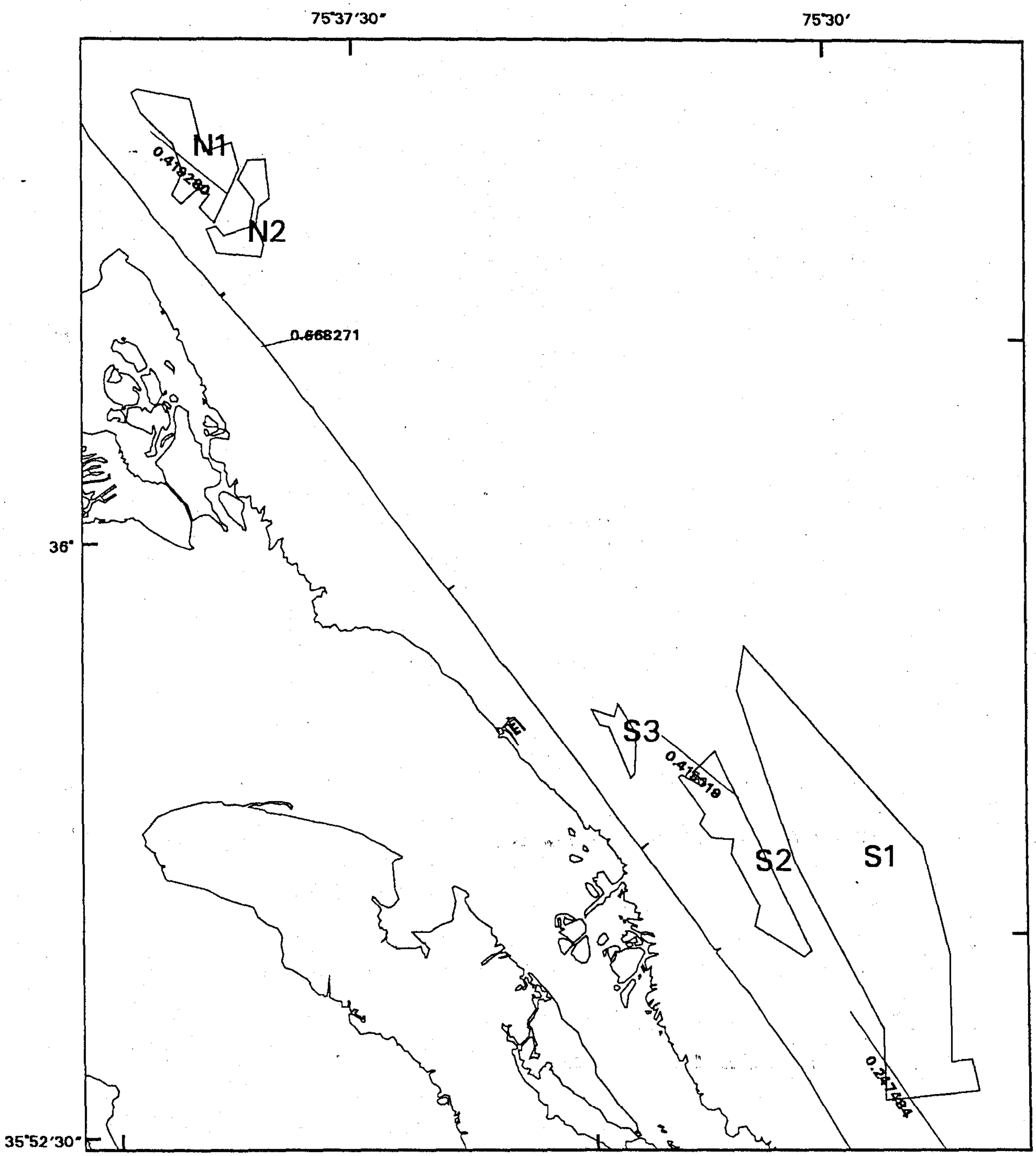
Shoreline

Data Collection Cruises (Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas + 5 Km buffer

USFWS - D. Newcomb, 5/11/99

MAP 6 - 1 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1993



Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

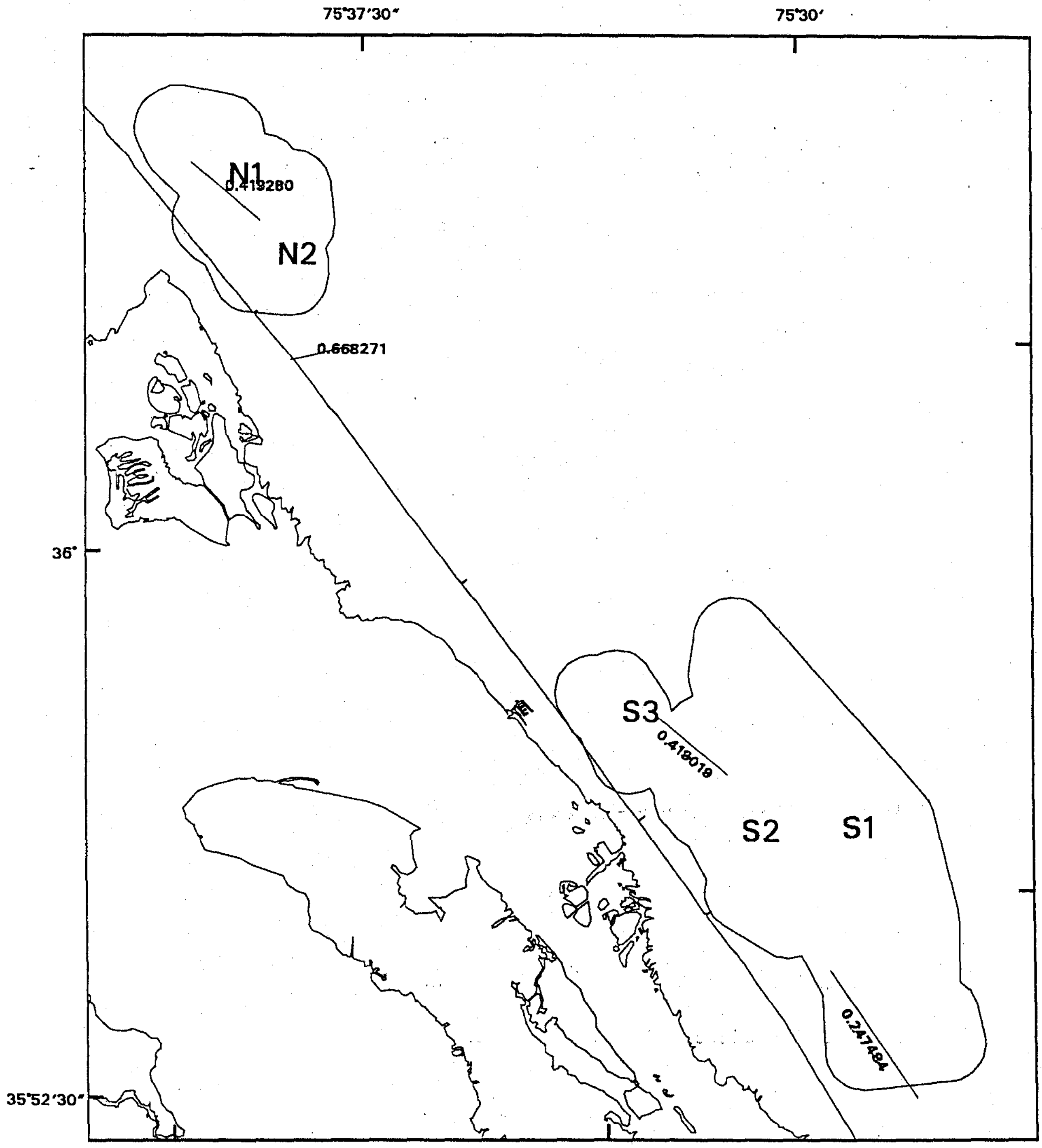
Sand Borrow Areas

0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

USFWS - D. Newcomb, 5/11/99

MAP 6 - 2 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1993



Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

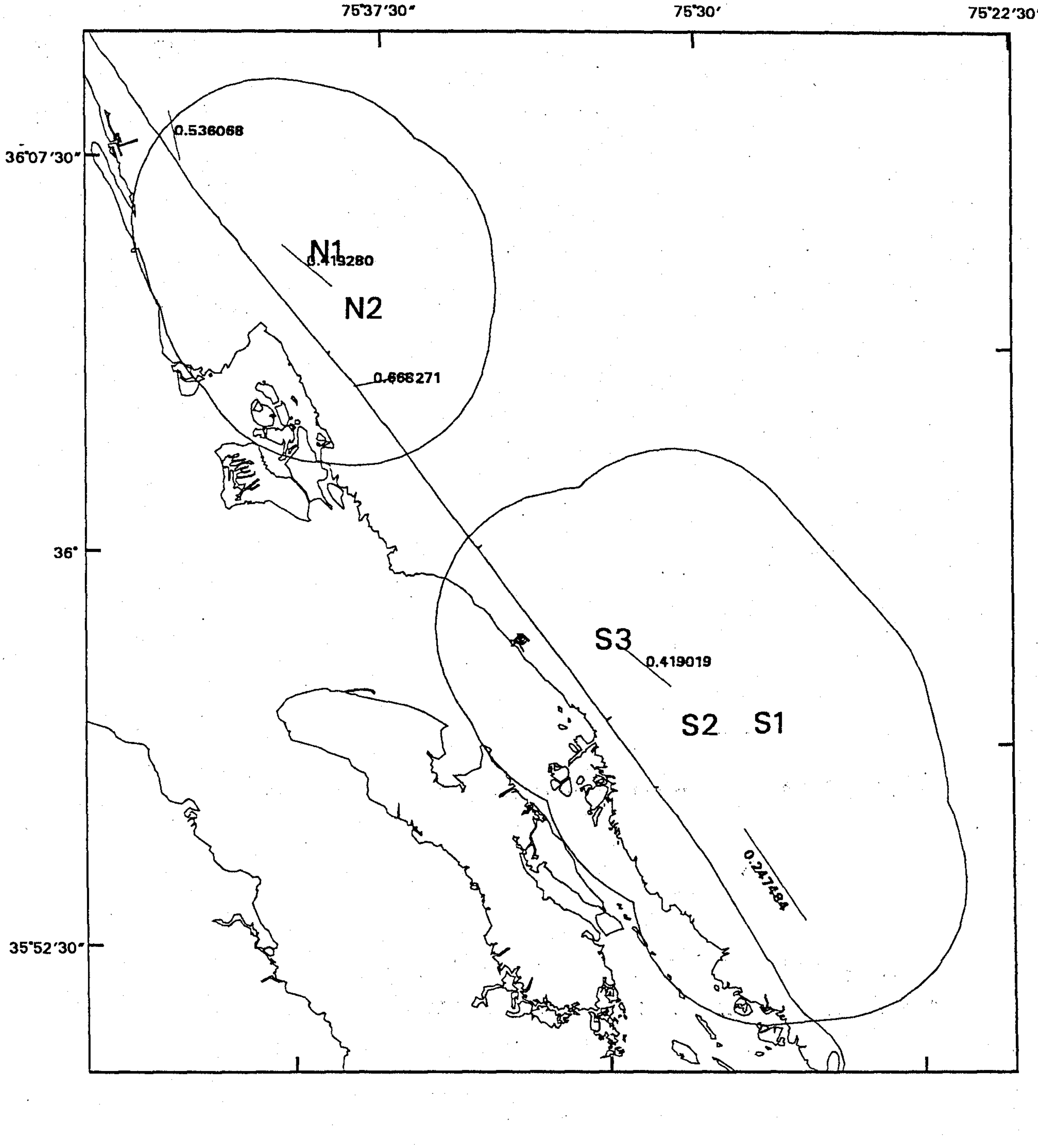
Sand Borrow Areas + 1 Km buffer

0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

USFWS - D. Newcomb, 5/11/99

MAP 6 - 3 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1993



Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

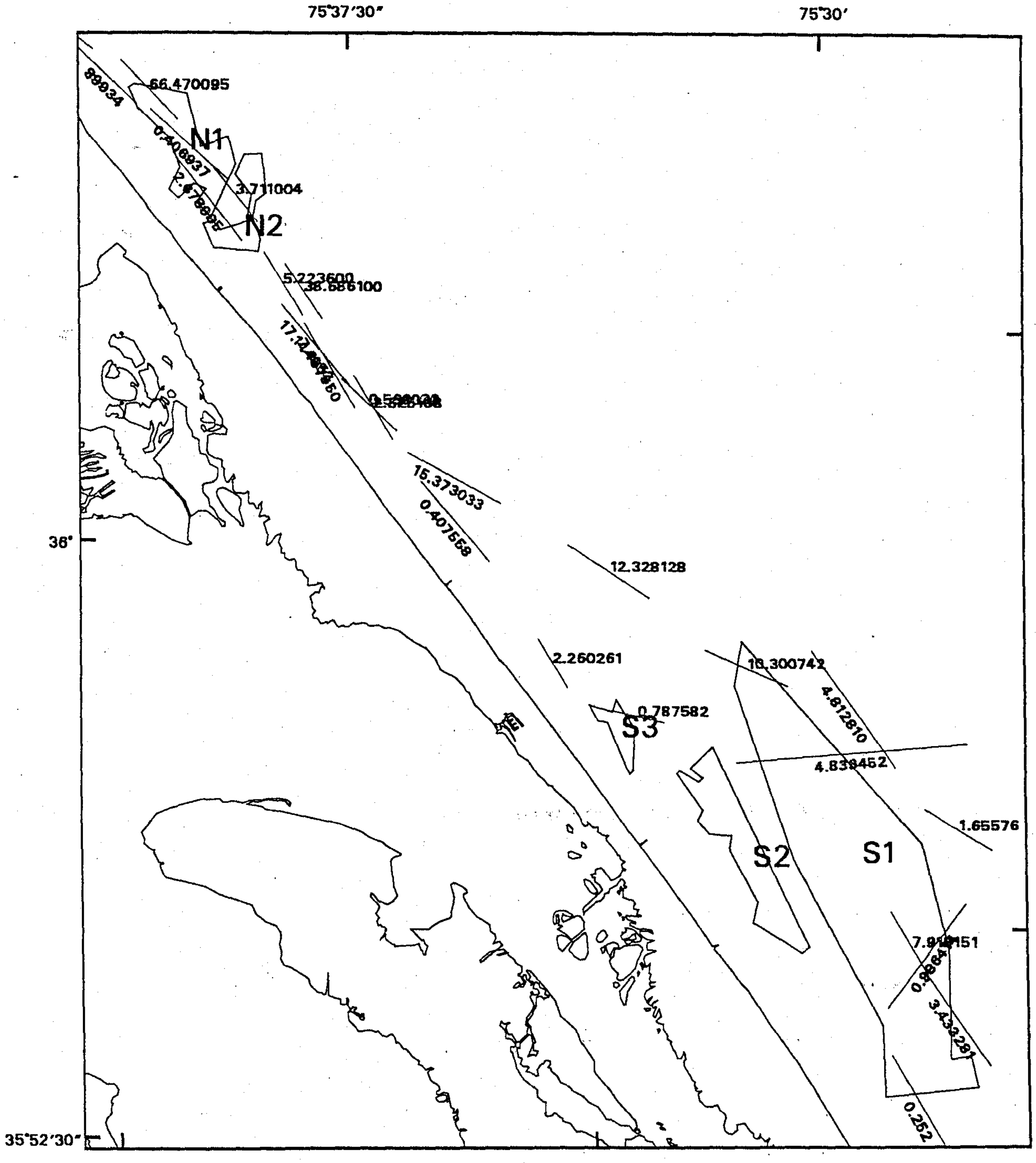
Sand Borrow Areas + 5 Km buffer

0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

USFWS - D. Newcomb, 5/11/99

MAP 7 - 1 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1994



Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

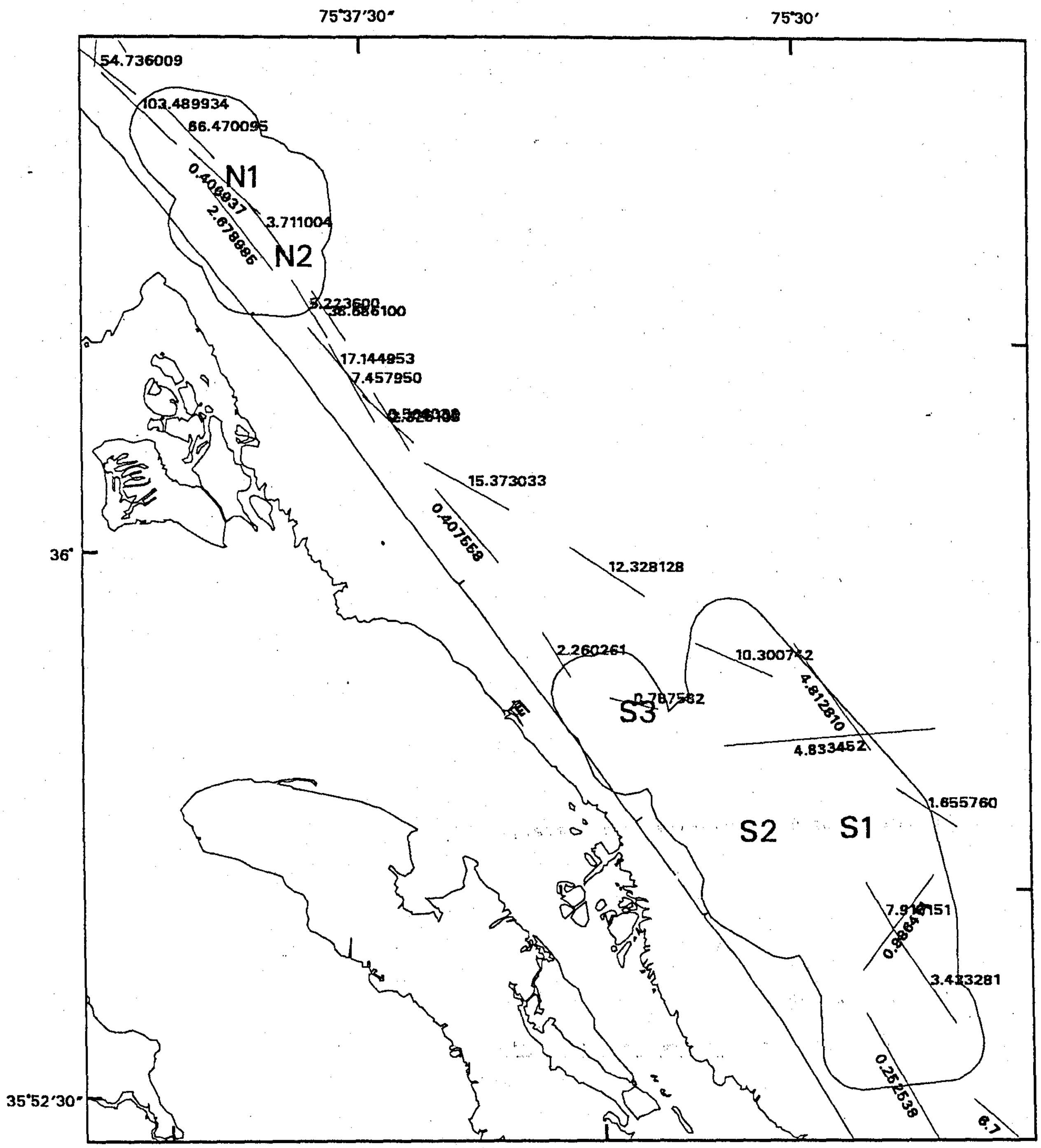
Sand Borrow Areas

0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

USFWS - D. Newcomb, 5/11/99

MAP 7 - 2 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1994



0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS

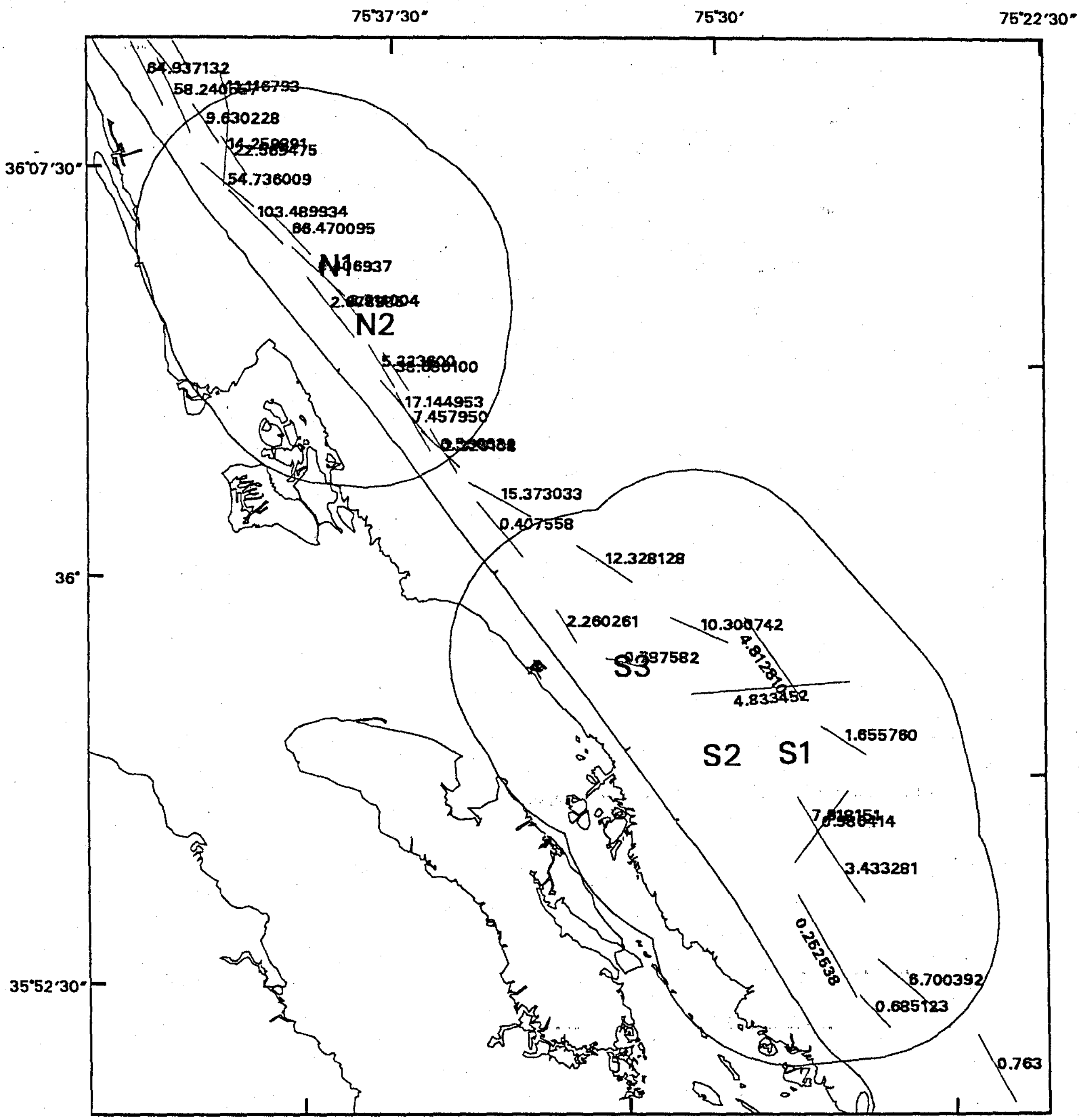
Shoreline

Data Collection Cruises (Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas + 1 Km buffer

USFWS - D. Newcomb, 5/11/99

MAP 7 - 3 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1994



0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

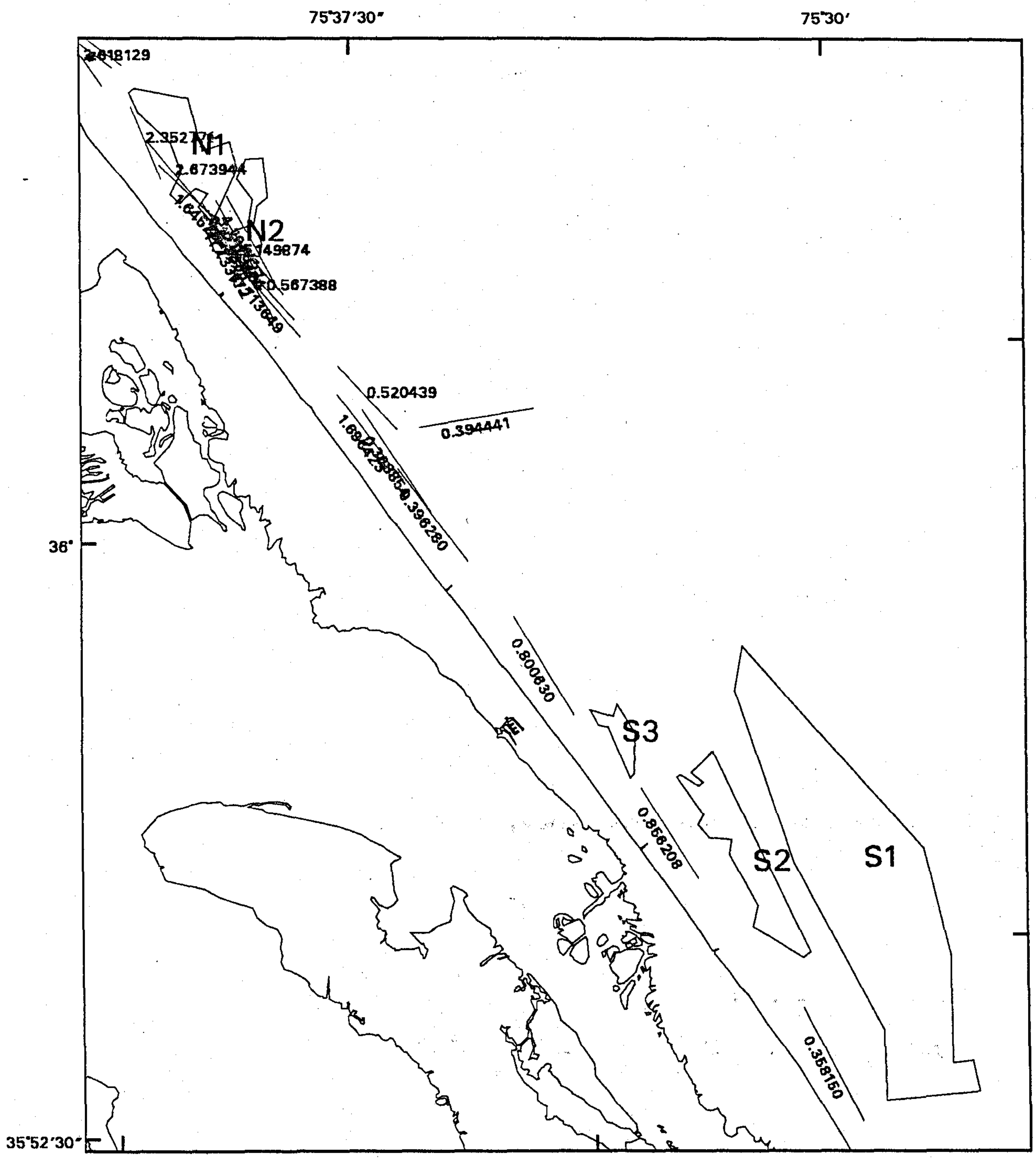
Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas + 5 Km buffer

USFWS - D. Newcomb, 5/11/99

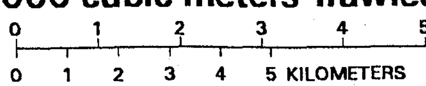
MAP 8 - 1 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1995



Shoreline

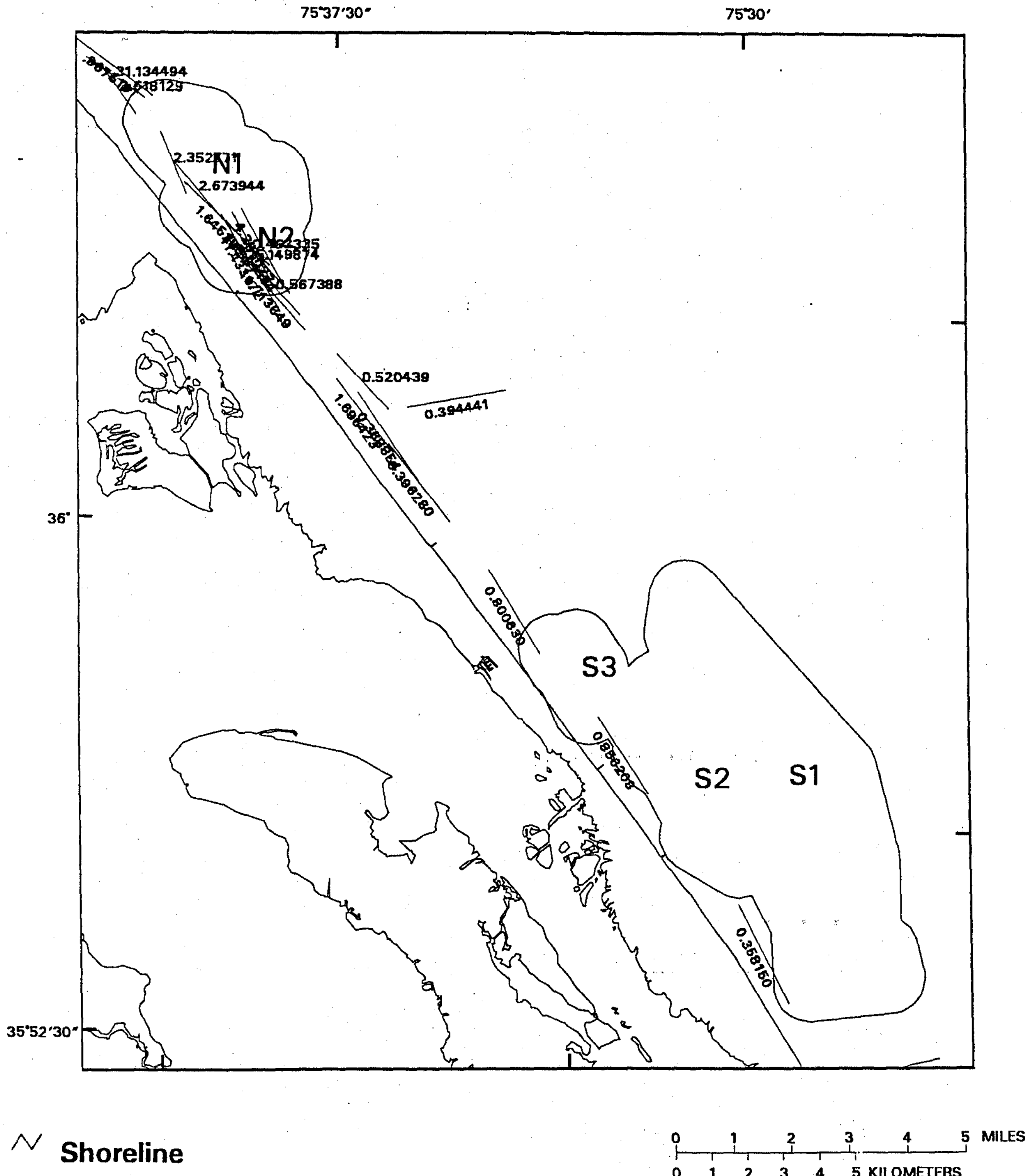
Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas



USFWS - D. Newcomb, 5/11/99

MAP 8 - 2 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1995



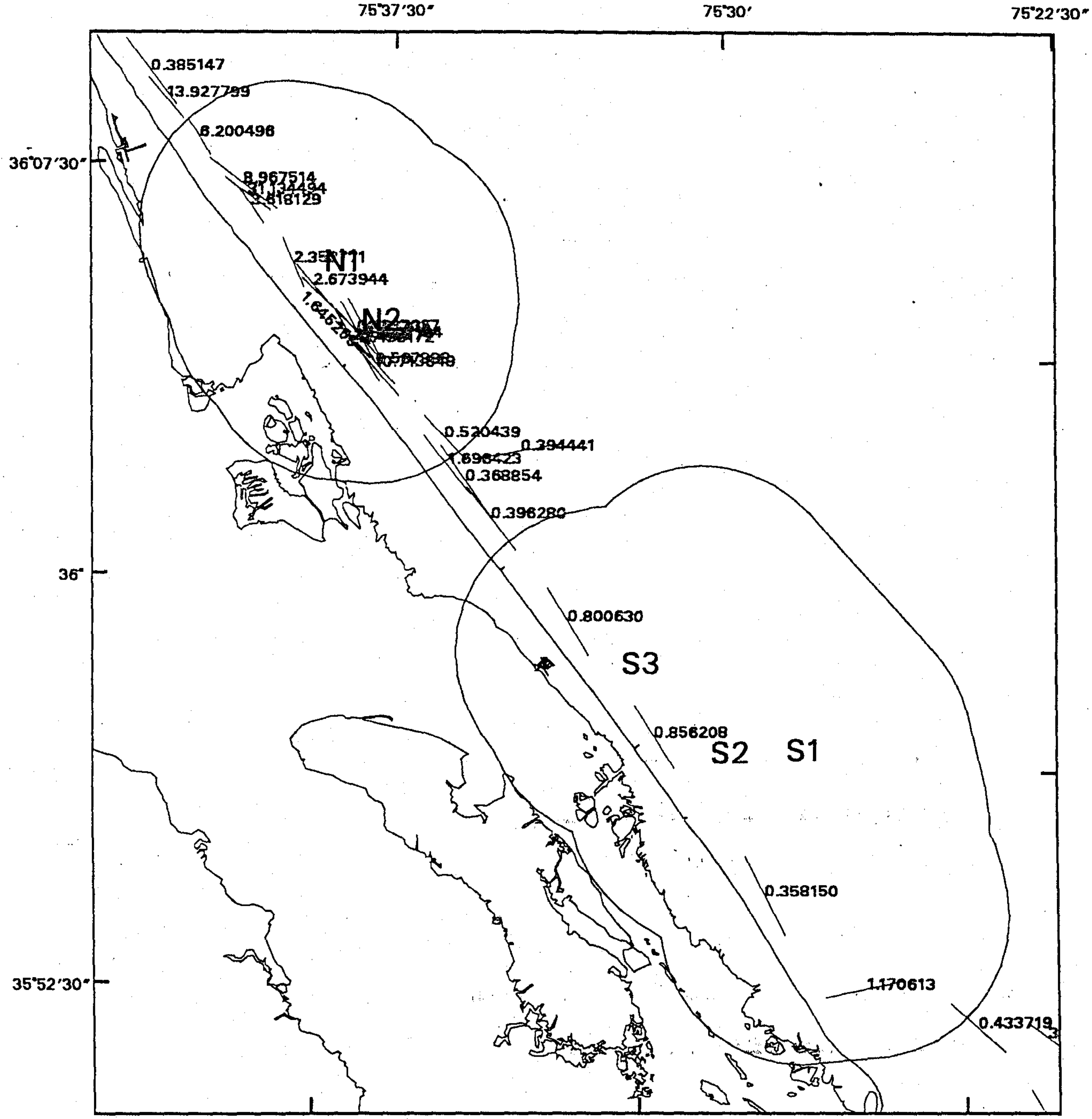
Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas + 1 Km buffer

USFWS - D. Newcomb, 5/11/99

MAP 8 - 3 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1995



0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

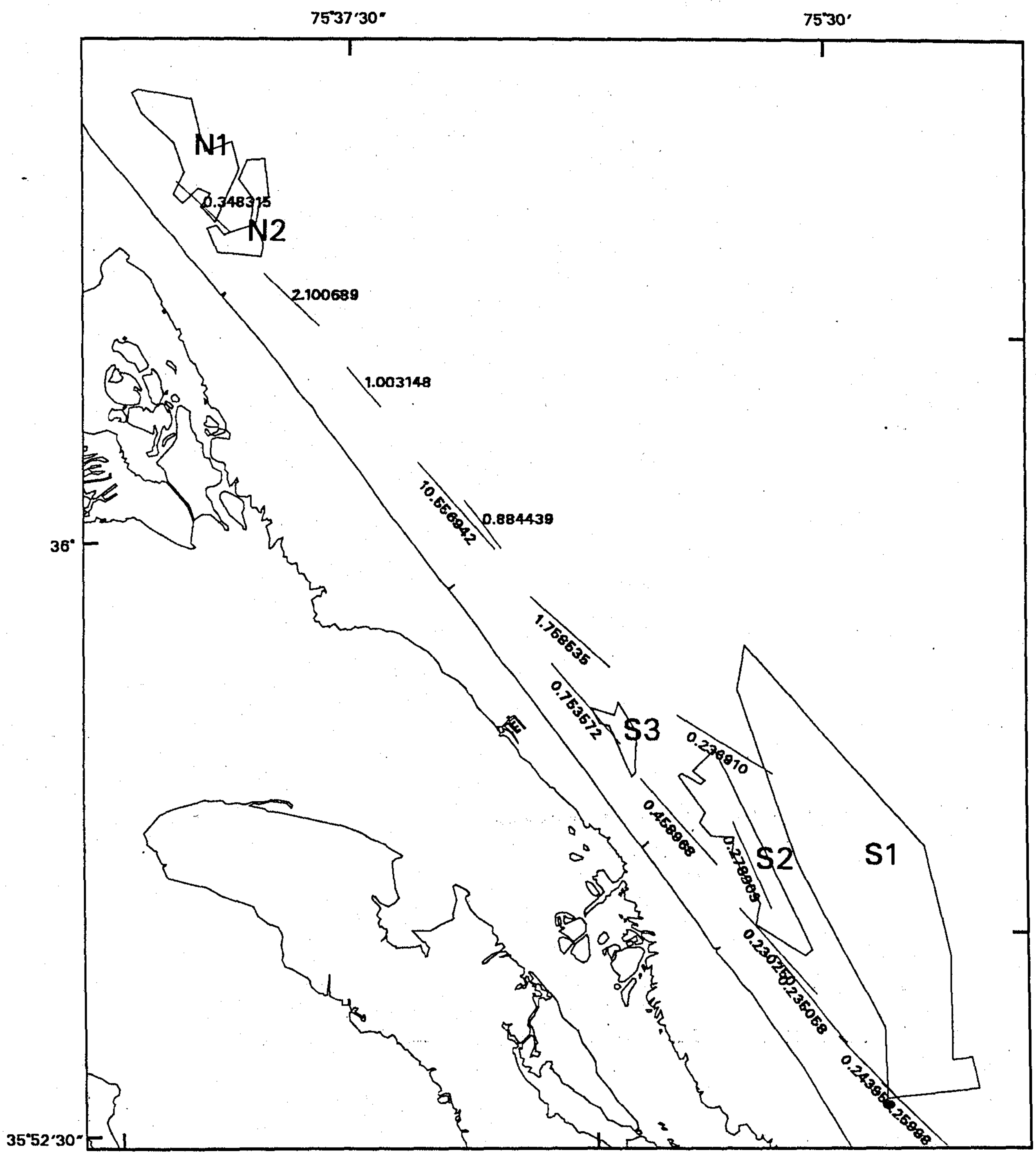
Shoreline

Data Collection Cruises (Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas + 5 Km buffer

USFWS - D. Newcomb, 5/11/99

MAP 9 - 1 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1996



Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

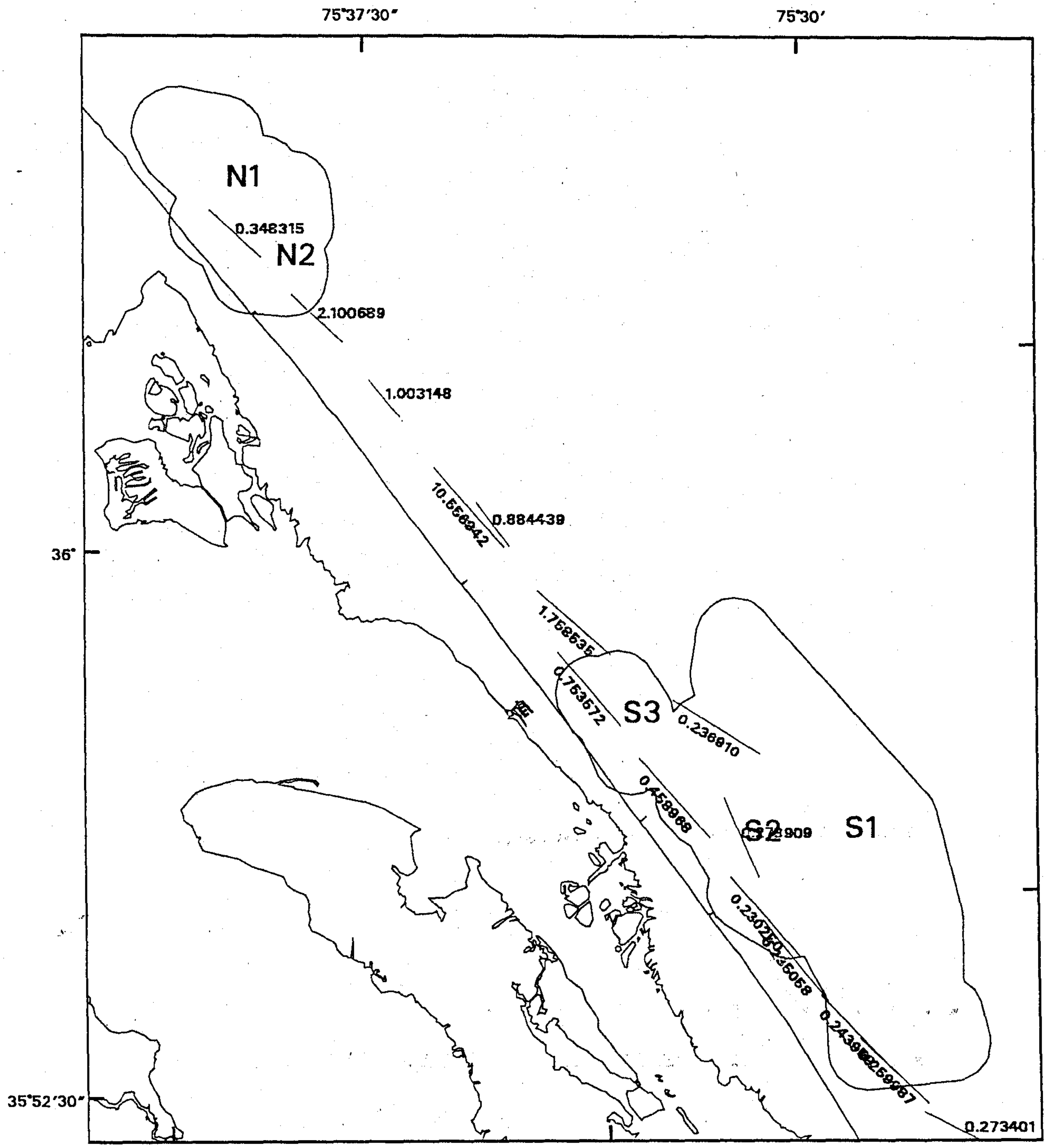
Sand Borrow Areas

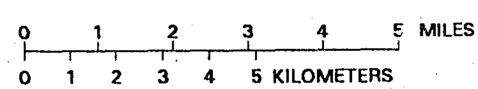
0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

USFWS - D. Newcomb, 5/11/99

MAP 9 - 2 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1996





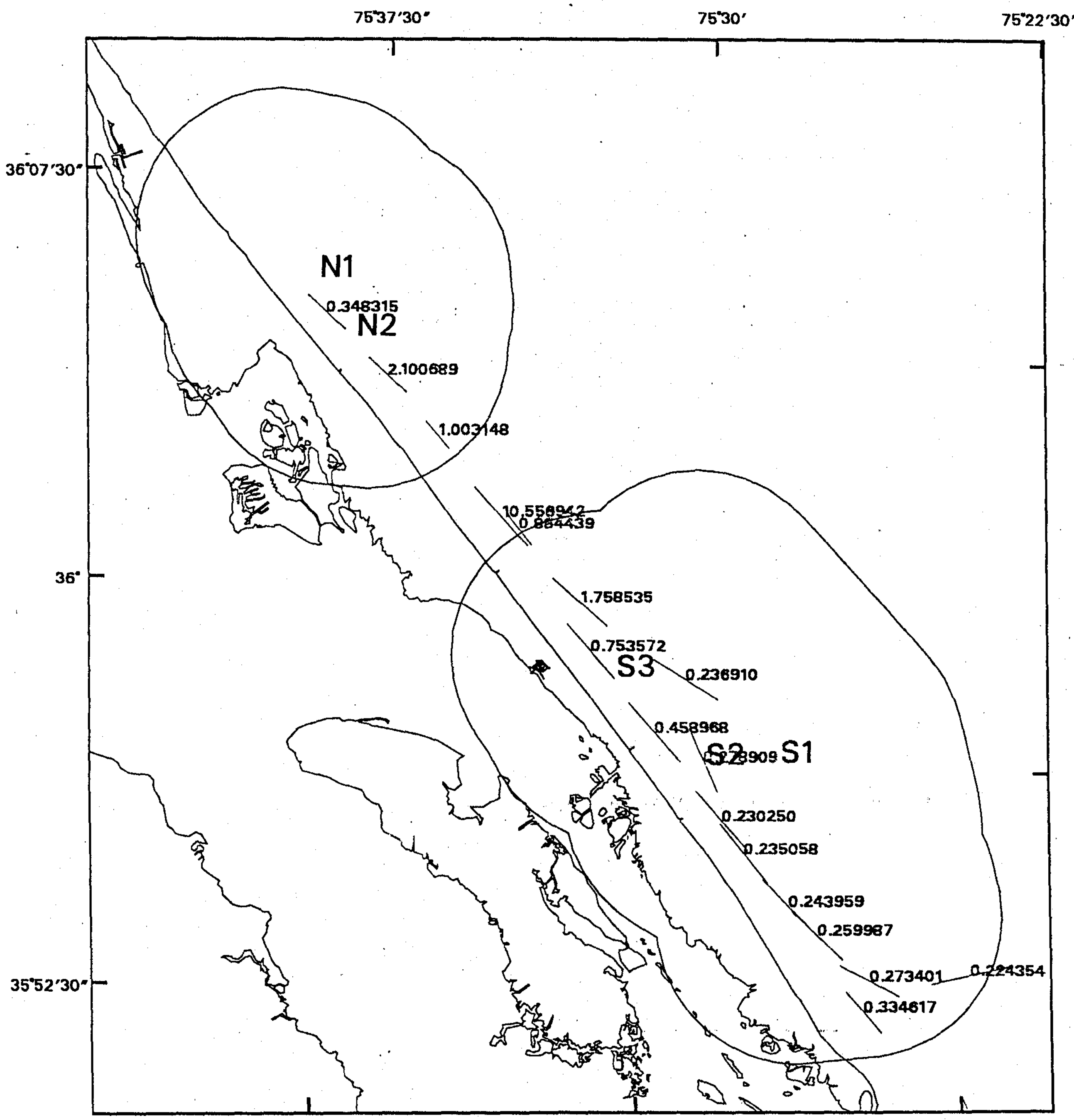
Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas + 1 Km buffer

USFWS - D. Newcomb, 5/11/99

MAP 9 - 3 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1996



Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

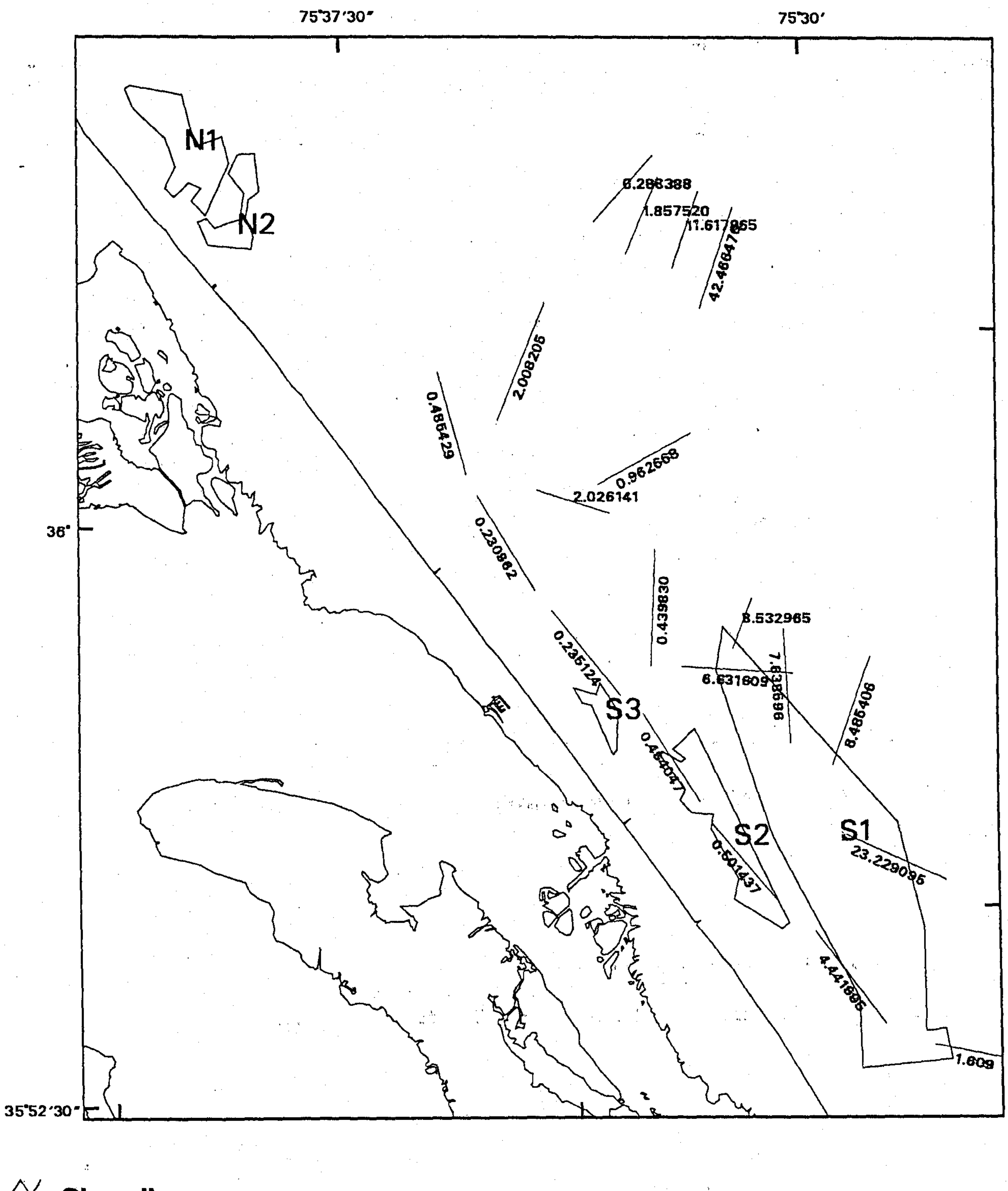
Sand Borrow Areas + 5 Km buffer

0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

USFWS - D. Newcomb, 5/11/99

MAP 10 - 1 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1997



Shoreline

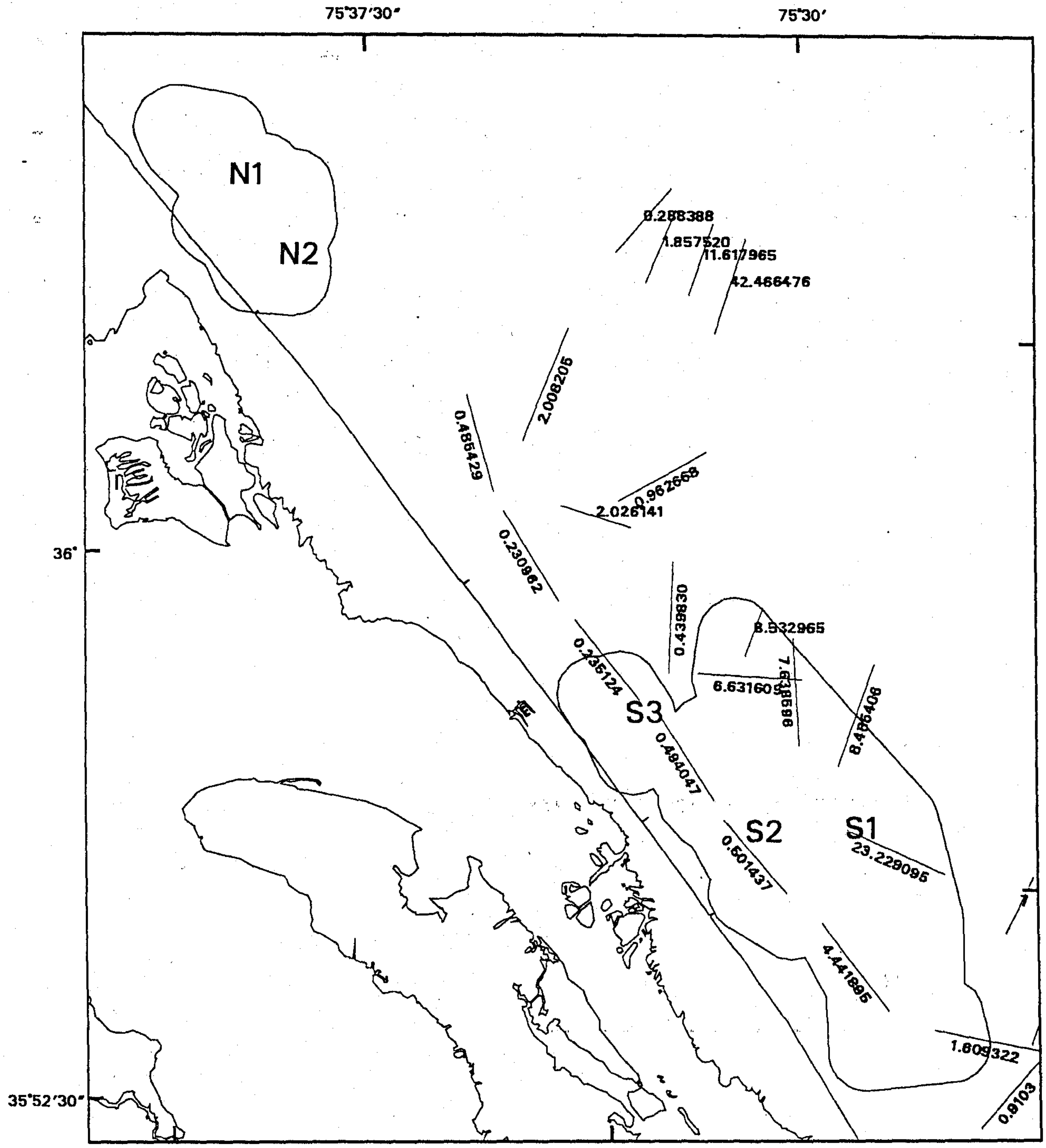
Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas

0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS

USFWS - D. Newcomb, 5/11/99

MAP 10 - 2 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1997



Shoreline

Data Collection Cruises
(Catch per Unit Effort - Fish/1000 cubic meters Trawled)

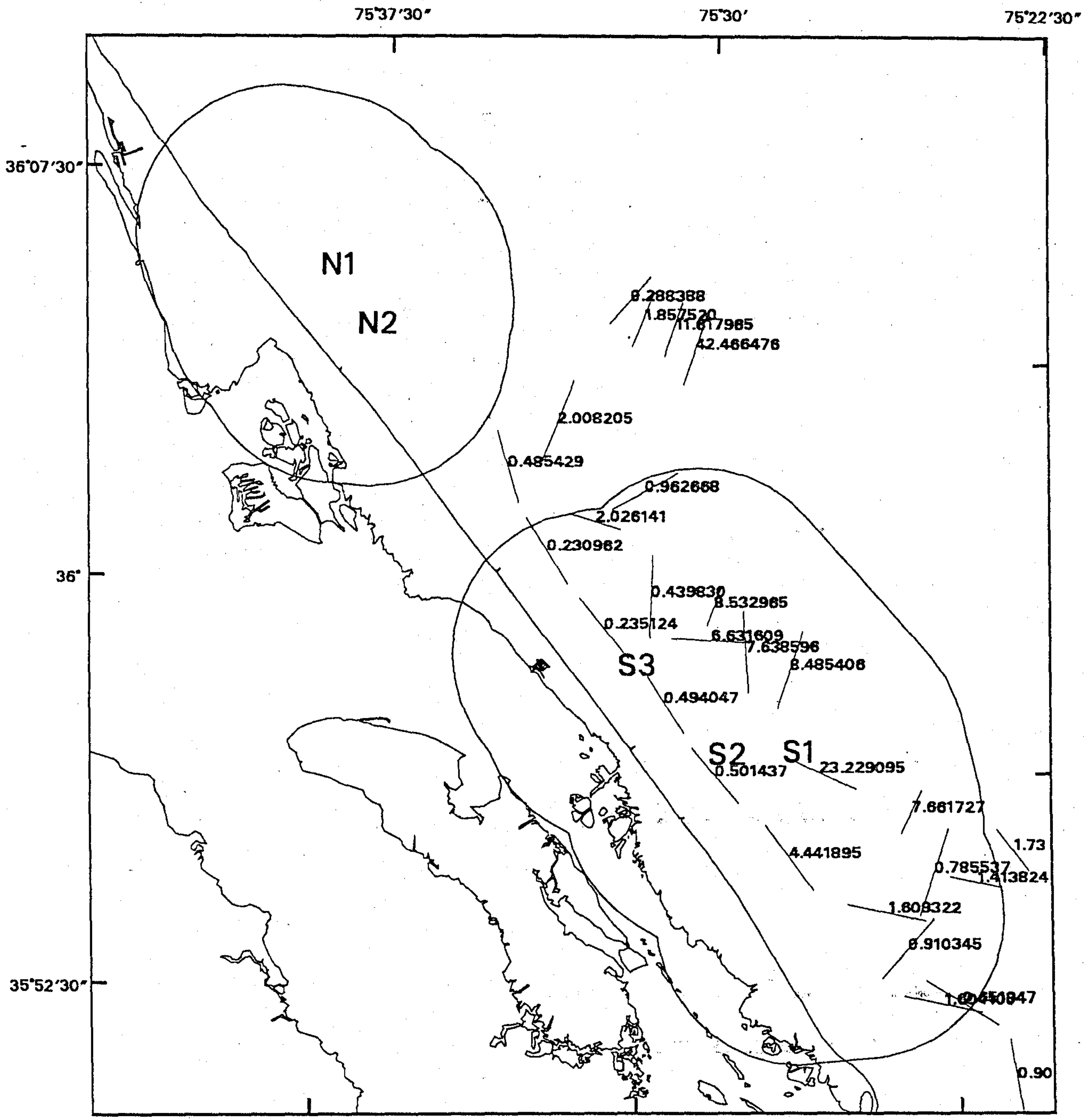
Sand Borrow Areas + 1 Km buffer

0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

USFWS - D. Newcomb, 5/11/99

MAP 10 - 3 STRIPED BASS COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS 1997



0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS

Shoreline

Data Collection Cruises (Catch per Unit Effort - Fish/1000 cubic meters Trawled)

Sand Borrow Areas + 5 Km buffer

USFWS - D. Newcomb, 5/11/99

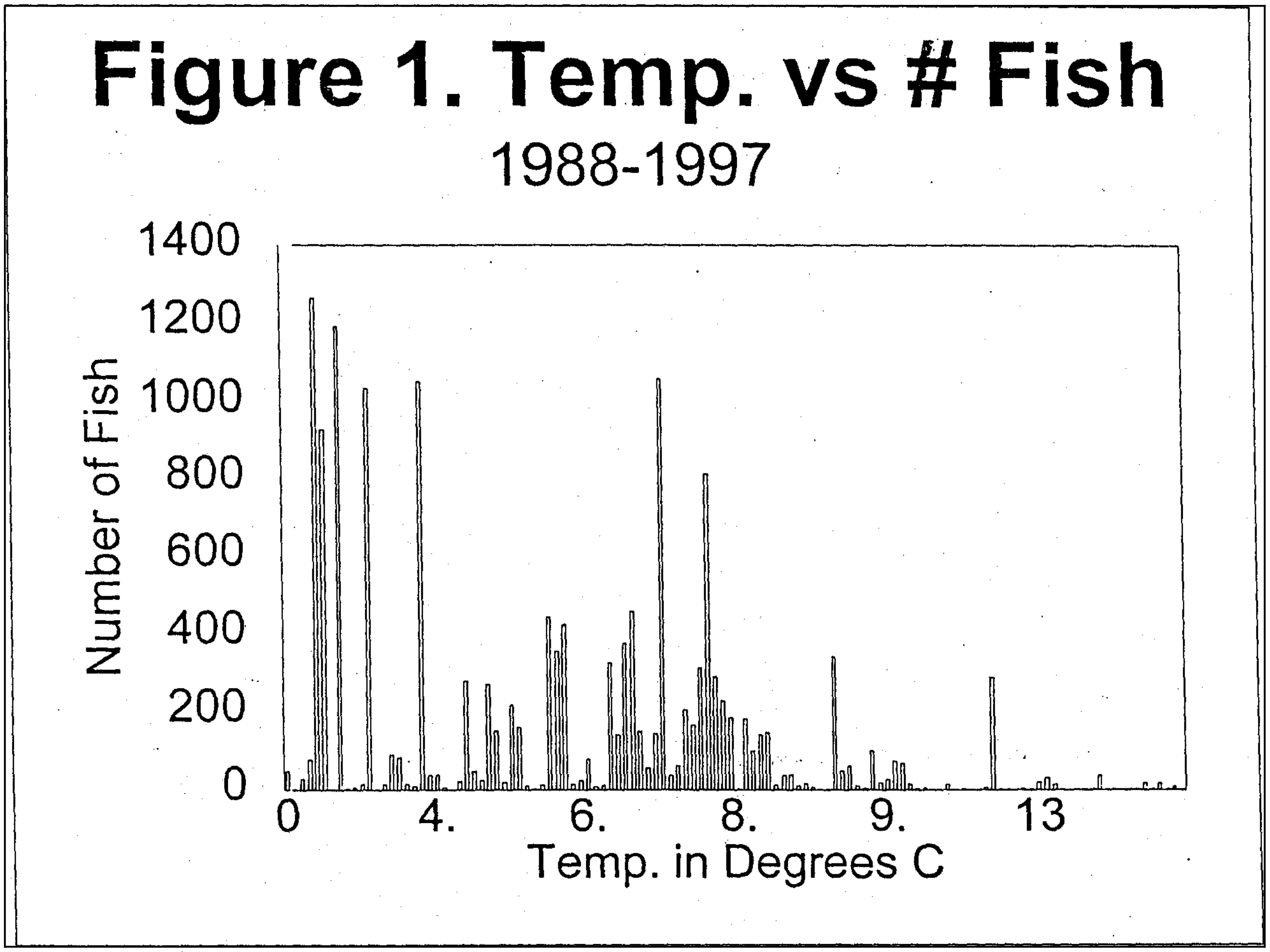


Figure 1. Temp. vs # Fish
1988-1997
Number of Fish
1400
1200
1000
800
600
400
200
0
0
4.
6.
8.
9.
13
Temp. in Degrees C

Figure 2. Depth vs. # of Fish

1988-1997

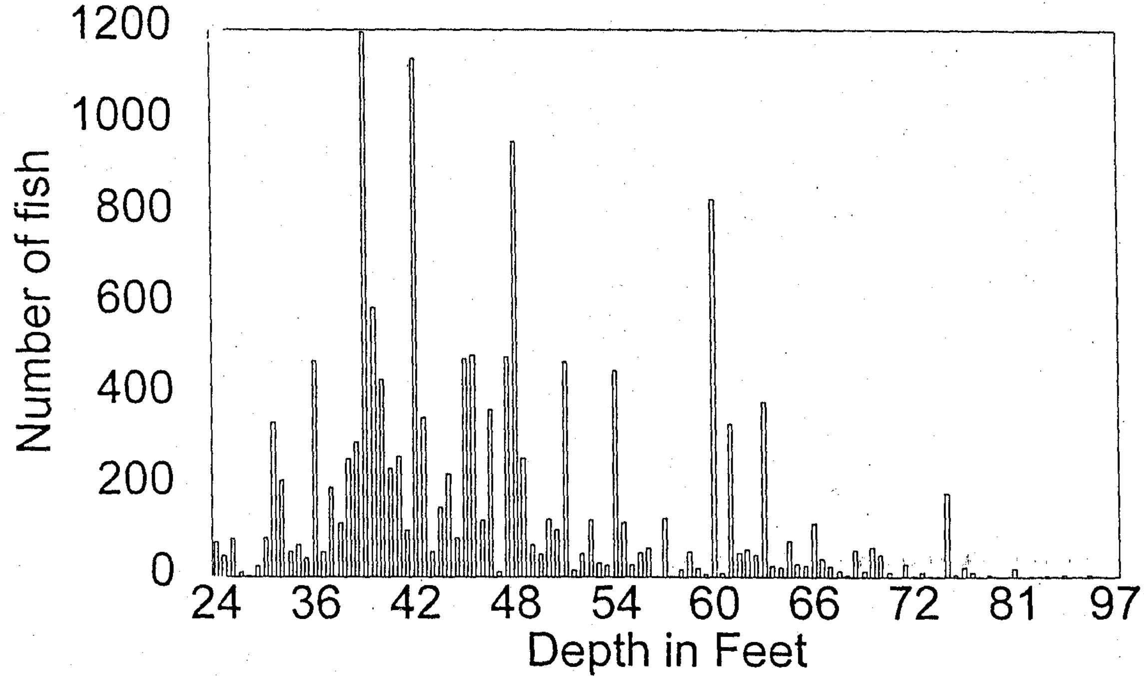


Table 2. Number of cruise tows in proposed borrow sites, and number adjacent to each site within 1 and 5 kilometer radii, 1988-1999 (U.S. Fish and Wildlife Service et al., unpublished data).

Year	Dates	Tows	Tows[1] In Proposed Borrow Sites (N1, N2, S1, S2, S3), + 1 km, and + 5 km														
			N1	+1	+5	N2	+1	+5	S1	+1	+5	S2	+1	+5	S3	+1	+5
1988	Jan 14-24	170	1	3	7	1	3	6	0	0	1	0	1	2	1	1	3
1989	Jan 15-23	175	1	3	6	1	1	3	0	1	4	0	1	4	1	1	4
1990	Jan 16-25	77	1	2	8	3	3	7	0	0	5	0	2	5	2	4	11
1991	Jan 23-Feb 2	81	1	3	11	1	2	12	5	5	19	1	4	8	1	2	5
1992	Jan 18-19; Feb 2-5	53	1	2	4	1	1	3	1	2	3	0	1	3	0	1	4
1993	Feb 2-8	55	1	1	3	0	0	2	1	1	2	1	1	2	0	0	1
1994	Jan 21-26	96	5	5	12	2	4	9	6	8	10	0	0	7	1	2	7
1995	Jan 23-29	57	5?[2]	6	15?	8?	8	12?	0	1	4?	0	1	3?	0	2	3
1996	Jan 23-25; Feb 7-12	204	1	1	2	0	1	3	3	3	11?	1	5	6?	1	3	7
1997	Feb 1-7	131	0	0	0	0	0	0	7	7	15?	2	2	9?	0	2	9?
1998	Jan 16-23[3]	64															
1999	Feb 2-9[3]																

[1] Tows in borrow sites occur only in those sites; for 1 and 5 km radii, tows may occur in more than one site.

[2] Numbers followed by a ? indicate that the actual number of tows in the site is uncertain; further analysis is needed.

[3] Data for 1998 and 1999 are not yet included in the database; analysis is continuing.

Table 3a. Tows(N) within each proposed borrow site and within 1km radius and striped bass CPUE(number of fish per thousand cubic meters; where N>1, value is mean CPUE), by year, SEAMAP Cooperative Winter Tagging Cruises (U.S. Fish and Wildlife Service et al., unpublished data).

	YEAR	1988		1989		1990		1991		1992		1993	
SITE		N	CPUE	N	CPUE	N	CPUE	N	CPUE	N	CPUE	N	CPUE
N1		3	0.70	3	0.47	2	0.67	3	1.54	2	0.50	1	0.42
N2		3	1.14	1	0.20	3	8.75	2	0.75	1	0.87	0	-
S1		0	-	1	0.20	0	-	5	0.28	2	0.38	1	0.25
S2		1	1.28	1	0.19	2	5.25	4	0.27	1	0.13	1	0.42
S3		1	2.26	1	0.18	4	1.20	2	0.46	1	0.16	0	-
	TOTAL	6[1]	1.39	7	0.32	11	3.90	15[1]	0.62	6	0.34	3	0.36

[1] In cases where one or more tows occurred in two adjacent sites, tows were included in both site averages, but only included once for the annual average; therefore, total N may be less than the sum of all site Ns.

Table 3b. Tows(N) within each proposed borrow site and within 1 km radius and striped bass CPUE(number of fish per thousand cubic meters; where N>1, value is mean CPUE), by year, SEAMAP Cooperative Winter Tagging Cruises (U.S. Fish and Wildlife Service et al., unpublished data).

	YEAR	1994		1995		1996		1997		1998[1]		1999[1]	
SITE		N	CPUE	N	CPUE	N	CPUE	N	CPUE	N	CPUE	N	CPUE
N1		5	35.35	6	8.40	1	0.35	0	-				
N2		4	12.57	8	9.08	1	2.10	0	-				
S1		8	4.27	1	0.36	3	0.25	7	8.65				
S2		0	-	1	0.85	5	0.29	2	0.50				
S3		2	1.52	2	0.83	3	0.99	2	0.36				
	TOTAL	17	15.17	16	12.43	11	0.63	10	6.18				

[1] Data for 1998 and 1999 not yet available.

Table 4. CPUE rank of proposed borrow sites, from highest (1) to lowest (5) values, as observed in SEAMAP Cooperative Offshore Winter Tagging Cruises, 1988-1999[1,2] (U.S. Fish and Wildlife Service et al., unpublished data).

SITE RANK	YEAR	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1		S3	N1	N1	N1	N2	N1/S2	N1	N2	N2	S1		
2		S2	N2/S1	N2	N2	N1	S1	N2	N1	S3	S2		
3		N2	S2	S3	S3	S1	-	S1	S2	N1	S3		
4		N1	S3	N1	S1	S3	-	S3	S3	S2	-		
5		-	-	-	S2	S2	-	-	S1	S1	-		

[1] Data for 1998 and 1999 are not yet analyzed.
[2] Blank (-) cells are due to the fact that not all sites were sampled in all years.

Table 5. SEAMAP Cooperative Winter Tagging Cruise, summary of tag returns by state and year for striped bass (data analysis courtesy Victor Vecchio, NY Department of Environmental Conservation).

STATE	88	89	90	91	92	93	94	95	96	97	98	T	%
NS[1]	0	0	1	0	0	0	0	0	0	0	0	1	.03
ME	0	2	8	4	6	9	5	6	3	3	1	47	1.5
NH	0	1	0	2	3	1	3	5	0	0	0	15	0.5
MA	22	26	29	60	44	40	54	49	26	57	6	413	13.5
RI	6	3	9	11	15	9	5	9	8	8	3	86	2.8
CT	6	7	3	9	10	16	7	7	5	9	2	81	2.7
NY	19	23	32	38	33	33	34	32	32	40	14	330	10.8
NJ	9	18	10	17	10	10	17	12	16	16	6	141	4.6
PA	0	1	1	1	0	0	3	2	0	0	0	8	0.3
DE	1	0	6	6	1	4	8	7	8	4	2	47	1.5
MD	30	16	79	124	153	102	267	205	106	104	36	1222	40.1
DC	0	0	2	1	0	0	2	1	0	1	0	7	0.2
VA	37	11	49	48	59	48	129	64	36	57	9	547	17.9
NC	22	2	12	0	7	10	13	11	6	17	6	106	3.5
Total	152	110	241	321	341	282	547	410	246	316	85	3051	100

[1] Nova Scotia

Striped Bass Benthic Dependency Inferred from Food Habits

Digestive tracts of 143 striped bass were collected during the cruises beginning in 1994 and continuing through the present year. Of the 143 collected, 126 (88.1 percent) contained food. Food habits data from striped bass in the study area are presented in Tables 6-13 (NMFS and USFWS et al., unpublished data). Data are presented by year (Tables 6-11), in summary form for the entire time series (Table 12) and by category (fish versus invertebrates) and family (Engraulidae, which are anchovies; Clupeidae, shads and herrings; and Sciaenidae, which are drums, including Atlantic croaker, spot, spotted seatrout and weakfish, among others; Table 13).

Combining data for all years sampled, fish were the dominant prey in terms of frequency of occurrence, number and volume (Tables 12-13). Fish dominated the volume in every individual year as well, constituting from 94.6 % to 100 % of the stomach contents, although in recent years the number of stomachs collected is very small (Table 13). Invertebrates appeared in 15.9 % of the tracts containing food, but were numerically and volumetrically far less abundant, constituting only 1.1 % of identifiable organisms and 0.8 % of total volume. Invertebrates constituted 4.7 % of the contents volume in 1995, but were not present to any great degree in all other years.

Fish prey were totally dominated by anchovies (*Anchoa* sp.), which occurred 80.9 % of the time, and comprised 92.3 % by number and 40.8 percent by volume of the diet (Table 12). Clupeids ranked second overall in terms of frequency of occurrence (38.9 %), and were important volumetrically (47.1 %) but less so numerically (2.4 %). Clupeids which were identified as prey included: American shad (*Alosa sapidissima*), Atlantic herring (*Clupea harengus*), blueback herring (*Alosa aestivalis*), and menhaden (*Brevoortia tyrannus*) (Table 12). Sciaenids were also important in the diet of striped bass during the years sampled. Species identified included: Atlantic croaker (*Micropogonias undulatus*), black drum (*Pogonias cromis*), and spot (*Leiostomus xanthurus*). Overall, sciaenids occurred in the stomachs 14.3 % of the time, and comprised 1.5 % of the diet by number, and 7.7 percent by volume.

In individual years, invertebrates occurred from 0-26.3 % of the time, but constituted only a small fraction of the contents in terms of numbers and volume (Table 13). Invertebrates which were identified included: bivalve and gastropod mollusks (ark shell, *Anadara brasiliana* and dove shell, *Anachis obesa*), polychaete worms, portunid crab, sand shrimp (*Crangon septemspinosa*), sea cucumber (*Thyone briaereus*), and squid.

Overall, the percent of benthic or benthic-consuming prey (in which we include all the sciaenids which were identified, as well as the benthic invertebrates) appeared to be more important in the early years of the study and less so in the last three years. Volume of benthic-associated prey during 1994-1996 ranged from 0.2 to 12.8 % for sciaenids and from trace amounts to 0.3 % for benthic species such as sand shrimp (Tables 6-11; Table 13). In recent years, no invertebrates were present, however sample sizes are very small.

Table 6. STRIPED BASS STOMACH CONTENTS, 1994

Year: 1994
Month: January 22-25
Sizes (mm TL): 439-765
Total Stomachs: 73
Number w/ Contents: 72 (98.6%)

Item	Freq. Occur. (N = 72)		Number (N = 2,315)		Volume (ml) (N = 4,010.4)	
	No.	%	No.	%	No.	%
FISH	72	100.0	2,285	98.7	3,979.1	99.2
Engraulidae	62	86.1	2,116	91.4	1,788.5	44.6
<u>Anchoa sp</u>	62	86.1	2,116	91.4	1,788.5	44.6
Clupeidae	26	36.1	50	2.2	1,532.0	38.2
<u>Alosa aestivalis</u>	4	5.6	5	0.2	19.0	0.5
<u>Alosa sapidissima</u>						
<u>Brevoortia tyrannus</u>	21	29.2	41	1.8	1,493.0	37.2
Unid. clupeid	1	1.4	4	0.2	20.0	0.5
Sciaenidae	13	18.1	46	2.0	516.5	12.9
<u>Leistomus xanthurus</u>	1	1.4	1	tr	10.0	0.2
<u>Micropogonias undulatus</u>	1	1.4	1	tr	8.0	0.2
<u>Pogonias cromis</u>						
Unid. sciaenid	11	15.3	44	2.0	498.5	12.4
Stromateidae						
<u>Peprilus alepidotus</u>						
Unid. Fish	22	30.6	73	3.1	142.1	3.5
INVERTEBRATES	13	18.1	30	1.3	26.3	0.7
Sea Cucumber						
<u>Thyone briaereus</u>						

Cont.

Mollusks	2	2.8	2	tr	1.6	tr
Squid						
Pelecypoda	1	1.4	1	tr	1.5	tr
Anadara brasiliana	1	1.4	1	tr	1.5	tr
Gastropoda	1	1.4	1	tr	0.1	tr
Anachis obesa	1	1.4	1	tr	0.1	tr
Crustacea	11	15.3	27	1.2	21.7	0.5
Crangon septemspinosa	4	5.6	19	0.8	12.8	0.3
Isopoda (parasite?)	6	8.3	6	0.3	0.9	tr
Lironeca ovalis	6	8.3	6	0.3	0.9	tr
Unid. crustacean	2	2.8	2	tr	8.0	0.2
Portunid crab						
Ceratapsis sp.						
Polycheate	1	1.4	1	tr	3.0	tr
MISCELLANEOUS	2	2.8	-	-	5.0	0.1
Fibers	2	2.8	-	-	5.0	0.1
Rocks						
Unid. Matter						

Benthic or benthic feeders:
F.O. = 16 stomachs = 22.2%
Number = 49 items = 2.1%
Volume = 521.1 ml = 13.0%

Table 7. STRIPED BASS STOMACH CONTENTS, 1995

Year: 1995
Month: January 26-29
Sizes (mm TL): 525-718
Total Stomachs: 19
Number w/ Contents: 19 (100.0%)

Item	Freq. Occur. (N = 19)		Number (N = 527)		Volume (ml) (N = 684.4)	
	No.	%	No.	%	No.	%
FISH	19	100.0	518	98.3	647.6	94.6
Engraulidae	17	89.5	493	93.5	262.1	38.3
Anchoa sp	17	89.5	493	93.5	262.1	38.3
Clupeidae	7	36.8	12	2.3	290.5	42.4
Clupea harengus						
Alosa aestivalis						
Alosa sapidissima						
Brevoortia tyrannus	7	36.8	12	2.3	290.5	42.4
Unid. clupeid						
Sciaenidae	4	21.1	6	1.1	75.0	11.0
Leistomus xanthurus						
Micropogonias undulatus	4	21.1	6	1.1	75.0	11.0
Pogonias cromis						
Unid. sciaenid						
Stromateidae						
Peprilus alepidotus						
Unid. Fish	3	15.8	7	1.3	20.0	2.9
INVERTEBRATES	5	26.3	6	1.1	32.1	4.7
Sea Cucumber	1	5.3	1	0.2	10.0	1.5

Thyone briaereus	1	5.3	1	0.2	10.0	1.5
Cont.						
Mollusks	1	5.3	1	0.2	21.5	3.1
Squid	1	5.3	1	0.2	21.5	3.1
Pelecypoda						
Anadara brasiliana						
Gastropoda						
Anachis obesa						
Crustacea	3	15.8	3	0.6	0.1	tr
Crangon septemspinosa	1	5.3	1	0.2	0.1	tr
Isopoda (parasite?)	2	10.5	2	0.4	tr	tr
Lironeca ovalis	2	10.5	2	0.4	tr	tr
Unid. crustacean						
Portunid crab						
Cerataspsis sp.						
Polycheate	1	5.3	1	0.2	0.5	0.1
MISCELLANEOUS	4	21.1	3	0.6	4.7	0.7
Fibers						
Rocks	3	15.8	3	0.6	0.7	0.1
Unid. Matter	3	15.8	-	-	4.0	0.6

Benthic or benthic feeders:
F.O. = 9 stomachs = 47.4%
Number = 11 items = 2.1%
Volume = 86.2 ml = 12.6%

Table 8. STRIPED BASS STOMACH CONTENTS, 1996

Year: 1996
Month: February 8-12
Sizes (mm TL): 665-1,087
Total Stomachs: 34
Number w/ Contents: 25 (73.5%)

Item	Freq. Occur. (N = 25)		Number (N = 650)		Volume (ml) (N = 2,384.5)	
	No.	%	No.	%	No.	%
FISH	25	100.0	648	99.7	2,383.0	99.9
Engraulidae	17	68.0	612	94.2	1,001.0	42.0
Anchoa sp	17	68.0	612	94.2	1,001.0	42.0
Clupeidae	14	56.0	23	3.5	1,286.0	53.9
Clupea harengus	1	4.0	2	0.3	280.0	11.7
Alosa aestivalis	2	8.0	4	0.6	191.0	8.0
Alosa sapidissima	1	4.0	1	0.2	25.0	1.0
Brevoortia tyrannus	7	28.0	11	1.7	706.0	29.6
Unid. clupeid	4	16.0	5	0.8	84.0	3.5
Sciaenidae	1	4.0	1	0.2	5.0	0.2
Leistomus xanthurus						
Micropogonias undulatus						
Pogonias cromis	1	4.0	1	0.2	5.0	0.2
Unid. sciaenid						
Stromateidae	1	4.0	1	0.2	70.0	2.9
Peprilus alepidotus	1	4.0	1	0.2	70.0	2.9
Unid. Fish	4	16.0	11	1.7	21.0	0.9
INVERTEBRATES	1	4.0	1	0.2	1.0	tr
Sea Cucumber						

Thyone briaereus

Cont.						
Mollusks						
Squid						
Pelecypoda						
Anadara brasiliana						
Gastropoda						
Anachis obesa						
Crustacea	1	4.0	1	0.2	1.0	tr
Crangon septemspinosa						
Isopoda (parasite?)						
Lironeca ovalis						
Unid. crustacean						
Portunid crab	1	4.0	1	0.2	1.0	tr
Ceratapsis sp.						
Polycheate						
MISCELLANEOUS	1	4.0	1	0.2	0.5	tr
Fibers						
Rocks	1	4.0	1	0.2	0.5	tr
Unid. Matter						

Benthic or benthic feeders:
F.O. = 3 stomachs = 12.0%
Number = 3 items = 0.5%
Volume = 6.5 ml = 0.3%

Table 9. STRIPED BASS STOMACH CONTENTS, 1997

Year: 1997
Month: February 2-6
Sizes (mm TL): 500-846
Total Stomachs: 12
Number w/ Contents: 7 (58.3%)

Item	Freq. Occur. (N = 7)		Number (N = 115)		Volume (ml) (N = 626.7)	
	No.	%	No.	%	No.	%
FISH	6	85.7	113	98.3	626.0	99.9
Engraulidae	5	71.4	110	95.6	96.0	15.3
Anchoa sp	5	71.4	110	95.6	96.0	15.3
Clupeidae	2	28.6	3	2.6	530.0	84.6
Clupea harengus	2	28.6	3	2.6	530.0	84.6
Alosa aestivalis						
Alosa sapidissima						
Brevoortia tyrannus						
Unid. clupeid						
Sciaenidae						
Leistomus xanthurus						
Micropogonias undulatus						
Pogonias cromis						
Unid. sciaenid						
Stromateidae						
Peprilus alepidotus						
Unid. Fish						
INVERTEBRATES	1	14.3	1	0.9	0.5	0.1
Sea Cucumber						

Thvone briaereus

Cont.						
Mollusks						
Squid						
Pelecypoda						
Anadara brasiliana						
Gastropoda						
Anachis obesa						
Crustacea	1	14.3	1	0.9	0.5	0.1
Crangon septemspinosa						
Isopoda (parasite?)						
Lironeca ovalis						
Unid. crustacean						
Portunid crab						
Ceratapsis sp.	1	14.3	1	0.9	0.5	0.1
Polycheate						
MISCELLANEOUS	1	14.3	1	0.9	0.2	tr
Fibers						
Rocks	1	14.3	1	0.9	0.2	tr
Unid. Matter						

Benthic or benthic feeders:
F.O. = 1 stomach = 14.3%
Number = 1 item = 0.9%
Volume = 0.2 ml = tr

Table 10. STRIPED BASS STOMACH CONTENTS, 1998

Year: 1998
Month: January 20
Sizes (mm TL): ?
Total Stomachs: 1
Number w/ Contents: 1 (100.0%)

Item	Freq. Occur. (N = 1)		Number (N = 5)		Volume (ml) (N = 5.0)	
	No.	%	No.	%	No.	%
FISH	1	100.0	5	100.0	5.0	100.0
Engraulidae	1	100.0	5	100.0	5.0	100.0
Anchoa sp	1	100.0	5	100.0	5.0	100.0
Clupeidae						
Clupea harengus						
Alosa aestivalis						
Alosa sapidissima						
Brevoortia tyrannus						
Unid. clupeid						
Sciaenidae						
Leistomus xanthurus						
Micropogonias undulatus						
Pogonias cromis						
Unid. sciaenid						
Stromateidae						
Peprilus alepidotus						
Unid. Fish						
INVERTEBRATES						
Sea Cucumber						

Thyone briaereus

Cont.
Mollusks
Squid
Pelecypoda
Anadara brasiliana
Gastropoda
Anachis obesa
Crustacea
Crangon septemspinosa
Isopoda (parasite?)
Lironeca ovalis
Unid. crustacean
Portunid crab
Ceratapsis sp.
Polycheate
MISCELLANEOUS
Fibers
Rocks
Unid. Matter

Benthic or benthic feeders:
F.O. = 0 stomachs = 0.0%
Number = 0 items = 0.0%
Volume = 0 ml = 0.0%

Table 11. STRIPED BASS STOMACH CONTENTS, 1999

Year: 1999
Month: February 6
Sizes (mm TL): 615-862
Total Stomachs: 4
Number w/ Contents: 2 (50.0%)

Item	Freq. Occur. (N = 2)		Number (N = 2)		Volume (ml) (N = 4.0)	
	No.	%	No.	%	No.	%
FISH	2	100	2	100	4.0	100
Engraulidae						
Anchoa sp						
Clupeidae						
Clupea harengus						
Alosa aestivalis						
Alosa sapidissima						
Brevoortia tyrannus						
Unid. clupeid						
Sciaenidae						
Leistomus xanthurus						
Micropogonias undulatus						
Pogonias cromis						
Unid. sciaenid						
Stromateidae						
Peprilus alepidotus						
Unid. Fish	2	100	2	100	4.0	100
INVERTEBRATES						
Sea Cucumber						

Thyone briaereus

Cont.
Mollusks
Squid
Pelecypoda
Anadara brasiliana
Gastropoda
Anachis obesa
Crustacea
Crangon septemspinosa
Isopoda (parasite?)
Lironeca ovalis
Unid. crustacean
Portunid crab
Ceratapsis sp.
Polycheate
MISCELLANEOUS
Fibers
Rocks
Unid. Matter

Benthic or benthic feeders:
F.O. = 0 stomachs = 0.0%
Number = 0 items = 00.0%
Volume = 0 ml = 0.0%

Table 12. STRIPED BASS STOMACH CONTENTS SUMMARY

Years: 1994, 1995, 1996, 1997, 1998, 1999
Months: January, February
Sizes (mm TL): 439-1,087
Total Stomachs: 143
Number w/ Contents: 126 (88.1%)

Item	Freq. Occur. (N = 126)		Number (N = 3,614)		Volume (ml) (N = 7,715)	
	No.	%	No.	%	No.	%
FISH	125	99.2	3,571	98.8	7,644.7	99.1
Engraulidae	102	80.9	3,336	92.3	3,152.6	40.9
Anchoa sp	102	80.9	3,336	92.3	3,152.6	40.9
Clupeidae	49	38.9	88	2.4	3,638.5	47.2
Clupea harengus	3	2.4	5	0.1	810.0	10.5
Alosa aestivalis	6	4.8	9	0.2	210.0	2.7
Alosa sapidissima	1	0.8	1	tr	25.0	0.3
Brevoortia tyrannus	35	27.8	64	1.8	2,489.5	32.3
Unid. clupeid	5	4.0	9	0.2	104.0	1.3
Sciaenidae	18	14.3	53	1.5	596.5	7.7
Leistomus xanthurus	1	0.8	1	tr	10.0	0.1
Micropogonias undulatus	5	4.0	7	0.2	83.0	1.1
Pogonias cromis	1	0.8	1	tr	5.0	0.1
Unid. sciaenid	11	8.7	44	1.2	498.5	6.5
Stromateidae	1	0.8	1	tr	70.0	0.9
Peprilus alepidotus	1	0.8	1	tr	70.0	0.9
Unid. Fish	31	24.6	93	2.6	187.1	2.4
INVERTEBRATES	20	15.9	38	1.1	59.9	0.8
Sea Cucumber	1	0.8	1	tr	10.0	0.1

Thyone briaereus	1	0.8	1	tr	10.0	0.1

Cont.

Mollusks	3	2,4	3	0.1	23.1	0.3
Squid	1	0.8	1	tr	21.5	0.3
Pelecypoda	1	0.8	1	tr	1.5	tr
Anadara brasiliana	1	0.8	1	tr	1.5	tr
Gastropoda	1	0.8	1	tr	0.1	tr
Anachis obesa	1	0.8	1	tr	0.1	tr
Crustacea	16	12.7	32	0.9	23.3	0.3
Crangon septemspinosa	5	4.0	20	0.6	12.9	0.2
Isopoda (parasite?)	8	6.3	8	0.2	0.9	tr
Lironeca ovalis	8	6.3	8	0.2	0.9	tr
Unid. crustacean	2	1.7	2	tr	8.0	0.1
Portunid crab	1	0.8	1	tr	1.0	tr
Ceratapsis sp.	1	0.8	1	tr	0.5	tr
Polycheate	2	1.6	2	tr	3.5	tr
MISCELLANEOUS	8	6.3	5	0.1	10.4	0.1
Fibers	2	1.6	-	-	5.0	tr
Rocks	4	3.2	4	0.1	1.2	tr
Unid. Matter	3	2.4	-	-	4.0	tr

Benthic or benthic feeders:
F.O. = 28 stomachs = 22.2%
Number = 63 items = 1.7%
Volume = 613.8 ml = 7.9%

Table 13. Percentages of important food items of striped bass collected during the winter off North Carolina stratified by year, and by frequency of occurrence (F.O.), number of food items (No.), and food volume (Vol.).

Year	Fish			Invertebrates		
	F.O.	No.	Vol.	F.O.	No.	Vol.
1994	100.0	98.7	99.2	18.1	1.3	0.7
1995	100.0	98.3	94.6	26.3	1.1	4.7
1996	100.0	99.7	99.9	4.0	0.2	tr
1997	85.7	98.3	99.9	14.3	0.9	0.1
1998	100.0	100.0	100.0	0.0	0.0	0.0
1999	100.0	100.0	100.0	0.0	0.0	0.0

Year	Engraulidae			Clupeidae			Sciaenidae		
	F.O.	No.	Vol.	F.O.	No.	Vol.	F.O.	No.	Vol.
1994	86.1	91.4	44.6	36.1	2.2	38.2	18.1	2.0	12.9
1995	89.5	93.5	38.3	36.8	2.3	42.4	21.1	1.1	11.0
1996	68.0	94.2	42.0	56.0	3.5	53.9	4.0	0.2	0.2
1997	71.4	95.6	15.3	28.6	2.6	84.6	-	-	-
1998	100.0	100.0	100.0	-	-	-	-	-	-
1999	- 1/	-	-	-	-	-	-	-	-

1/ fish found in stomachs in 1999 could not be identified to family.

Size Distribution

Length-frequency of fish captured in tows in and near the proposed borrow sites will be analyzed to compare size of those fish with that of fish observed in other areas. This analysis requires additional time to complete.

Atlantic Sturgeon in/near Proposed Borrow Areas

Maps 11-1 through 11-3 depict tows occurring in or near the proposed borrow sites which resulted in captures of Atlantic sturgeon. Most tows captured only a single sturgeon. Atlantic sturgeon were captured in and adjacent to sites N1, N2, S2 and S3.

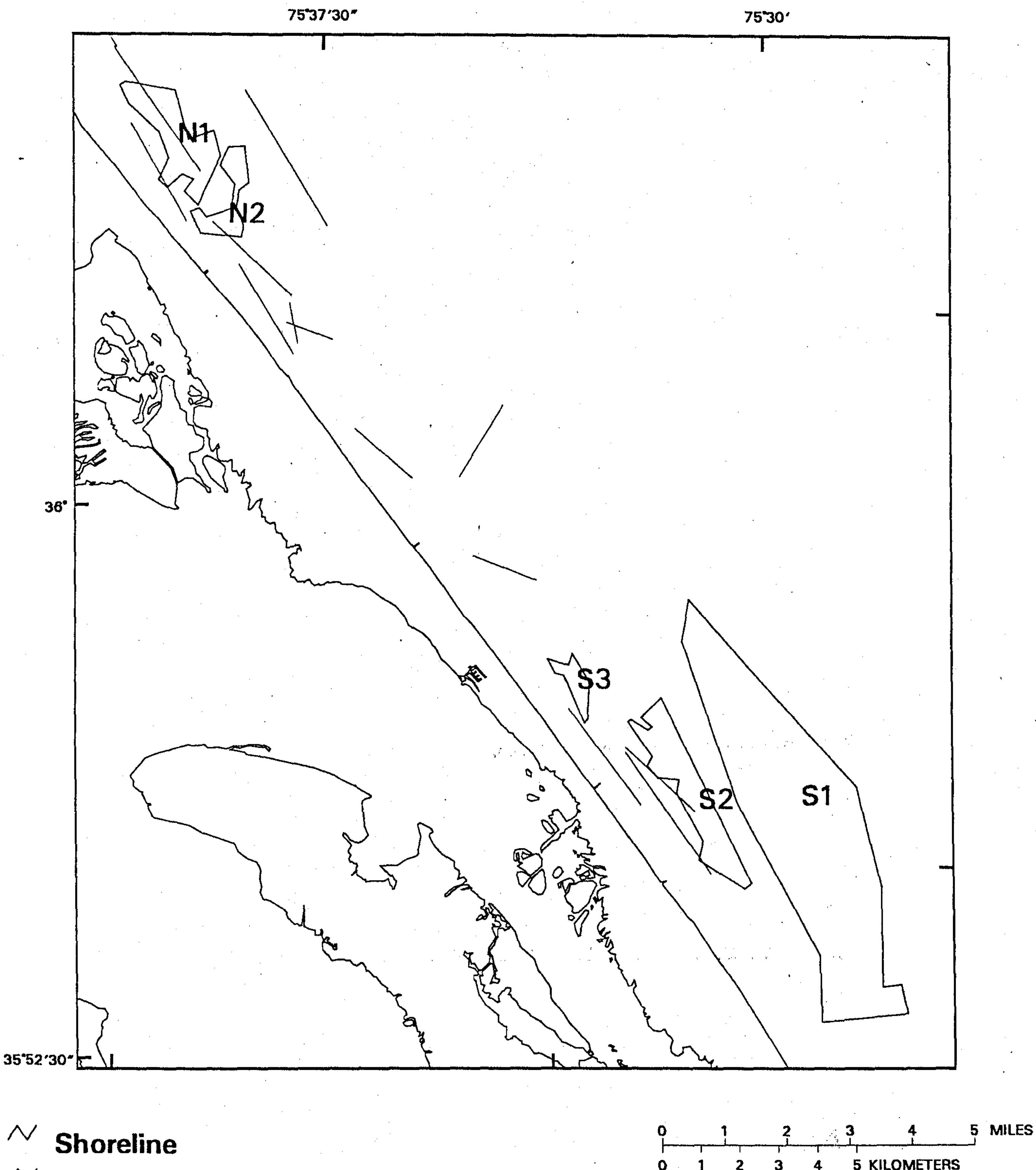
DISCUSSION

Value of the Study Area to Fish and Fisheries

Even this relatively cursory review of limited historic literature, and recent fishery management plans, indicates the highly significant value of the study area, including the proposed borrow sites, to a variety of fish, as well as invertebrate species, which are of importance ecologically, commercially and recreationally. Such value is inferred from the designation of the area as EH or EFH for many species by the ASMFC, federal Fishery Management Councils or NMFS, or both ASMFC and Council(s), and by the high percentage of stomachs containing food of those examined, indicating the importance of the study area as a winter feeding ground.

The fact that the proposed borrow sites may constitute a relatively small percentage of the EH or EFH area designated for a given species may be irrelevant, given the extreme ecological importance of the area to wintering species. The importance of the area for providing an abundance of high quality, high-nutrition prey (anchovies and menhaden) for migratory species prior to the initiation of their rigorous spawning journey, cannot be understated. The importance of the area for striped bass is unquestionable, and the same degree of importance may exist for other species as well. The existence of an area with abundant food, where fish can rest and feed in a relatively undisturbed manner, is likely critical for building energy reserves for both the coming spring migration, development and maturation of reproductive products, and successful reproductive behavior and spawning activity on the spawning grounds. In this regard, the importance of the study area to wintering migratory fish species is likely analogous to the importance of similar wintering or migratory stopover areas for migratory waterfowl and shorebirds. Such areas may be visited for only a short period of time during the journey to the breeding/nesting grounds; however, the protein-rich macroinvertebrate fauna consumed are critical to subsequent successful breeding and mating behavior, clutch production, and brood-rearing activities (R.E. Noffsinger, Wildlife Habitat Management, USFWS, Manns Harbor, NC, personal communication to RWL). Birds which are not in peak condition may not successfully

MAP 11 - 1 ATLANTIC STURGEON COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS



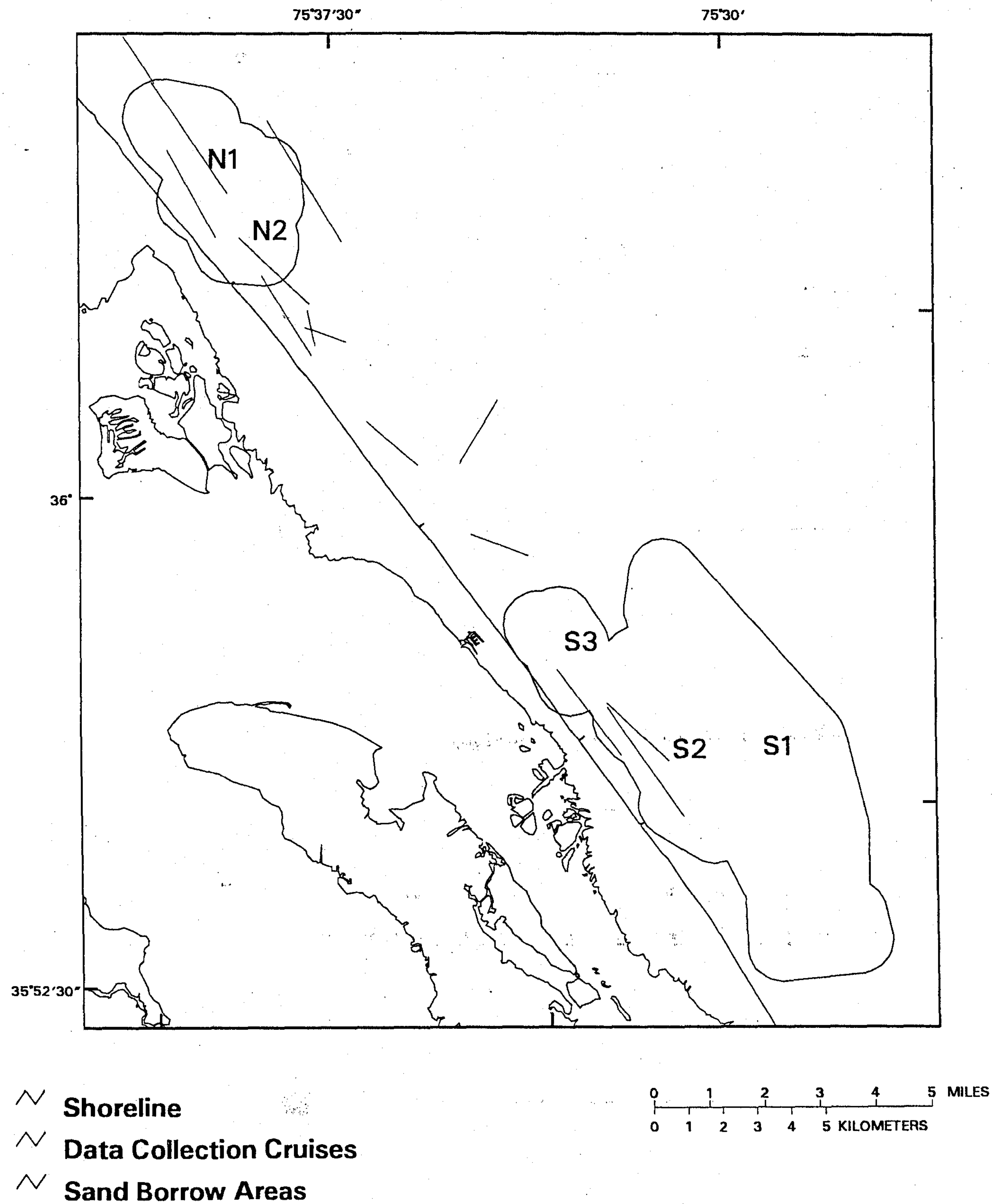
Shoreline

Data Collection Cruises

Sand Borrow Areas

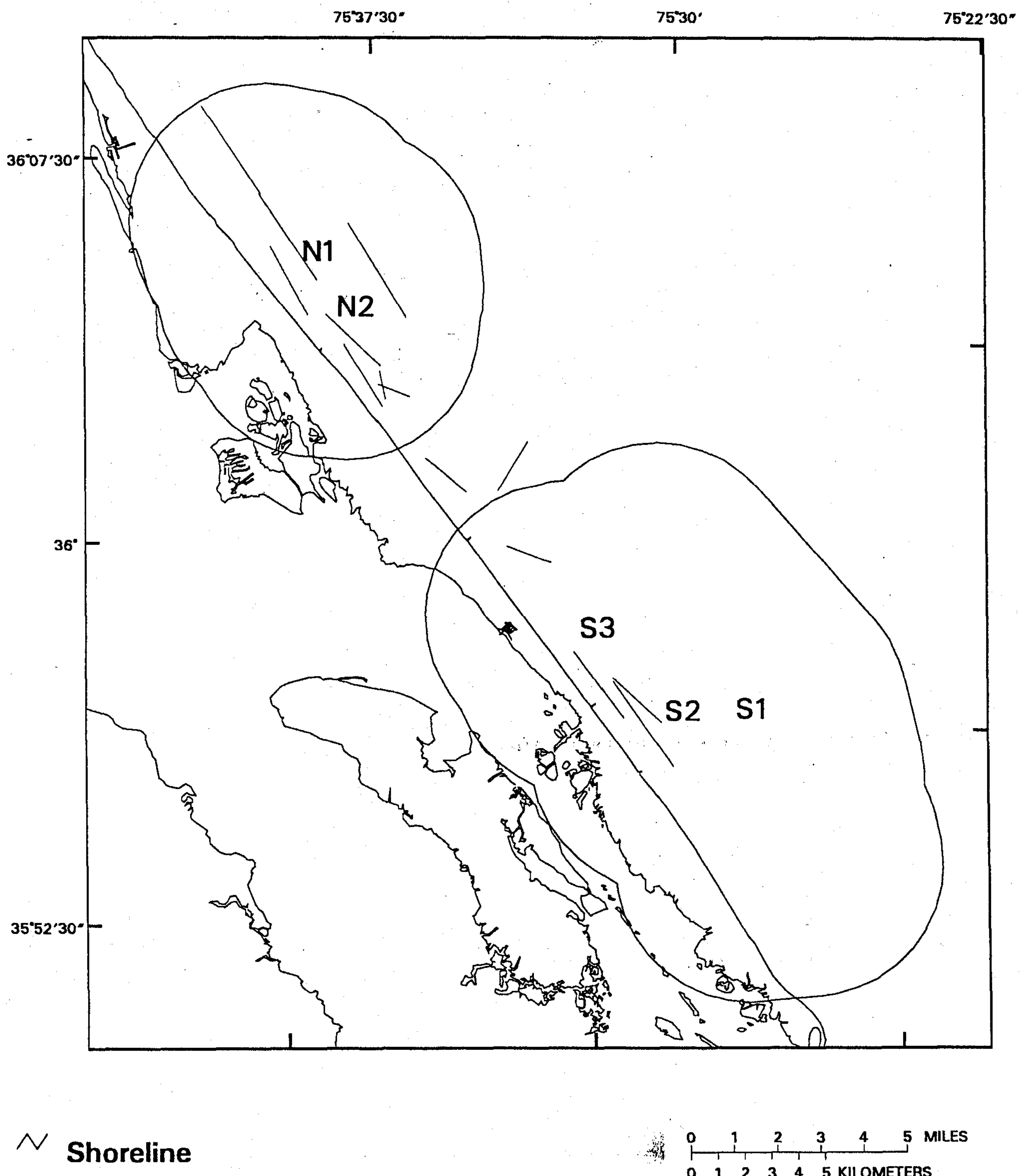
USFWS - D. Newcomb, 5/21/99

MAP 11 - 2 ATLANTIC STURGEON COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS



USFWS - D. Newcomb, 5/21/99

MAP 11 - 3 ATLANTIC STURGEON COLLECTION CRUISES NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS



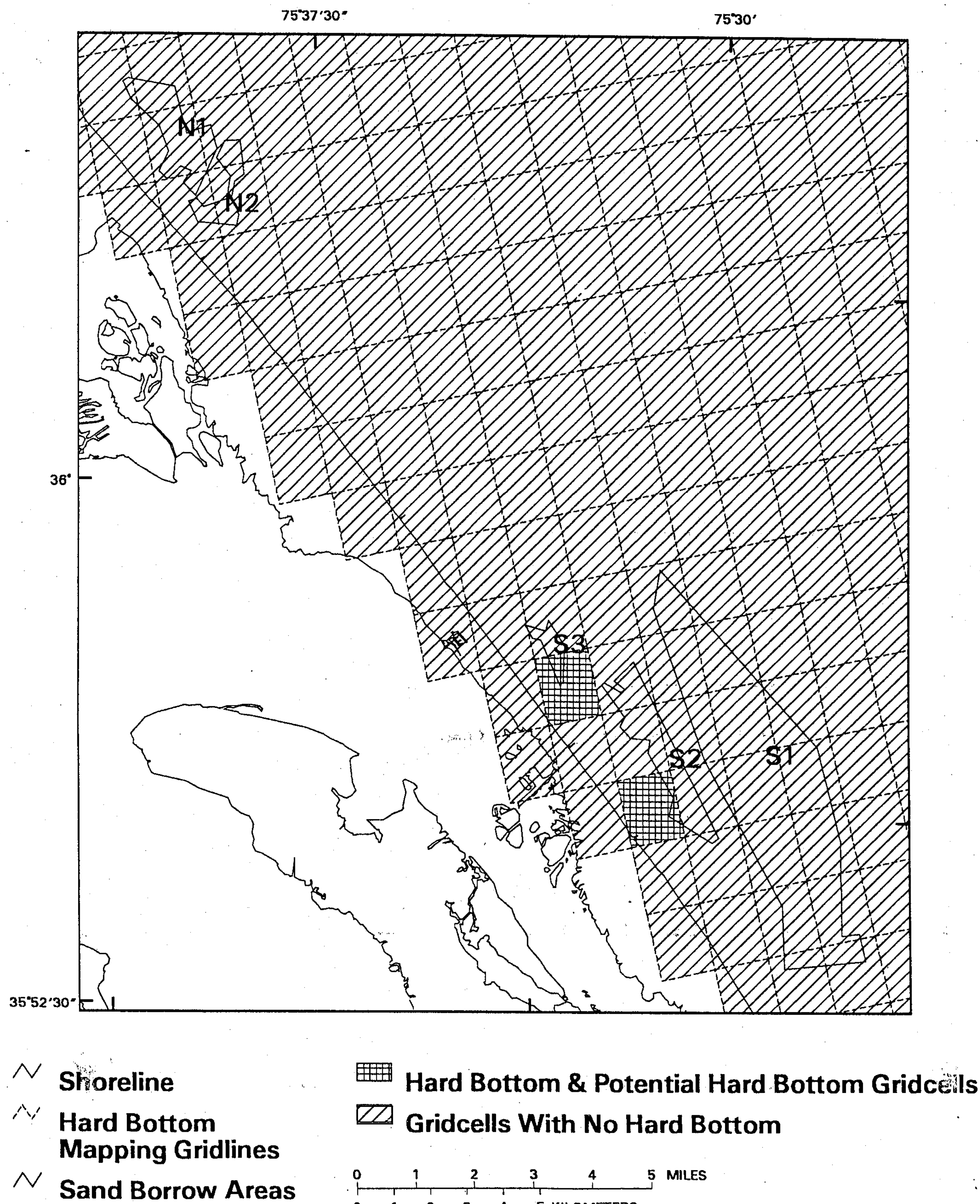
Shoreline

Data Collection Cruises

Sand Borrow Areas

USFWS - D. Newcomb, 5/21/99

MAP 12 SAB SEAMAP PROJECT MAPPED HARD BOTTOM AREAS NEAR DARE COUNTY BEACHES PROJECT BORROW AREAS



USFWS - D. Newcomb, 6/21/99

complete their life cycle, and we suspect the same is true for fish which are unable to successfully feed and rest during the winter to prepare for their spring spawning migration.

Given the likely importance of the study area to striped bass and other species, the potential impacts of the proposed project are of great concern. It appears, based on the analysis by Drs. Hall (1999) and Dolan (personal communication to RWL) that the potential is high for disturbance and alteration of the proposed borrow sites in particular, as well as the study area in general, not only during construction of the proposed project, but also on a permanent and ongoing basis during project maintenance. It is unknown at this time exactly what the impacts of the anticipated disturbance will be on fish and invertebrates, as well as wintering waterfowl, which may use the study area. We are committed to work with the Corps to assess the likelihood of such impacts and to develop ways to avoid or minimize such impacts, should the proposed project eventually be constructed.

It is the opinion of the authors that the best strategy for ensuring that no impacts occur is to avoid the construction alternative entirely. Our present understanding is that Hall (1999) preferentially recommends a non-structural alternative to the Corps' proposed sand-mining and beach deposition proposal, and we concur with that recommendation. Any future documents prepared for the project should thoroughly evaluate such an alternative, including the purchase and placement in public ownership of any beachfront property which succumbs to the combined forces of beachfront erosion, hurricane-induced wave action, and/or rising sea level. Implementation of a non-structural alternative will avoid all construction-related impacts to all species using the study area.

Striped Bass Presence and Abundance in the Study Area

Striped bass were captured in all years, at all sites where tows were conducted. Given the historical use of the area by striped bass, it is apparent that the species is reestablishing a presence in the area, no doubt as a result of recovery facilitated by the imposition of a stringent management plan (ASMFC Striped Bass Plan Development Team 1995). Catch per unit effort values were consistently higher in and near the proposed northern borrow sites than in and near the proposed southern ones, however the statistical validity of the observed trend has yet to be determined. As expected, value of CPUE tends to rise in more recent years, consistent with the recovery of the stock. Data are presently being analyzed to compare the CPUE of striped bass from tows in and near the proposed borrow sites to those outside the area, in an effort to assess relative importance of the proposed borrow sites.

Striped Bass Winter Habitat Characterization

Additional analysis is needed to further characterize striped bass winter habitat in the study area. Plots of fish numbers versus depth and temperature suggest little correlation with depth, but indicate a strong correlation with lower temperatures. This conclusion is again to be expected, given that all the sampling was conducted in the winter, when temperatures are normally lower.

Even though the range of temperatures sampled was narrow, numbers of striped bass within tows did appear to be somewhat consistently higher at temperatures below 5 degrees Centigrade (Figure 1).

Striped Bass Benthic Dependency

Based on our preliminary analysis, striped bass in the study area do not appear to be highly dependent upon prey which are benthic or which feed upon benthos, and are very dependent upon schooling filter feeders from the families Engraulidae and Clupeidae. However, it must be noted that in the initial years of collecting samples, 1994 and 1995, the percent volume of sciaenids constituted 12.8 and 11 % of the contents, respectively. The number of samples collected during those years is higher than in subsequent years; therefore, the greater volume of benthic-dependent prey from those years may better reflect actual dependence upon benthic prey than the results from later years, in which sample sizes are very small. From the perspective of having adequate sample size, results from 1994, in which the highest number of stomachs was collected, may most accurately reflect the characteristics of striped bass food habits in the study area. In that year, fish comprised 98.9 % of the contents by volume and invertebrates 0.7 %. Sciaenids constituted 12.8 %, a majority of which (12.4 %) were not identifiable to species. Additional sampling on a more intensive basis is required to definitively document the diet of striped bass in and near the proposed borrow sites.

One conclusion that the data do warrant making is that the study area is a very important feeding area for wintering striped bass. The overall percentage of stomachs which contained food, all years combined, was 88.1 %, which is very high. Percentages from individual years ranged from 50-100 percent, which is again very high considering that sample sizes in the later years are very small (Tables 6-11). The importance of the wintering area in providing a readily abundant source of food, given that wintering striped bass need to build nutritional reserves for undertaking a long and stressful spawning migration, cannot be overly stated.

Much additional information is required in order to fully assess the impact of the Corps' proposed study area modifications upon the use of the area for foraging by striped bass and their prey, and as a staging area for migration to the spawning grounds. As noted by Quinn and Leggett (1987) migration reflects the internal state of the fish, including changes in hormones associated with osmoregulatory and reproductive physiology, and the preeminent biological needs of the fish at that time--such as predator avoidance, travel, growth, or reproduction (Quinn and Leggett 1987, p. 377). The influence of oceanographic features, they note, may vary substantially depending upon the motivational state of the fish involved. Alterations proposed by the Corps in the wintering grounds must be carefully assessed against the high importance of the area for a significant percentage of the migratory striped bass brood stock from the east coast.

Striped Bass Size Distribution

This issue will be discussed in the final version of this report.

Atlantic Sturgeon in/near Proposed Borrow Areas

Atlantic sturgeon juveniles were present in and near the proposed borrow sites. Four of the five sites yielded Atlantic sturgeon juveniles during SEAMAP Cooperative Winter Tagging Cruise operations, suggesting that the areas are used as a winter nursery by the species.

RECOMMENDED CONSERVATION MEASURES

Impact Avoidance Options

The most effective strategy for avoiding impacts to fish, and fisheries, in and near the proposed borrow sites is not to construct the project. This will avoid all the impacts associated with the proposed project. Impacts which would occur are addressed in detail in Hall (1999) and MAFMC et al. (1998) and include: 1) direct removal/burial of organisms as a result of dredging and placement of dredged or mined material; 2) turbidity/siltation effects, including increased light attenuation from turbidity, alteration of bottom type, and physical effects of suspended sediments on organisms; 3) contaminant release, and uptake, including nutrients, metals, and organics from interstitial water and the resuspended sediments; 4) release of oxygen-consuming substances, such as sulfides; noise/disturbance to terrestrial and aquatic organisms; 6) and, alterations to the hydrodynamic regime and physical habitat. All these impacts would be avoided under the no construction alternative.

A second alternative would be to relocate structures jeopardized by the retreating beachfront, rather than providing artificial protection against natural processes. This alternative also would avoid all impacts to aquatic resources by avoiding any impacts which will result from dredging sand deposits from offshore areas and placing them on the beach.

A third option is to seek alternative sources of material for constructing the proposed project other than offshore deposits which lie within significant wintering grounds for major stocks of highly important ecological, commercial and recreational fishery resources. This could include upland sites, as well as alternative ocean or estuary sites, if they can be located, where resource values may be less and where EH or EFH has not been designated. This option would avoid the impacts to the offshore wintering grounds, but would still entail placement of sediments upon the beach and associated deposition impacts.

Necessary Future Research and Monitoring

The following studies should be funded by the U.S. Army Corps of Engineers, Wilmington District, should they decide to pursue the proposed project (costs of the studies should be fully developed and included in the Corps' cost-benefit analysis of project alternatives):

- 1) Additional survey work should be conducted during the SEAMAP Cooperative Winter Tagging cruise in 2000, 2001 and possibly additional years to further determine the composition and density of fish, marine mammal and avian communities using the proposed borrow sites;

- 2) partner with the NMFS, or with commercial fishermen through the NC Fishery Resources Grant Program of the NC Marine Fisheries Commission, to conduct a survey of the proposed borrow sites to determine species present in or near the sites during the remainder of the year;

- 3) detailed monitoring and analysis of benthos present in the proposed borrow sites should be conducted, especially during the winter months when Atlantic sturgeon, spiny dogfish, striped bass and weakfish are present in and near the proposed borrow sites;

- 4) additional food habits studies of selected species using the proposed borrow sites should be conducted, to more precisely define the percentage of benthic prey in the diets of those species (possible candidate species may include Atlantic croaker, spiny dogfish, striped bass, weakfish);

- 5) ambient turbidity levels present in the proposed borrow sites should be measured, under a variety of sea and wind conditions, to provide a baseline against which measurements made during any Corps construction or maintenance activities can be assessed;

- 6) fine-scale bottom topography of the proposed borrow sites should be prepared, in order to assess the degree of change which occurs during any future sand-mining of the sites, as well as to assess the degree to which current topographic features of the sites may provide resting/sheltering areas for wintering fish;

- 7) quantitative studies, similar to those being funded by the NC Department of Transportation, Division of Highways, on Pea Island to the south, should be designed to assess the impact of beach deposition of mined sands upon coquina (*Donax variabilis*) and mole crab (*Emerita talpoidea*) populations which form the base of surf-zone aquatic food webs and will be adversely impacted by the proposed project, ;

- 8) and, quantitative assessment should be conducted of the numbers and species of benthic organisms killed during any sand-mining of the proposed borrow sites.

Essential Fish Habitat Consultation Requirements

The U.S. Army Corps of Engineers, Wilmington District, must consult with the National Marine Fisheries Service regarding the impact of the proposed project on those species for which the proposed borrow sites and adjacent areas have been determined to constitute Essential Fish Habitat (reference Table 1). Although the study area has not been formally designated as EFH for anadromous species, Councils are mandated to comment to the Corps regarding the impact of the proposed project on those species; therefore, the New England, Mid-Atlantic and South Atlantic Fishery Management Councils, as well as the Atlantic States Marine Fisheries Commission, should be contacted and provided with an opportunity to review the Corps' draft environmental document for the proposed project.

The consultation process in the Southeast Region of the NMFS is addressed in NMFS (1999). As noted in the introduction and Table 1 of this report, the study area has been designated as EFH for species other than those addressed herein through the analysis of data from Cooperative Winter Tagging Cruises. NMFS (1999) contains a list of the species managed by the SAFMC and NMFS, their EFH, and the geographically defined Habitat Areas of Particular Concern (HAPC) identified in Council Fishery Management Plans. In North Carolina, the SAFMC identified the sandy shoals of Cape Hatteras, not too distant from the study area, as an HAPC.

Consultation requirements in the Magnuson-Stevens Fishery Conservation and Management Act direct federal agencies to consult with NMFS when any of their activities may have an adverse effect on EFH (NMFS 1999; see also NOAA 1999 for information on the NMFS northeast region). The EFH rules define an **adverse effect** as "any impact which reduces quality and/or quantity of EFH...[and] may include direct (e.g., contamination or physical disruption), indirect (e.g., loss of prey, reduction in species' fecundity), site-specific or habitat wide impacts, including individual, cumulative, or synergistic consequences of actions." Since the proposed project would result in the removal from the study area of an estimated 88.7 million cy of substrate during the course of the proposed 50-year project life, it would appear that it meets the criteria for constituting an adverse effect and that the Southeast Region of NMFS should be contacted by the Corps for that purpose.

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APPENDIX C

Review of the Beach Nourishment Plan for Dare County, North Carolina

by

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Review of the Beach Nourishment Plan for Dare County, North Carolina
Submitted to the U.S. Fish and Wildlife Service
Raleigh, North Carolina

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1.0 Introduction

The success of any beach restoration project, and the environmental consequences, are usually determined on the amount of sand available, its compatibility with sands in the area being nourished, and the distance the sand must be transported. As simple as this may seem, success is seldom achieved completely because, with the exception of tidal inlets, most source areas for beach nourishment are sedimentary deposits that have developed from processes that differ to some degree from those responsible for the formation of beaches. The mean sand size of an offshore source may, for example, match the beaches to be nourished, suggesting that compatibility would not be a problem, but if the range of sand sizes (sorting) is significantly different, this can contribute to lower retention of the nourishment as well as serious environmental problems. If the grain size of the new sand is smaller than the native beach material, it will be removed from the nourished beach at rates higher than anticipated. The rapid removal of the fine fraction of the nourishment can lead to increased turbidity and alteration of the beach-face configuration, changes that can impact the intertidal fauna living on and within the beach.

2.0 Evaluation of Beach Nourishment Design

In the evaluation of a beach nourishment project, the factors that are taken into consideration are: [1] the compatibility of the nourishment with the native sand; [2] whether the amount of sand needed to rebuild the beaches is correctly estimated relative to the characteristics of the nourishment material and the processes acting on the beach (waves and storms); [3] that the sand is placed on the beach (configuration) so that the losses are minimized; and [4] that the environmental implications of the nourishment project have been taken into consideration. The least desirable and potentially harmful sediment that can be introduced as nourishment is material in the silt and clay-size ranges. Many coastal engineers maintain that a successful beach nourishment project is possible with up to 10 percent fine grain-sized sediment, but these judgements are based mostly on the engineering and economic objectives. Most beach fauna cannot survive a beach nourishment project that includes as much as 10 to 15 percent silt and clay.

2.1 <u>Compatibility of the Beach Nourishment</u>: Compatibility is a term used by coastal engineers and scientists to describe the match between the attributes of the indigenous beach sediment and the attributes of the material being introduced. The degree of "compatibility" will generally determine the success or failure of the beach nourishment project. The morphology of a beach is determined by the marine processes active in the area in association with the sediment characteristics. Fine sand beaches with moderate wave and current action will have a particular morphology reflective of the process-sediment relationship. Coarse-grained beaches exposed to the same moderate wave and current action will have a distinctly different morphology.

2.2 Physical Implications of Compatibility: In any beach nourishment project, the primary objective is to add sand that has attributes that are as close as possible to the native beach materials. If the new sand size differs significantly from the indigenous beach material, this will lead to a new morphologic state, which may be unattractive, unstable, and unacceptable environmentally. Fine-grained sediment (0.10 mm and less) responds to hydraulic processes differently than medium-to coarse-grained sediment (0.30 to 0.75 mm). Fine-grained sediment, for example, is more likely to consolidate or compact into tightly structured deposits with flatter profiles than those produced by medium-to coarse-grained sediment, and although the fine-grained sediment is more difficult to mobilize by waves and currents, once it is placed in motion it is easily transported away from the higher energy hydraulic environments of the beach and inshore.

Beach nourishment composed of sand coarser than the native beach sediment is seldom available because source areas for materials in the larger size ranges are rare. Beach nourishment projects carried out in Florida have utilized material from offshore locations (rocky outcrops) that is cemented into aggregates and thus responds to hydraulic processes accordingly. Although these beaches have been rebuilt with the coarser material, the success as measured from the standpoint of maintaining attractive stable beaches, similar to the pre-project beach conditions, may not be achieved.

Compatibility also affects the retention of the new beach fill. Even if the average grain size of the introduced sediment is almost an exact match with the beach receiving the nourishment (i.e., seemingly compatible), this will not necessarily result in a successful and stable beach because the range of grain sizes in the sediment, or its sorting, plays an important role. For example, if the average grain size of the native beach sediment is 0.50mm, with a range in sizes between 0.35 and 0.80mm, the nourishment introduced is not fully compatible if it has a significantly different spread or range of sizes; that is, the average for the new sand could be exactly the same as the beach (0.50mm), but the range in sediment sizes could be from 0.10 to 0.70mm. In this hypothetical case, the finer fraction of the new material, sediment in the 0.10 to 0.30 size range, would be selectively sorted and removed from the new beach by wave and current action.

2.3 Biological Implications of Compatibility: In addition to the importance of sediment compatibility relative to the physical implications, there are significant biological factors to consider. Beaches are high-energy hydraulic systems. The fact that one does not find beaches composed of clay or fine silt-sized particles reflects the high sediment transport processes within the surf-zone and across and along the subaerial beaches. If a beach nourishment project includes new material with a significant amount of silt or clay, this will lead to rapid removal and transport offshore or into the bays and sounds via the inlets. The result is usually high sediment content in the transport pathways (turbidity), and accumulations of the fine-grained material in areas of lower hydraulic energy. If the silt and finer grain sizes represent approximately 10% or more of the nourishment material, as this "winnowing" process of the fine particle takes place, the beach morphology will also change. The slopes will be flatter, near vertical beach scarps will develop, and the beach surface will be densely packed and difficult to penetrate.

The mobilization and transport of the finer materials in the beach nourishment can impact the invertebrates that occupy the beach and nearshore areas. Most of these organisms (see later section) have evolved and adapted to living in a high-energy hydraulic environment; in fact, many actually depend on the fluid motions to alter their locations on the beach to optimize feeding opportunities. With the introduction of a new range in sediment sizes, and the multitude of physical changes that result, many of these indigenous invertebrates simply cannot survive. The impacts can be of two types: (1) In the case of large quantities of sediment placed on the beach or within the inshore over a relatively short period of time, the organisms can be overwhelmed and unable to avoid permanent burial and death; (2) If the new sediment compatibility is significantly different, this may alter the normal habitats to such a degree that the organisms may not be able to adapt.

3.0 Evaluation of the Dare County Beach Nourishment Plan

In the discussion that follows, I have separated my comments into direct and indirect implications of the Corps of Engineers plan to nourish the beaches of Dare County as described in the documents available to me at this time.

3.1 Direct Implications: As stated above, the most important factor that will determine the overall environmental implications of a beach nourishment project is the compatibility of the introduced beach material with the indigenous beach sands. One might assume that if the source areas for the nourishment are sedimentary deposits immediately offshore from the beach that compatibility would be assured, but this is not necessarily the case. In many nourishment projects, the sands offshore is finer than the native sand with different sorting attributes.

Based on the data obtained from the Corps of Engineers, including the size analyses of sediment samples from the subaerial beach (Figures 1 and 2; Table 1 attached at the end of this report) and vibracores from offshore locations (Figures 1 and 2; Table 2), it is possible to compare the differences in the overall attributes of the source areas and the subaerial beach.

3.2 Characteristics of the Native Beach Sand: Table 1 provides the results of size analyses of samples collected from the subaerial beach between Southern Shores and South Nags Head; the locations are given on Figures 1 and 2. The station locations are indicated on the figures as numbers starting to the north at Southern Shores with station number 10, and ending to the south at South Nags Head with station number 1020. Five samples were collected at each station location, starting at the lower part of the beach (lower foreshore) and progressing across the beach to the base or toe of the dune (if one existed). The samples were processed for size and sorting characteristics at the Corps of Engineers laboratory in Atlanta.

In Table 1 I have provided at the bottom of each column of sample results the mean grain size for the samples in each of the beach locations. It can be seen from these results that the mean for all of the lower foreshore samples was 1.60 mm; the midforeshore, 0.87 mm; the upper-foreshore, 0.81 mm; the berm, 0.71, and the toe of the dune, or uppermost on the beach, 0.61 mm.

Figures 3-1 through 3-5 provide a second presentation of the beach sample results. In these figures I have plotted the raw data (the irregular line on each chart), the grand mean for all of the samples collected at the five stations (the horizontal lines), and a smooth curve that filters out much of the high frequency variation. These figures allow comparison of the beach sand sizes from one location to another along the coast in the Dare County project area. It is evident in all of these tabulations and plots that the sediment making up the beaches of Dare County in the project area is coarse-grained; and that the northern sector of the project area (Southern Shores and Kitty Hawk) has significantly coarser beaches than areas to the south. However, smaller is a relative term in that the grain size for the beach environments in the South Nags Head area is still relatively coarse, averaging 0.50 mm for the mid-foreshore. These results are similar to the mid-foreshore samples collected along Pea Island during a monitoring project carried out in conjunction with the dredging of Oregon Inlet (Dolan and Donoghue, 1996).

3.3 <u>Characteristics of the Nourishment Sediment:</u> Table 2 is a tabulation of the size analyses for "vibracores" that were collected offshore from the beaches in the project areas in regions that might serve as potential source areas for beach nourishment. I have restructured the original Corps of Engineers spreadsheet to list the results in numerical order, and I have calculated the mean grain sizes and sorting (D16 and D84) for the samples collected from each core; in other words, the mean sediment size for each vibracore. On the last page of this table, I have listed the "grand mean" grain size and sorting for all of the cores listed. The overall mean for the vibracore samples of D16, D50, and D84 is 0.18 mm, 0.31 mm, and 0.70 mm, respectively.

On Figures 1 and 2 the Corps of Engineers has identified the most promising source areas for nourishment within the overall field covered by the vibracoring. These are listed as N1, N2, and S1, S2, and S3. In an effort to obtain a better indication of the direct relationship between source area and native beach sand characteristics, I tabulated the results of the size analysis of the vibracores collected within each of these areas. These are listed on Table 3.

3.4 <u>Compatibility of the Sediment from Potential Borrow Sites with Native Beach Sands</u>: It is clear from the Corps of Engineers sediment data that there is a significant difference between the average sand sizes of the samples collected from the subaerial beaches in the Dare County project areas and the vibracore data collected from offshore. For example, the mean grain size for the three beach foreshore samples sites is 1.09 mm, compared to the grand mean grain size for all of the vibracores of 0.31 mm. This is a very significant difference. Further comparison of the summary statistics shows that even the grand mean of the coarsest fraction of the vibracores (D84) is still significantly smaller than the mean of the mid-foreshore (0.70 mm versus 1.09 mm) sand. On Figure 4 I have plotted the D84, D50, and D16 statistics for the vibracore results on a plot of the mean sand size along Dare County. It can be seen that most of the sand sizes of the native beaches are coarser than the D84 of the offshore material.

The obvious conclusion is that a substantial percentage of the material that would be extracted from the identified source areas offshore would be finer in grain size than the native beaches, and thus suggests that the hydraulics of the beaches in the project area would be too energetic for the finer fraction to have a very long residence time in the project areas. The tabulations of the vibracore results for the areas specifically designated as promising nourishment sites by the Corps of Engineers are listed below in Table 3 with comparison data from adjacent beach areas within the project areas. When one compares the sediment sizes for the onshore beaches with the size characteristics of the sediment from the identified borrow areas offshore (Table 3), the difference is evident. I believe these differences are significant and have potential implications both in terms of the benefit/cost and the environmental impacts.

TABLE 3

Beach Sand Sizes	Sediment Sizes from Offshore Sources	
1.5mm	N1	0.38mm
1.2 mm	N2	0.38mm
1.4mm	S3	0.32mm
1.2mm	S2	No data
0.9mm	S1	0.37mm

3.5 <u>Compatibility Discussion:</u> It is important to recognize that the success of any beach nourishment project can be considered in relative terms. Theoretically, every cubic yard of sediment that is placed on a beach serves to some degree as mitigation to future erosion. The fundamental questions are: (1) Will the sediment that is introduced mix and merge with the native sand, and thus increase the budget of sediment that has adjusted to the level of the sediment transport processes (waves, tides, and currents) present; (2) If not, how long will the incompatible fraction of nourishment remain and benefit the beach system; and (3) Is the incompatible fraction of the nourishment large enough to produce a change in the beach system and thus introduce environmental problems? Clearly, based on the evidence available, there is a significant difference between the average size characteristics of the native beaches along Dare County and the sediment identified as suitable for nourishment. However, it is possible that even with the finer fraction of the offshore material, there would be a place in the sediment/hydraulic system where it would fit and thus contribute to the mitigation of the long-term erosion trend. In the case of the fine fraction, which in this case could represent up to 50 percent of the material placed on the beaches, the most likely location for this "fit" would be in the offshore segment of the beach profiles. The benefits of adding fine-grained sediment to the offshore profile are debatable.

4.0 Ecological Implications of the Nourishment

As indicated earlier in this report, even if the match between the native sand and the nourishment is perfect, the fact that millions of cubic yards of sand are being added to a relatively narrow beach and inshore zone will result in some biological response. In most cases the immediate outcome of nourishment is the direct burial and death of most of the intertidal organisms that are not mobile enough to leave the area of sand discharge. Most of the organisms that live on the beaches and surf-zone have high rates of reproduction and short life cycles. However, we have learned from our research on Pea Island that the recovery rate for the animals we monitored was directly related to (1) the size of the sediment, (2) the volume of the dredged material placed on the beach, and (3) the season in which the nourishment was carried out.

4.1 <u>Impact of Nourishment on Inshore and Beach-face Organisms:</u> Based on past investigations of beach nourishment projects (Stauble, 1992; Reilly and Bellis, 1983; Culter and Mahadevan, 1982; and Bowman and Dolan, 1981), the most informative attributes of the beach system that can be investigated with respect to nourishment projects are: the compatibility of the sands; how the new sediment changes the morphology of the beach; and if an indicator species is present, how did it respond to the nourishment? We, along with several other investigators, have studied the response of two of the most common and abundant beach-face (foreshore) organisms found along the Outer Banks, the filter feeders, *Emerita talpoida* (the common mole crab) and the coquina clan *(Donax).*

One important manifestation of the adaptability of *Donax* and *Emerita* to the beach-face is their mobility. Both animals move up and down the beach with each wave uprush; and they stay within the swash zone as the tides change by moving out of the sand on the uprush, if they prefer a higher location on the beach, or in the backrush of the waves as the tides fall, if they prefer a lower location. They do this in steps, moving in mass with almost every wave, in an effort to maintain their position in the active swash zone with optional feeding conditions. Therefore, the "health" of the *Emerita* and *Donax* is closely linked with the sediment characteristics of the beach, and the availability of natural seawaters surging up and down the beach-face. Extremely critical is sediment grain size (Matta, 1977) because mole crabs do not actually burrow into the beach as they change locations within the swash zone, but rather vibrate their lower appendages and legs to create a "quicksand" condition in their immediate area. This makes it easy for them to penetrate or burrow into the sand with a minimum expenditure of energy. Anything that significantly alters the beach-face sands has the potential to impact *Emerita* numbers. If the sand is too coarse, too fine, too well sorted, or contains too many heavy minerals (dark sands), mole crabs find it difficult or impossible to burrow into the beach.

Emerita and *Donax* are also sensitive to air and water temperature, so they are highly seasonal (Reilly and Bellis, 1983; Metta, 1977; and Bowman and Dolan, 1981). They begin to appear in considerable numbers in early April, reaching their peaks in early to late summer, then move out of the beach-face into the inshore zone in late October and November, where the adults that survive the summer and fall "hibernate" for the winter. In addition, the distribution of mole crabs along the shore is commonly very "patchy," as the biologists call it. Their numbers or densities can vary by a factor of ten from sample sites along a three-mile reach of the coast. Just why this is so is still under review by biologists; some say it is a matter of happenstance, while others are convinced that patchiness reflects differences in processes, sediment sizes, the beach profile, and shoreline configuration (Cubit, 1969; Dillery and Knapp, 1970; and Bowman and Dolan, 1981). Still, mole crabs are usually abundant by most measures at any location along the coast during their peak biological season. The increase in numbers along the coast is not a question of few or none in one place, and many in another, but rather many versus a great many in some locations.

One other aspect of beach nourishment that appears to be important with respect to the "health" of *Emerita* and *Donax* is water quality, especially turbidity (Reilly and Bellis, 1983). If the source material for a beach nourishment project includes a significant amount of fine-grained sediment (silts and clays), this may not only impact the distribution of *Emerita* and *Donax* in the areas of discharge, but also have a more lasting impact on the adults that winter offshore. Reilly and Bellis (1983) concluded that the high turbidity contributed to the continued reduction in *Emerita* numbers following beach nourishment on Bogue Banks, North Carolina.

I have included as an attachment to this report a summary of the research that Dr. Cinde Donoghue and I carried out on Pea Island concerning the environmental impacts of placing dredged material on the wildlife refuge's beaches. I must point out that the sand in question was removed from Oregon Inlet so it closely matched the attributes of the native sand. We found, like many other investigators, depressed numbers of *Emerita* and *Donax* in areas that were nourished. Reilly and Bellis (1983) found similar results following a nourishment project on Bogue Banks, North Carolina, and concluded that this was due primarily to increased turbidity; however, this 1992 cycle of dredging in Oregon Inlet did not appear to introduce a high level of turbidity so this may not be the explanation. Placing the nourishment on the beach in August/September, and thus greatly depressing the population late in their annual cycle, may carry over to the next year's new stock. But whether this reduction is due to the beach fill or is related to some aspect of the organism's natural history is a question that we cannot answer at this time.

Although the animals living in the areas of the beach where nourishment is placed are probably more severely impacted, several other organisms are known to suffer. For example, by changing the configuration of the beach (Figure 5), the habitats of sea turtles, ghost crabs, and some nesting birds are altered, in some cases resulting in their complete elimination. In addition, the finer fraction of the beach nourishment will be separated hydraulically and transported into the nearshore sediment transport pathways. The degree to which this sediment is lethal is not fully understood, but the limited evidence available (Hurme and Pullen, 1988) suggests that recovery is slow at best. Again, the critical factors are compatibility, the rate at which the nourishment is added, and the season of the year. The season of maximum biological activity for most of the organisms that live in the beach and inshore along the Outer Banks of North Carolina range from mid-March to mid-October (see Figure 6 and the other figures and discussion in the attached report by Donoghue). Therefore, the frequent placement of nourishment on the beaches during this period, as well as the high volume anticipated, increases the likelihood of permanent ecological implications.

5.0 Other Implications

There are two additional environmental issues that should be considered with respect to the Dare County nourishment project. If the beach nourishment is hydraulically sorted, and the fine fraction is "mobilized," turbidity levels in the area are going to increase by as much as an order of magnitude until the very fine sands, silts, and clays are redistributed into lower energy environments. However, with the volume of sediment called for initially (14.7 million cubic yards) in the nourishment plan, along with the estimated requirement of 4.6 million cubic yards of "re-nourishment" every three years, I doubt that the beach and inshore systems will ever have an opportunity to equilibrate to the new supply of sediment. This means that any physical or biological processes that are impacted by higher levels of turbidity (i.e., from recreation to benthic organisms) should be assessed in terms of a permanent change. For example, if the majority of the larval fish migrate along the coast within the inshore longshore transport system, as suggested by several marine biologists, there could be a negative impact if turbidity levels increase significantly.

Finally, the potential implications of producing a large excavation area immediately offshore from the beaches and barrier island should be investigated. Based on the maps provided by the Corps of Engineers (Figure 2), the "borrow site" for the South Nags Head segment of the project has a surface area of 5.3 million square yards. If this site is expected to yield the approximately 10 million cubic yards of nourishment called for in the plan for Nags Head and South Nags Head, it will require dredging the designated borrow area to a depth of about six feet initially, followed by an additional one foot every three years for the 50 years of the project. The total nourishment needed for the 50 years for Nags Head and South Nags Head alone is approximately 63 million cubic yards. This results in the excavation of site S1 to a depth of about 30 feet to balance the needs with the area of the source material. I would also like to point out that to compound this problem approximately half of the cores taken from within site S1 have what I consider to be incompatible material for beach nourishment; therefore, the excavation for useful beach nourishment will require deeper dredging or new borrow sites offshore. The full implications of creating an excavation site offshore that is 3 miles long, 0.5 miles wide, with a starting depth of six feet, then progressively increasing in depth to 30 feet, needs to be considered. The implications that come to mind include the alteration of wave and current action, water quality, fish habitat, and larval fish migration. There are locations in Florida, for example, where sand has been excavated from offshore borrow sites in locations similar to those planned for the Dare County project. I believe the environmental conditions in these excavations turned out to be less than desired.

6.0 Summary and Recommendations

The beaches along the coast of Dare County have been eroding for decades, with rates ranging from a few feet to as much as eight feet per year. The replenishment of the sand lost to natural processes through beach nourishment is one of the more acceptable forms of mitigation, but unless there is a good match between the nourishment and the native beach sands, a project like this can lead to more harm than good. The offshore sources for nourishment identified by the Corps of Engineers offer some material that appears to be suitable for beach restoration along the coast of Dare County; however, the sample results also show a distinct lack of compatibility in many cases. The percentage of fine sediment within the vibracores collected from offshore should be of concern. It appears from my analyses that approximately 50 percent of the sediment from the identified borrow sites is either too fine to remain in the system, or only marginally compatible. The possible implications of using sediment with this amount of fine material include:

- i) A more rapid loss of volume and thus less long-term protection from storms surge and further erosion.
- ii) Significant changes in the physical characteristics of the beaches including flatter gradients, vertical scarping, and high surface compaction.
- iii) Higher potential ecological impacts due to differences in the behavior of fine fraction sediment and the coarser native materials.
- iv) The creation of a large excavation hole in the offshore that will alter wave refraction, inshore currents, and possibly larval fish migration, and lead to the development of a large sink for the accumulation of organic material and fine-grained sediment.

6.1 Recommendations: The geologic data and the plan for nourishing the beaches of Dare County have, as best I can determine, not been subject to a rigorous compatibility analysis along the lines suggested by James and Krumbein in their earlier Corps of Engineers research. The outcome of such an assessment would provide valuable information to better judge both the economic and environmental implications of the project. It would also be worthwhile to investigate the potential rates of sediment losses from the beach fills based on the grain sizes of the offshore versus beach-face sediment data, and complementary to this, it would be very helpful in this evaluation to have an assessment of the most likely sediment transport pathways (i.e., along the lines of Inman and Dolan, 1989) and ultimate locations of fine-grained sedimentation that would result.

7.0 References

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onshore

Station	Dune Toe	Berm Center	Upper Foreshore	Mid foreshore	Lower foreshore
0	1.15	1.27	1.18	0.83	1.41
1	0.84	0.75	0.80	1.03	2.15
10	0.97		1.20	1.92	1.87
20	0.83	0.57	0.64	0.86	1.78
30	1.93	0.91	0.90	0.59	1.98
40	1.79	1.16	1.02	1.02	1.01
50	1.23	1.46	1.69	1.36	2.76
60	0.87	0.52	1.12	1.44	3.24
70	0.93	0.95	0.88	0.91	2.74
80	1.10	1.42	1.26	0.91	3.30
90	0.17	1.02	1.40	1.04	3.01
100	2.98	2.77	2.15	1.48	1.54
110	1.72	2.86	3.28	3.38	5.12
120	1.24	0.30	0.33	0.35	0.72
130	0.70	0.87	0.88	1.72	2.33
140	2.03	0.70	0.55	0.68	2.68
150	1.10	1.65	0.62	0.76	2.63
160	0.57	1.01	0.54	0.79	2.16
170	0.69	0.78	1.25	1.80	1.50
180	0.43	1.53	0.76	1.07	1.16
190	0.45	0.73	0.62	0.44	2.32
200	0.63	1.25	0.52	0.54	0.76
210	0.59	1.55	0.62	0.83	0.60
220	0.69	1.51	1.11	1.35	1.01
230	0.93	0.89	0.77	0.80	0.64
240	1.04	0.95	1.46	0.65	0.94
250	0.67	1.09	0.55	0.55	1.67
260	0.69	0.49	0.56	0.90	1.05
270	0.80	0.51	0.69	0.80	2.52
280	0.52	0.55	0.50	0.61	0.71
290	0.68	0.63	0.56	0.47	1.36
300	0.64	0.55	0.85	1.67	1.15
310	0.61	0.89	0.58	0.73	3.13
320	0.61	0.64	1.15	0.57	1.14
330	0.54	0.54	0.74	1.03	0.72
340	0.46	0.45	3.46	1.37	0.31
350	0.42	0.60	0.61	0.42	0.86
360	0.29	0.85	0.22	0.96	0.87
370	0.48	3.75	0.22	0.57	0.34
380	0.40	0.35	0.37	0.43	0.73
390	0.84	0.29	1.00	0.53	1.02
400	0.34	0.35	0.62	0.77	1.16
410	0.44	0.38	0.77	0.90	0.94
420	0.79	0.34	0.70	1.19	0.70
430	0.49	0.98	0.74	0.54	1.10
440	0.51	0.50	0.62	0.71	1.55
450	0.47	0.40	1.11	1.31	1.44

Table 1-1

460	0.64	0.39	0.46	1.45	0.99
470	0.45	0.40	0.60	0.74	1.30
480	0.78	0.57	0.48	0.67	1.47
490	0.68	0.62	0.66	1.11	1.97
500	0.50	0.51	0.90	1.34	1.23
510	0.63	0.60	0.54	0.75	1.01
520	0.57	0.59	0.66	0.80	1.87
530	0.56	0.72	0.81	0.53	0.74
540	0.47	0.77	0.58	0.60	1.10
550	0.41	0.49	0.54	0.80	1.82
560	0.42	0.50	0.71	1.13	2.16
570	0.47	0.47	0.72	1.04	1.12
580	0.36	0.52	0.57	0.89	1.06
590	0.47	0.66	0.61	0.78	2.29
600	0.53	0.57	0.85	0.69	1.92
610	0.29	0.59	0.60	1.26	2.08
620	0.52	1.19	1.56	0.82	2.11
630	0.41	0.31	0.37	0.96	2.75
640	0.27	0.29	0.73	1.01	4.16
650	0.53	0.25	1.36	1.56	4.36
660	0.48	0.76	0.49	2.80	0.56
670	0.62	0.39	0.50	0.61	1.43
680	2.57	1.14	0.95	0.88	1.68
690	0.32	0.69	1.42	1.16	0.88
700	0.72	0.89	1.12	0.41	0.89
710	0.25	0.39	0.43	0.39	2.44
720	0.33	1.43	1.17	0.96	1.38
730	0.79	0.59	0.50	0.43	2.61
740	0.35	1.21	0.67	0.32	1.39
750	0.34	0.76	0.63	0.65	1.98
760	0.35	0.63	0.58	0.55	0.71
770	0.40	0.29	0.78	0.52	1.50
780	0.30	1.29	1.41	0.52	1.76
790	0.30	0.34	0.37	0.38	1.55
800	0.37	0.21	0.39	1.06	0.42
810	0.36	0.26	0.41	0.54	2.72
820	0.29	0.55	1.62	0.82	0.87
830	0.23	0.39	0.82	0.56	2.31
840	0.27	0.31	1.32	0.91	1.68
850	0.33	0.28	0.27	0.45	2.20
860	0.26	0.36	1.80	1.54	2.51
870	0.34	0.34	0.32	0.62	1.08
880	0.25	0.25	0.25	0.92	1.67
890	0.29	0.26	0.50	0.69	1.45
900	0.30	0.24	1.09	1.21	4.69
910	0.49	0.26	0.34	0.87	1.45
920	0.39	0.22	1.44	0.79	0.59
930	0.23	0.26	0.98	0.65	0.35
940	0.22	0.44	0.42	0.54	0.34

Table 1-2

941	0.22	0.44	0.55	0.63	2.09
950	0.38	0.45	0.31	0.81	0.85
960	0.36	0.33	0.27	0.23	1.09
970	0.28	0.51	0.50	0.38	0.80
980	0.27	0.37	0.52	0.52	0.69
990	0.24	0.30	0.36	0.57	0.66
1000	0.24	0.32	0.29	0.37	0.99
1010	0.29	0.32	0.37	0.35	0.96
1020	0.23	0.29	0.37	0.41	
	0.61	**0.71**	**0.81**	**0.87**	**1.60**

1998 USACOE/Dare County Offshore Borings

Boring #	Sample #	Grain size (mm)			Boring mean		
		D16	D50	D84	D16	D50	D84
priority 1							
NDC 452	- 1	0.076	0.120	0.190			
NDC 452	- 2	0.096	0.200	0.340			
NDC 452	- 3	0.106	0.270	0.550			
NDC 452	- mean				0.093	0.197	0.360
NDC 453	- 1	0.300	0.450	0.790			
NDC 453	- 2	0.320	0.490	0.900			
NDC 453	- 3	0.260	0.450	0.720			
NDC 453	- mean				0.293	0.463	0.803
NDC 456	- 2	0.120	0.250	0.450			
NDC 456	- 3	0.170	0.300	0.750			
NDC 456	- 4	0.190	0.490	1.400			
NDC 456	- mean				0.160	0.347	0.867
NDC 457	- 1	0.350	0.610	1.300			
NDC 457	- 2	0.170	0.270	0.580			
NDC 457	- 3	0.120	0.270	0.570			
NDC 457	- mean				0.213	0.383	0.817
NDC 533	- 1	0.120	0.170	0.350			
NDC 533	- 2	0.850	0.150	0.250			
NDC 533	- 3	0.760	0.120	0.170			
NDC 533	- mean				0.577	0.147	0.257
NDC 534	- 1	0.170	0.220	0.310			
NDC 534	- 2	0.120	0.180	0.280			
NDC 534	- 3	0.082	0.130	0.360			
NDC 534	- 4	0.089	0.150	0.700			
NDC 534	- 5	0.220	0.450	1.200			
NDC 534	- mean				0.136	0.226	0.570
NDC 623	- 1	0.350	0.550	2.700			
NDC 623	- 2	0.220	0.400	0.900			
NDC 623	- 3	0.180	0.270	0.460			
NDC 623	- mean				0.250	0.407	1.353
NDC 624	- 1	0.950	2.900	7.200			
NDC 624	- 2	0.250	1.700	3.700			
NDC 624	- 4	0.170	0.350	0.660			
NDC 624	- 5	0.180	0.390	0.700			
NDC 624	- 6	0.090	0.250	0.590			
NDC 624	- 7	0.130	0.260	0.500			
NDC 624	- mean				0.295	0.975	2.225
NDC 627	- 1	0.230	0.390	0.600			
NDC 627	- 2	0.100	0.410	1.100			
NDC 627	- 3	0.150	0.220	0.350			
NDC 627	- 4	0.090	0.200	0.360			
NDC 627	- mean				0.143	0.305	0.603
NDC 629	- 1	0.170	0.360	0.700			
NDC 629	- 2	0.075	0.130	0.250			
NDC 629	- 3	0.120	0.210	0.350			
NDC 629	- mean				0.122	0.233	0.433
NDC 630	- 1	0.170	0.260	0.460			

Table 2-1

offshore

NDC 630	-	2	0.170	0.250	0.400			
NDC 630	-	3	0.170	0.240	0.350			
NDC 630	-	mean				0.170	0.250	0.403
NDC 700	-	1	0.090	0.170	0.250			
NDC 700	-	2	0.140	0.180	0.250			
NDC 700	-	4	0.076	0.130	0.210			
NDC 700	-	mean				0.102	0.160	0.237
priority 2	-							
NDC 505	-	1	0.080	0.130	0.190			
NDC 505	-	2	0.089	0.150	0.290			
	-	mean				0.085	0.140	0.240
NDC 465	-	1	0.080	0.130	0.400			
NDC 465	-	2	0.170	0.240	0.360			
NDC 465	-	mean				0.125	0.185	0.380
NDC 466	-	1	0.077	0.110	0.150			
NDC 466	-	2	0.085	0.150	0.300			
NDC 466	-	3	0.076	0.120	0.170			
NDC 466	-	mean				0.079	0.127	0.207
NDC 468	-	1	0.170	0.350	1.500			
NDC 468	-	2	0.090	0.180	0.360			
NDC 468	-	mean				0.130	0.265	0.930
NDC 531	-	1	0.095	0.320	1.200			
NDC 531	-	2	0.090	0.270	0.130			
NDC 531	-	mean				0.093	0.295	0.665
NDC 532	-	1	0.075	0.100	0.160			
NDC 532	-	mean				0.075	0.100	0.160
NDC 464	-	1	0.140	0.200	0.290			
NDC 464	-	mean				0.140	0.200	0.290
NDC 626	-	1	0.075	0.100	0.150			
NDC 626	-	2	0.080	0.140	0.510			
NDC 626	-	3	0.170	0.280	0.550			
NDC 626	-	mean				0.108	0.173	0.403
NDC 644	-	1	0.210	0.400	0.800			
NDC 644	-	2	0.110	0.200	0.350			
NDC 644	-	3	0.080	0.130	0.190			
NDC 644	-	mean				0.133	0.243	0.447
NDC 701	-	1	0.080	0.120	0.170			
NDC 701	-	2	0.080	0.140	0.300			
NDC 701	-	mean				0.080	0.130	0.235
priority 3	-							
NDC 527	-	1	0.079	0.100	0.150			
NDC 527	-	2	0.085	0.100	0.220			
NDC 527	-	3	0.076	0.100	0.150			
NDC 527	-	mean				0.080	0.100	0.173
NDC 537	-	1	0.085	0.140	0.650			
NDC 537	-	5	0.170	0.250	0.410			
NDC 537	-	6	0.150	0.230	0.350			
NDC 537	-	mean				0.135	0.207	0.470
NDC 539	-	1	0.075	0.099	0.300			
NDC 539	-	4	0.310	0.460	0.900			
NDC 539	-	mean				0.193	0.280	0.600
NDC 702	-	1	0.079	0.120	0.170			

Table 2-2

NDC 702	-	2	0.080	0.120	0.900			
NDC 702	-	mean				0.080	0.120	0.535
NDC 703	-	1	0.078	0.130	0.550			
NDC 703	-	3	0.080	0.170	0.600			
NDC 703	-	mean				0.079	0.150	0.575
NDC 704	-	1	0.077	0.120	0.180			
NDC 704	-	4	0.130	0.230	0.450			
NDC 704	-	5	0.170	0.270	0.470			
NDC 704	-	mean				0.126	0.207	0.367
NDC 706	-	2	0.120	1.300	1.600			
NDC 706	-	6	0.200	0.370	0.560			
NDC 706	-	7	0.250	0.420	0.660			
NDC 706	-	mean				0.190	0.697	0.940
NDC 708	-	1	0.090	0.170	4.000			
NDC 708	-	2	0.075	0.100	0.150			
NDC 708	-	mean				0.083	0.135	2.075
NDC 709	-	1	0.076	0.100	0.150			
NDC 709	-	2	0.076	0.120	0.700			
NDC 709	-	4	0.250	0.400	0.510			
NDC 709	-	mean				0.134	0.207	0.453
NDC 715	-	1	0.075	0.100	0.150			
NDC 715	-	2	0.430	0.850	2.000			
NDC 715	-	5	0.180	0.370	0.670			
NDC 715	-	6	0.210	0.360	0.700			
NDC 715	-	mean				0.224	0.420	0.880
priority 4	-							
NDC 431	-	1	0.090	0.180	0.800			
NDC 431	-	2	0.079	0.160	0.240			
NDC 431	-	mean				0.085	0.170	0.520
NDC 508	-	1	0.076	0.150	0.250			
NDC 508	-	2	0.080	0.120	0.190			
NDC 508	-	3	0.079	0.100	0.150			
NDC 508	-	mean				0.078	0.123	0.197
NDC 509	-	1	0.350	0.550	1.000			
NDC 509	-	3	0.078	0.120	0.180			
NDC 509	-	mean				0.214	0.335	0.590
NDC 510	-	1	0.300	0.450	0.800			
NDC 510	-	2	0.160	0.260	0.890			
NDC 510	-	mean				0.230	0.355	0.845
NDC 511	-	1	0.300	0.460	0.830			
NDC 511	-	2	0.240	0.400	0.600			
NDC 511	-	3	0.180	0.360	0.650			
NDC 511	-	mean				0.240	0.407	0.693
NDC 548	-	1	0.200	0.360	0.650			
NDC 548	-	3	0.076	0.098	0.140			
NDC 548	-	mean				0.138	0.229	0.395
NDC 550	-	1	0.075	0.240	0.550			
NDC 550	-	5	0.075	0.098	0.140			
NDC 550	-	mean				0.075	0.169	0.345
NDC 628	-	1	0.095	0.230	0.690			
NDC 628	-	2	0.085	0.170	0.260			
NDC 628	-	3	0.320	0.470	0.760			

Table 2-3

NDC 628	- mean				0.167	0.290	0.570
NDC 705	- 1	0.098	0.170	1.500			
NDC 705	- 2	0.090	0.160	0.270			
NDC 705	- 3	0.075	0.100	0.150			
NDC 705	- 4	0.080	0.110	0.160			
NDC 705	- mean				0.086	0.135	0.520
NDC 710	- 2	0.081	0.170	0.280			
NDC 710	- 3	0.080	0.150	0.260			
NDC 710	- 4	0.076	0.140	0.350			
NDC 710	- mean				0.079	0.153	0.297
NDC 711	- 1	0.088	0.150	0.240			
NDC 711	- 2	0.088	0.150	0.230			
NDC 711	- 3	0.078	0.100	0.150			
NDC 711	- 4	0.080	0.130	0.250			
NDC 711	- mean				0.084	0.133	0.218
priority 5	-						
NDC 514	- 1	0.230	0.360	0.520			
NDC 514	- 2	0.260	0.390	0.580			
NDC 514	- mean				0.245	0.375	0.550
NDC 515	- 1	0.360	0.580	1.100			
NDC 515	- mean				0.360	0.580	1.100
NDC 516	- 1	0.380	0.850	2.000			
NDC 516	- 2	0.078	0.150	0.240			
NDC 516	- mean				0.229	0.500	1.120
NDC 517	- 1	0.180	0.400	1.700			
NDC 517	- 2	0.095	0.180	0.290			
NDC 517	- 4	0.075	0.120	0.170			
NDC 517	- mean				0.117	0.233	0.720
NDC 518	- 1	0.250	0.650	2.900			
NDC 518	- 2	0.250	0.500	1.800			
NDC 518	- mean				0.250	0.575	2.350
NDC 519	- 1	0.085	0.160	0.250			
NDC 519	- 2	0.075	0.100	0.160			
NDC 519	- mean				0.080	0.130	0.205
NDC 521	- 1	0.260	0.490	1.300			
NDC 521	- 3	0.077	0.130	0.200			
NDC 521	- mean				0.169	0.310	0.750
NDC 522	- 1	0.280	0.440	0.700			
NDC 522	- 2	0.180	0.310	0.550			
NDC 522	- 4	0.080	0.130	0.180			
NDC 522	- mean				0.180	0.293	0.477
NDC 545	- 1	0.090	0.180	0.270			
NDC 545	- 2	0.085	0.170	0.250			
NDC 545	- mean				0.088	0.175	0.260
NDC 546	- 1	0.550	1.000	3.000			
NDC 546	- mean				0.550	1.000	3.000
NDC 551	- 1	0.080	0.160	0.270			
NDC 551	- mean				0.080	0.160	0.270
NDC 712	- 1	0.120	0.190	0.260			
NDC 712	- 3	0.079	0.130	0.190			
NDC 712	- mean				0.100	0.160	0.225
NDC 713	- 1	0.090	0.150	0.270			

Table 2-4

NDC 713	-	2	0.079	0.130	0.200			
NDC 713	-	3	0.078	0.100	0.150			
NDC 713	-	5	0.079	0.130	0.170			
NDC 713	-	6	0.075	0.100	0.150			
NDC 713	-	mean				0.080	0.122	0.188
priority 6	-							
NDC 469	-	1	0.077	0.100	0.140			
NDC 469	-	mean				0.077	0.100	0.140
NDC 470	-	1	0.080	0.100	0.150			
NDC 470	-	mean				0.080	0.100	0.150
NDC 476	-	1	0.080	0.110	0.160			
NDC 476	-	4	0.150	0.360	0.490			
NDC 476	-	5	0.150	0.380	0.500			
NDC 476	-	mean				0.127	0.283	0.383
NDC 478	-	3	0.200	0.400	0.990			
NDC 478	-	mean				0.200	0.400	0.990
NDC 490	-	2	0.100	0.700	5.000			
NDC 490	-	3	0.360	0.550	1.000			
NDC 490	-	6	0.100	0.210	0.360			
NDC 490	-	mean				0.187	0.487	2.120
NDC 494	-	1	0.081	0.120	0.250			
NDC 494	-	3	0.170	0.300	0.600			
NDC 494	-	4	0.180	0.280	0.500			
NDC 494	-	5	0.300	0.600	1.300			
NDC 494	-	mean				0.183	0.325	0.663
NDC 506	-	1	0.075	0.100	0.150			
NDC 506	-	2	0.080	0.250	0.500			
NDC 506	-	mean				0.078	0.175	0.325
NDC 507	-	2	0.270	0.450	0.750			
NDC 507	-	mean				0.270	0.450	0.750
NDC 529	-	2	0.100	0.210	1.200			
NDC 529	-	mean				0.100	0.210	1.200
NDC 530	-	1	0.075	0.100	0.140			
NDC 530	-	3	0.085	0.200	0.400			
NDC 530	-	4	0.180	0.290	0.800			
NDC 530	-	mean				0.113	0.197	0.447
priority 7	-							
NDC 436	-	A1	0.210	0.490	2.500			
NDC 436	-	A2	0.110	0.300	0.510			
NDC 436	-	A3	0.180	0.400	0.850			
NDC 436	-	A4	0.085	0.170	0.480			
NDC 436	-	mean				0.146	0.340	1.085
NDC 443	-	2	0.150	0.370	0.850			
NDC 443	-	A1	0.095	0.230	0.650			
NDC 443	-	A2	0.170	0.290	1.200			
NDC 443	-	mean				0.138	0.297	0.900
NDC 512	-	1	0.150	0.220	0.390			
NDC 512	-	mean				0.150	0.220	0.390
NDC 513	-	1	0.160	0.600	3.100			
NDC 513	-	2	0.150	0.410	0.990			
NDC 513	-	mean				0.155	0.505	2.045
NDC 524	-	1	0.099	0.180	0.280			

Table 2-5

NDC 524	-	2	0.091	0.180	0.280			
NDC 524	-	**mean**				**0.095**	**0.180**	**0.280**
NDC 526	-	1	0.085	0.150	0.280			
NDC 526	-	**mean**				**0.085**	**0.150**	**0.280**
NDC 535	-	5	0.120	0.290	0.900			
NDC 535	-	6	0.260	0.690	1.600			
NDC 535	-	**mean**				**0.190**	**0.690**	**1.600**
NDC 625	-	1	0.140	0.200	0.290			
NDC 625	-	2	0.076	0.130	0.210			
NDC 625	-	3	0.076	0.100	0.150			
NDC 625	-	**mean**				**0.097**	**0.143**	**0.217**
priority 8	-							
NDC 555	-	1	0.170	0.400	0.700			
NDC 555	-	2	0.280	0.440	0.760			
NDC 555	-	3	0.170	0.230	0.390			
NDC 555	-	4	0.150	0.260	0.380			
NDC 555	-	5	0.190	0.280	0.390			
NDC 555	-	**mean**				**0.192**	**0.322**	**0.524**
NDC 556	-	1	0.300	0.570	1.800			
NDC 556	-	2	0.280	0.470	0.850			
NDC 556	-	3	0.270	0.400	0.750			
NDC 556	-	4	0.200	0.300	0.450			
NDC 556	-	**mean**				**0.263**	**0.435**	**0.963**
NDC 557	-	1	0.220	0.410	2.500			
NDC 557	-	2	0.190	0.300	0.460			
NDC 557	-	3	0.180	0.260	0.350			
NDC 557	-	5	0.170	0.200	0.260			
NDC 557	-	**mean**				**0.190**	**0.293**	**0.893**
NDC 558	-	1	0.410	0.750	0.900			
NDC 558	-	2	0.280	0.450	0.460			
NDC 558	-	3	0.250	0.410	0.750			
NDC 558	-	4	0.210	0.330	0.550			
NDC 558	-	5	0.100	0.250	0.400			
NDC 558	-	**mean**				**0.250**	**0.438**	**0.612**
NDC 585	-	1	0.250	0.390	0.700			
NDC 585	-	2	0.074	0.160	0.210			
NDC 585	-	**mean**				**0.162**	**0.275**	**0.455**
NDC 593	-	1	0.250	0.340	0.500			
NDC 593	-	2	0.250	0.320	0.410			
NDC 593	-	4	0.160	0.290	0.380			
NDC 593	-	5	0.210	0.300	0.400			
NDC 593	-	**mean**				**0.218**	**0.313**	**0.423**
NDC 597	-	1	0.240	0.350	0.810			
NDC 597	-	2	0.170	0.210	0.420			
NDC 597	-	**mean**				**0.205**	**0.280**	**0.615**
priority 9	-							
NDC 497	-	1	0.890	0.130	0.190			
NDC 497	-	**mean**				**0.890**	**0.130**	**0.190**
NDC 498	-	1	0.160	0.220	0.340			
NDC 498	-	2	0.080	0.150	0.230			
NDC 498	-	3	0.220	0.490	0.890			
NDC 498	-	4	0.360	0.550	0.700			

Table 2-6

NDC 498	-	mean				0.205	0.353	0.540
NDC 567	-	1	0.079	0.100	0.150			
NDC 567	-	2	0.008	0.150	0.250			
NDC 567	-	mean				0.044	0.125	0.200
NDC 568	-	1	0.080	0.140	0.190			
NDC 568	-	3	0.150	0.190	0.240			
NDC 568	-	mean				0.115	0.165	0.215
NDC 570	-	1	0.099	0.180	0.210			
NDC 570	-	2	0.140	0.190	0.220			
NDC 570	-	3	0.140	0.210	0.360			
NDC 570	-	mean				0.126	0.193	0.263
NDC 572	-	1	0.078	0.100	0.150			
NDC 572	-	2	0.079	0.120	0.590			
NDC 572	-	mean				0.079	0.110	0.370
NDC 573	-	1	0.090	0.190	0.300			
NDC 573	-	mean				0.090	0.190	0.300
NDC 620	-	1	0.070	0.110	0.150			
NDC 620	-	2	0.430	0.700	6.500			
NDC 620	-	3	0.280	0.400	0.065			
NDC 620	-	mean				0.260	0.403	2.238
NDC 621	-	1	0.074	0.130	0.210			
NDC 621	-	2	0.430	0.650	1.800			
NDC 621	-	mean				0.252	0.390	1.005
NDC 622	-	1	0.075	0.110	0.170			
NDC 622	-	mean				0.075	0.110	0.170
NDC	-							
priority 10	-							
NDC 594	-	1	0.250	0.430	0.750			
NDC 594	-	2	0.260	0.430	0.700			
NDC 594	-	3	0.200	0.300	0.460			
NDC 594	-	4	0.290	0.460	0.700			
NDC 594	-	5	0.230	0.330	0.480			
NDC 594	-	6	0.290	0.450	0.650			
NDC 594	-	mean				0.253	0.400	0.623
NDC 595	-	1	0.260	0.400	0.800			
NDC 595	-	2	0.250	0.350	0.600			
NDC 595	-	3	0.260	0.390	0.650			
NDC 595	-	4	0.200	0.300	0.450			
NDC 595	-	5	0.200	0.310	0.450			
NDC 595	-	6	0.180	0.280	0.430			
NDC 595	-	mean				0.225	0.338	0.563
NDC 596	-	1	0.350	0.650	1.600			
NDC 596	-	2	0.260	0.400	0.700			
NDC 596	-	3	0.280	0.450	0.850			
NDC 596	-	4	0.210	0.310	0.450			
NDC 596	-	5	0.170	0.240	0.480			
NDC 596	-	mean				0.254	0.410	0.816
NDC 599	-	1	0.260	0.430	0.750			
NDC 599	-	2	0.250	0.400	0.700			
NDC 599	-	3	0.090	0.290	0.400			
NDC 599	-	4	0.170	0.260	0.400			
NDC 599	-	mean				0.193	0.345	0.563

Table 2-7

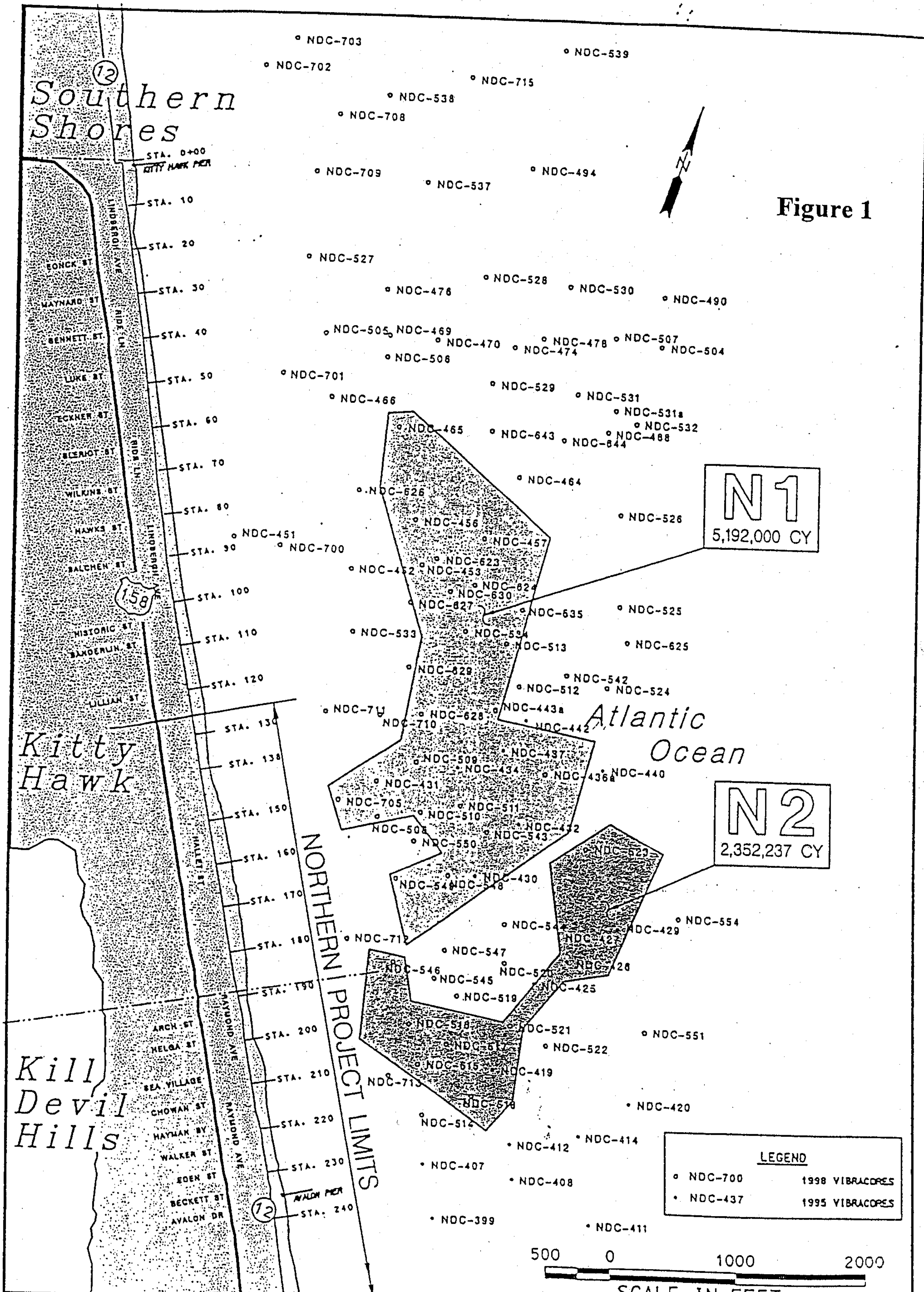
NDC 600	- 1	0.250	0.370	0.660			
NDC 600	- 2	0.240	0.350	0.550			
NDC 600	- 3	0.240	0.320	0.450			
NDC 600	- 4	0.230	0.350	0.590			
NDC 600	- 5	0.200	0.300	0.430			
NDC 600	- mean				0.232	0.338	0.536
NDC 602	- 1	0.300	0.500	0.900			
NDC 602	- 2	0.250	0.400	0.700			
NDC 602	- 3	0.260	0.490	0.800			
NDC 602	- 4	0.250	0.350	0.600			
NDC 602	- 5	0.200	0.310	0.500			
NDC 602	- 6	0.180	0.260	0.430			
NDC 602	- mean				0.240	0.385	0.655
NDC 604	- 1	0.310	0.650	2.000			
NDC 604	- 2	0.220	0.380	0.700			
NDC 604	- 3	0.170	0.210	0.320			
NDC 604	- 4	0.180	0.210	0.300			
NDC 604	- mean				0.220	0.363	0.830
NDC 609	- 1	0.250	0.430	1.000			
NDC 609	- 2	0.170	0.260	0.400			
NDC 609	- 3	0.160	0.210	0.350			
NDC 609	- mean				0.193	0.300	0.583
NDC 611	- 1	0.350	1.500	6.500			
NDC 611	- 2	0.250	0.350	0.650			
NDC 611	- 3	0.170	0.210	0.350			
NDC 611	- 4	0.230	0.650	3.700			
NDC 611	- 5	0.350	0.550	0.850			
NDC 611	- mean				0.270	0.652	2.410
NDC 707	- 1	0.210	0.340	0.700			
NDC 707	- 2	0.250	0.350	0.800			
NDC 707	- 3	0.090	0.260	0.390			
NDC 707	- 4	0.170	0.280	0.430			
NDC 707	- mean				0.180	0.308	0.580
priority 11	-						
NDC 574	- 1	0.080	0.130	0.180			
NDC 574	- 2	0.080	0.130	0.190			
NDC 574	- 3	0.074	0.100	0.150			
NDC 574	- mean				0.078	0.120	0.173
NDC 575	- 1	0.240	1.500	6.900			
NDC 575	- mean				0.240	1.500	6.900
NDC 576	- 1	0.075	0.120	0.170			
NDC 576	- 6	0.250	0.360	2.000			
NDC 576	- mean				0.163	0.240	1.085
NDC 577	- 1	0.100	0.170	0.230			
NDC 577	- 2	0.100	0.170	0.220			
NDC 577	- 3	0.100	0.160	0.220			
NDC 577	- 4	0.080	0.150	0.200			
NDC 577	- mean				0.095	0.163	0.218
NDC 578	- 1	0.360	0.590	1.000			
NDC 578	- 2	0.350	0.590	0.950			
NDC 578	- mean				0.355	0.590	0.975
NDC 583	- 1	0.270	0.430	0.800			

Table 2-8

NDC 583 - 2	0.270	0.390	0.690			
NDC 583 - 3	0.260	0.400	0.700			
NDC 583 - 4	0.270	0.430	0.790			
NDC 583 - 5	0.260	0.400	0.690			
NDC 583 - 6	0.230	0.500	0.760			
NDC 583 - mean				0.260	0.425	0.738
NDC 584 - 1	0.170	0.260	0.390			
NDC 584 - 2	0.160	0.220	0.350			
NDC 584 - mean				0.165	0.240	0.370
NDC 587 - 1	0.250	0.390	0.750			
NDC 587 - 2	0.250	0.360	0.700			
NDC 587 - 3	0.260	0.430	0.750			
NDC 587 - mean				0.253	0.393	0.733
NDC 588 - 1	0.250	0.400	0.700			
NDC 588 - 2	0.180	0.290	0.430			
NDC 588 - 3	0.240	0.350	0.700			
NDC 588 - mean				0.223	0.347	0.610
NDC 589 - 1	0.500	0.200	0.250			
NDC 589 - 2	0.083	0.170	0.230			
NDC 589 - 6	0.170	0.500	1.300			
NDC 589 - mean				0.251	0.290	0.593
NDC 590 - 1	0.300	0.550	1.500			
NDC 590 - 2	0.220	0.450	0.750			
NDC 590 - 3	0.250	0.350	0.610			
NDC 590 - 4	0.230	0.320	0.500			
NDC 590 - 5	0.250	0.350	0.600			
NDC 590 - mean				0.250	0.404	0.792
NDC 641 - 1	0.260	0.460	0.850			
NDC 641 - 2	0.230	0.310	0.400			
NDC 641 - 3	0.160	0.310	0.430			
NDC 641 - 4	0.170	0.280	0.370			
NDC 641 - mean				0.205	0.340	0.513
NDC 642 - 1	0.149	0.370	0.750			
NDC 642 - mean				0.149	0.370	0.750
TOTAL MEAN	0.180	0.314	0.709			

Table 2-9

Figure 1



NORTHERN BORROW AREA

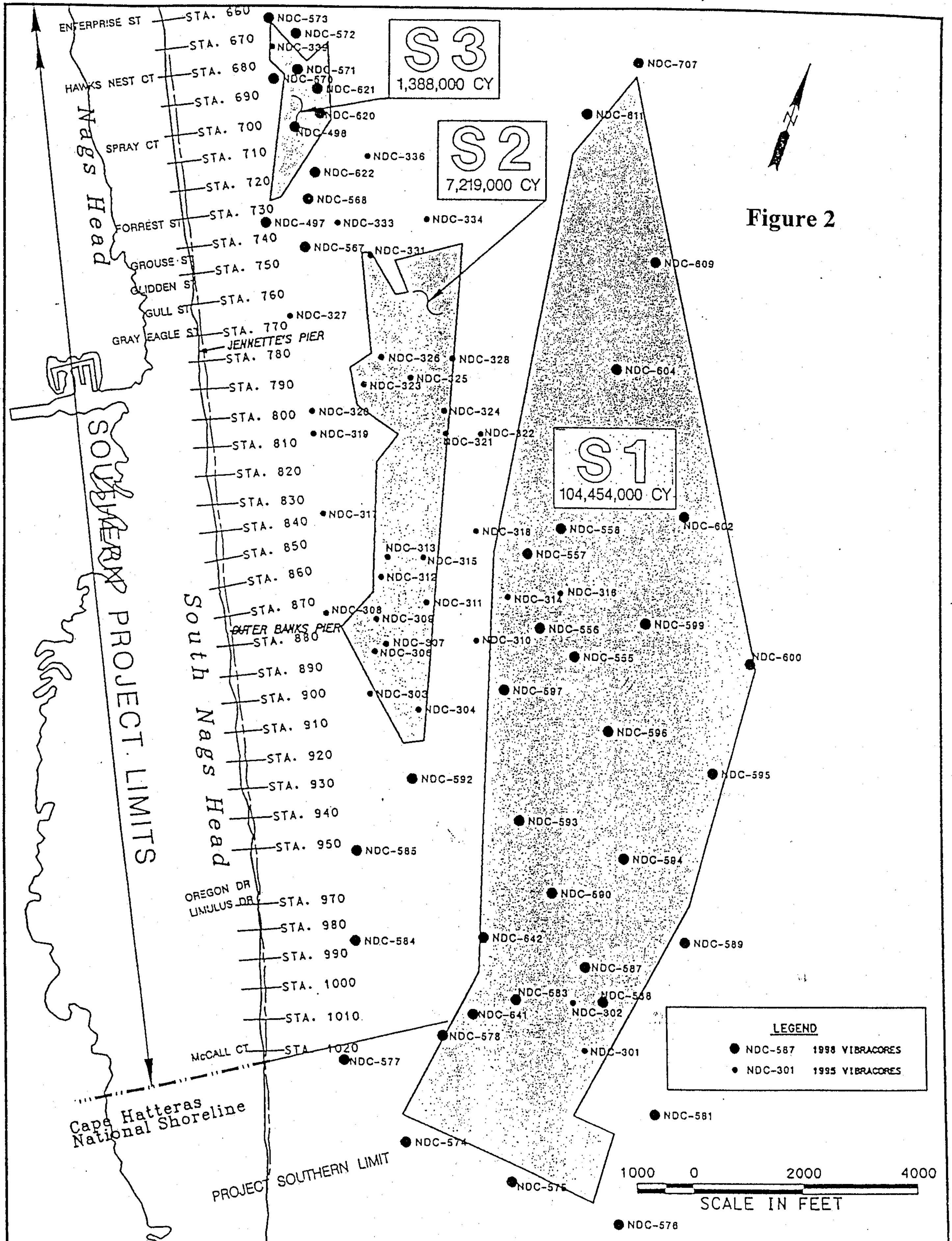


Figure 2

SOUTHERN BORROW AREA

Lower foreshore

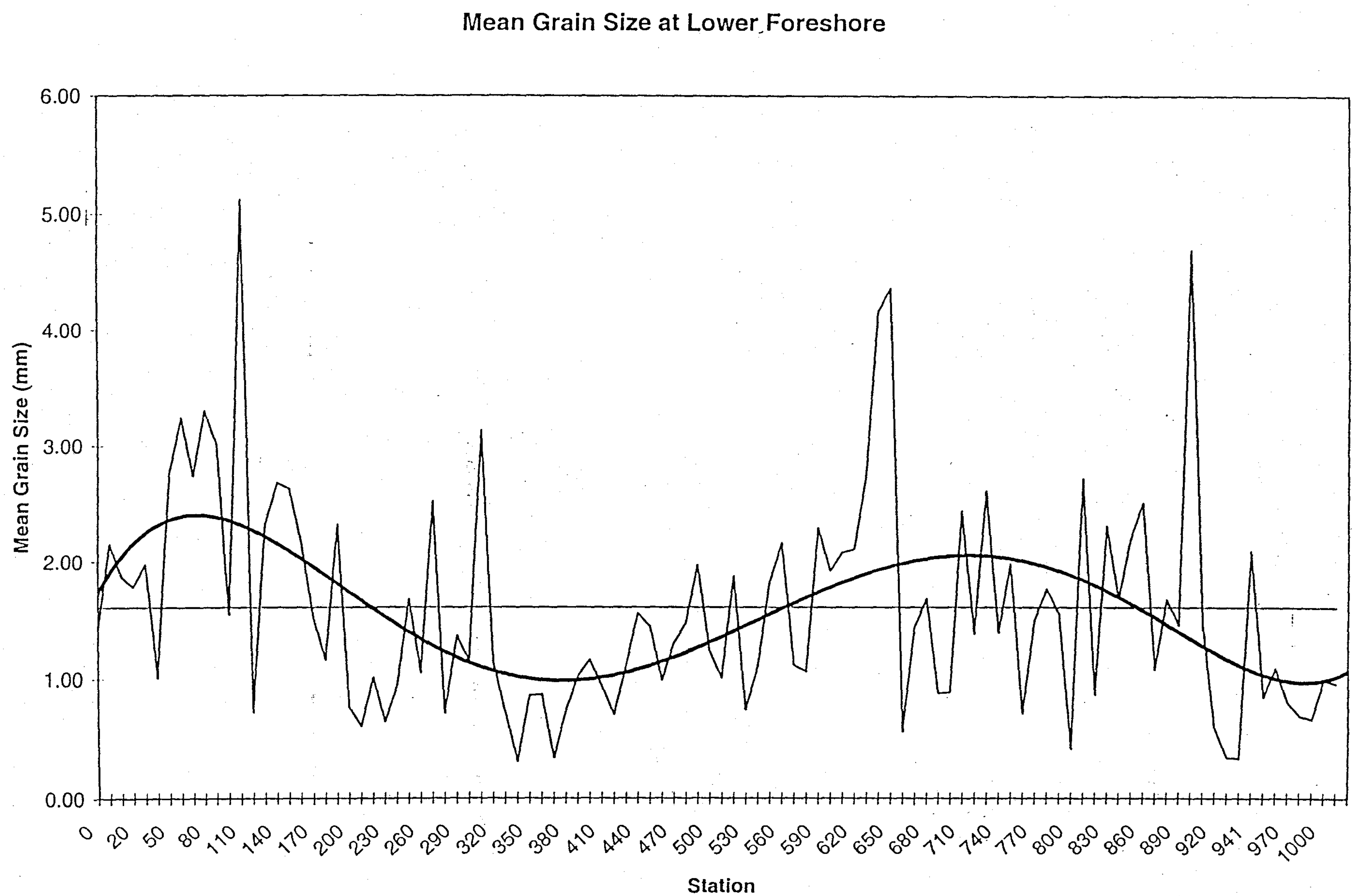


Figure 3-1 Lower Foreshore

Mid foreshore

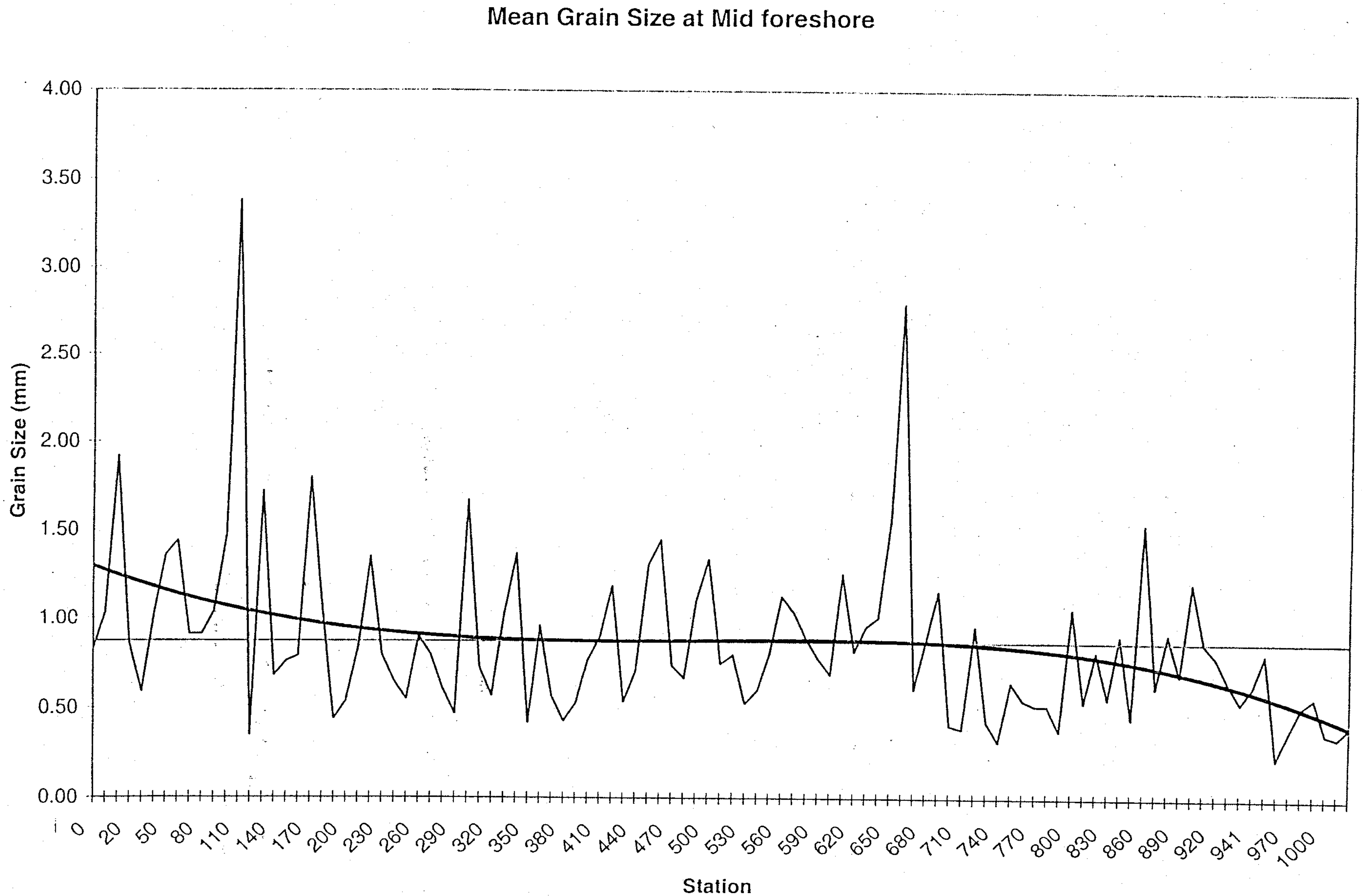


Figure 3-2 Mid Foreshore

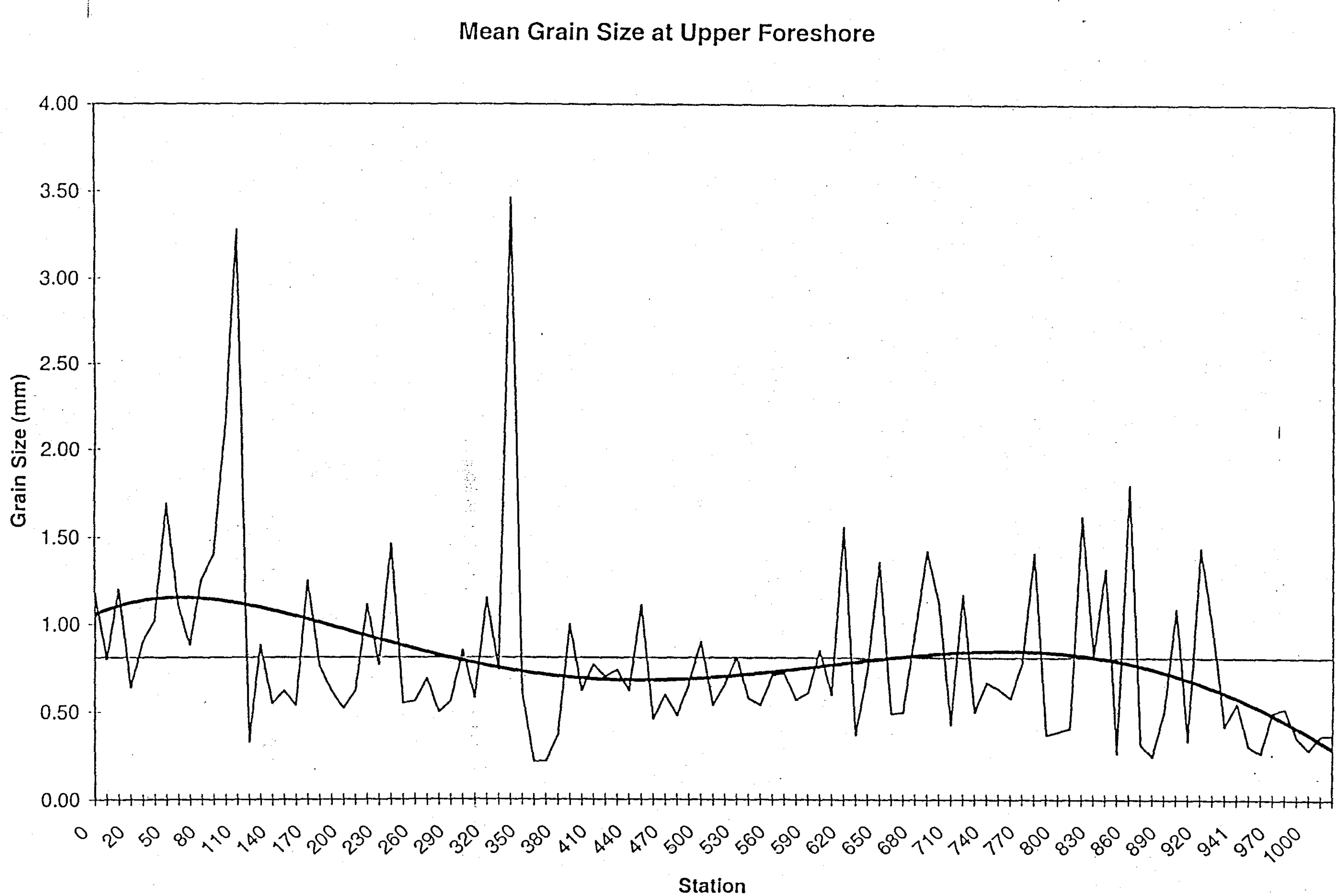


Figure 3-3 Upper Foreshore

Berm Center

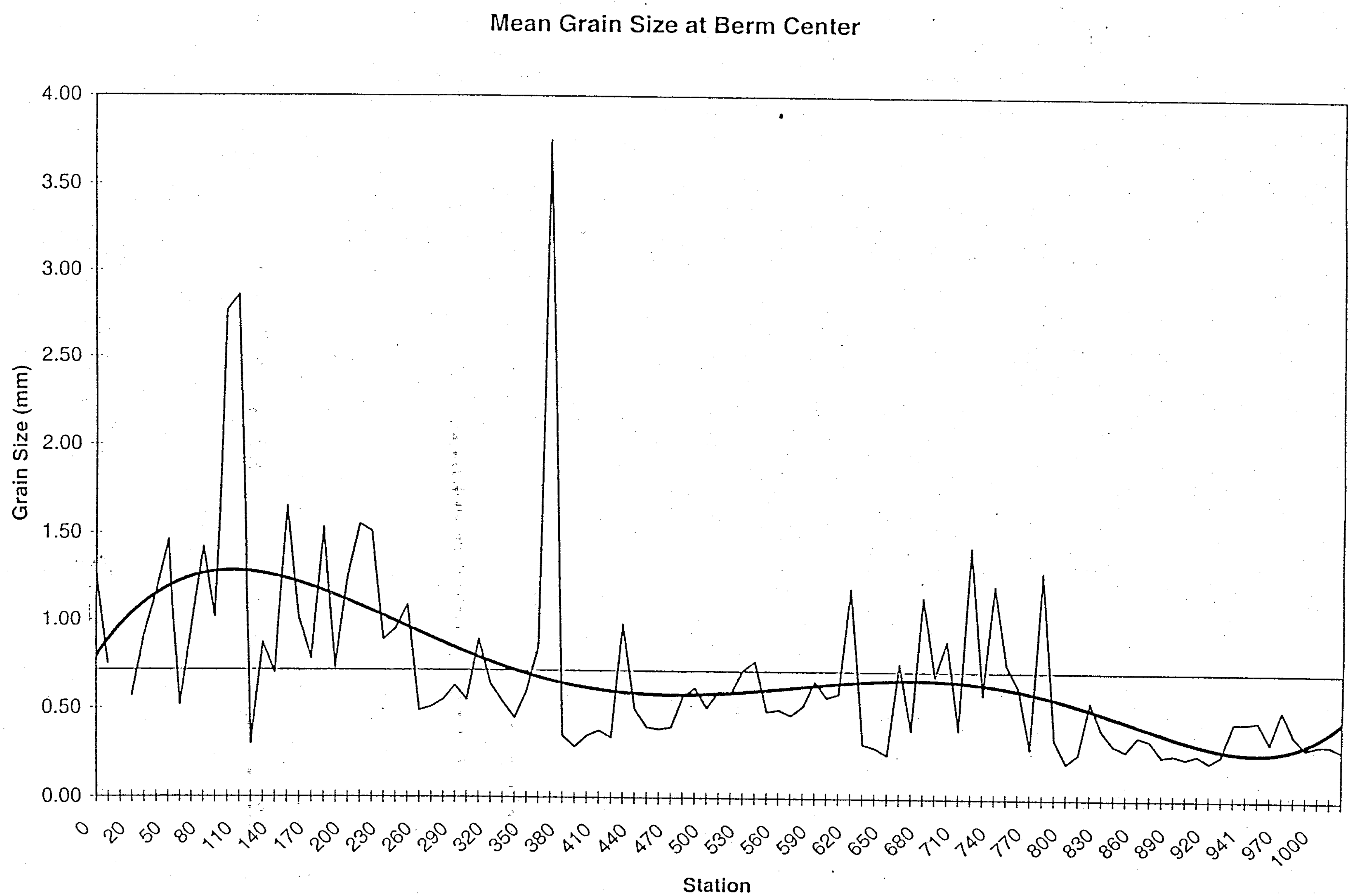


Figure 3-4 Center of Berm

Dune Toe

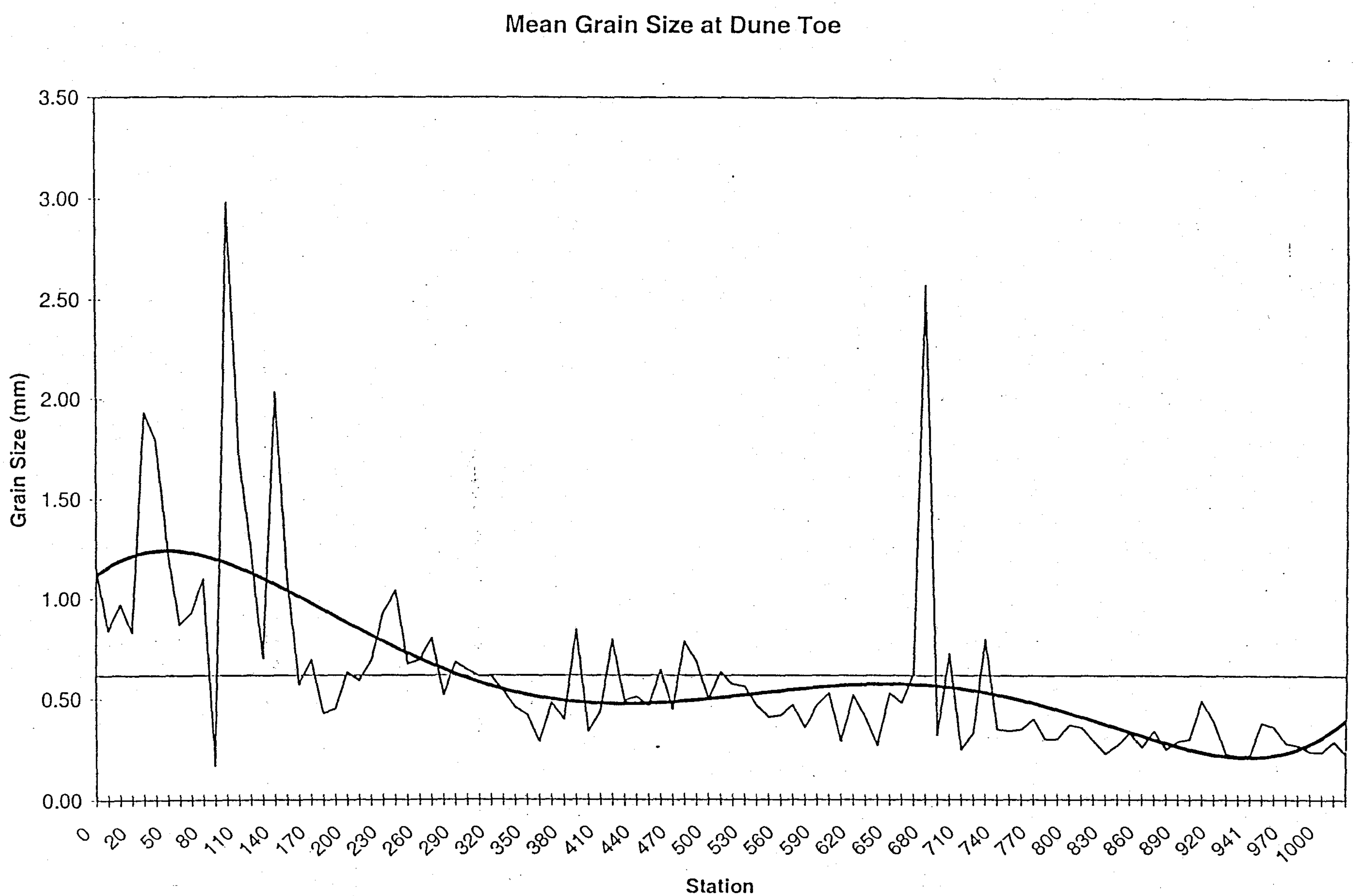


Figure 3-5 Base of the Dunes

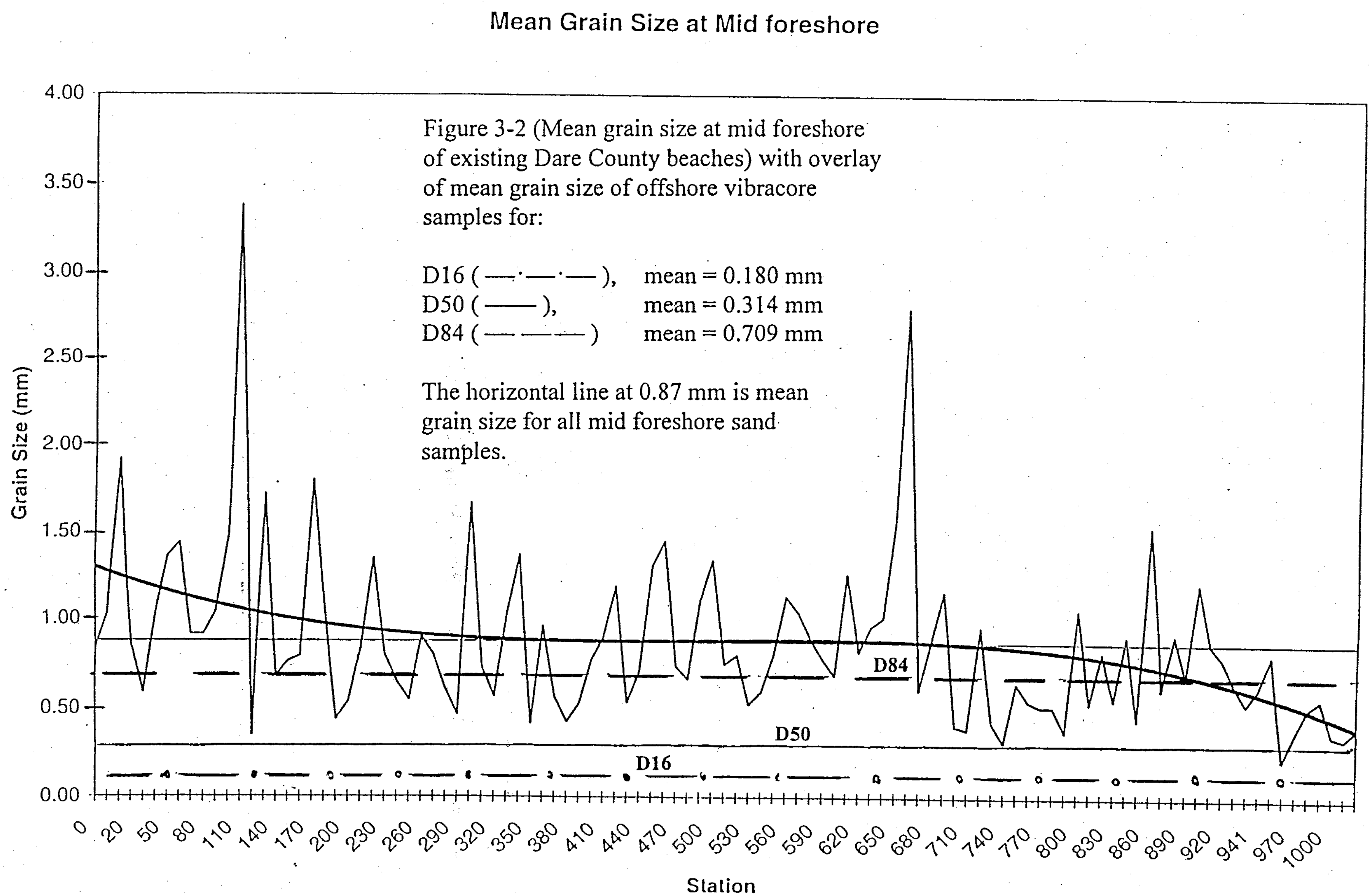
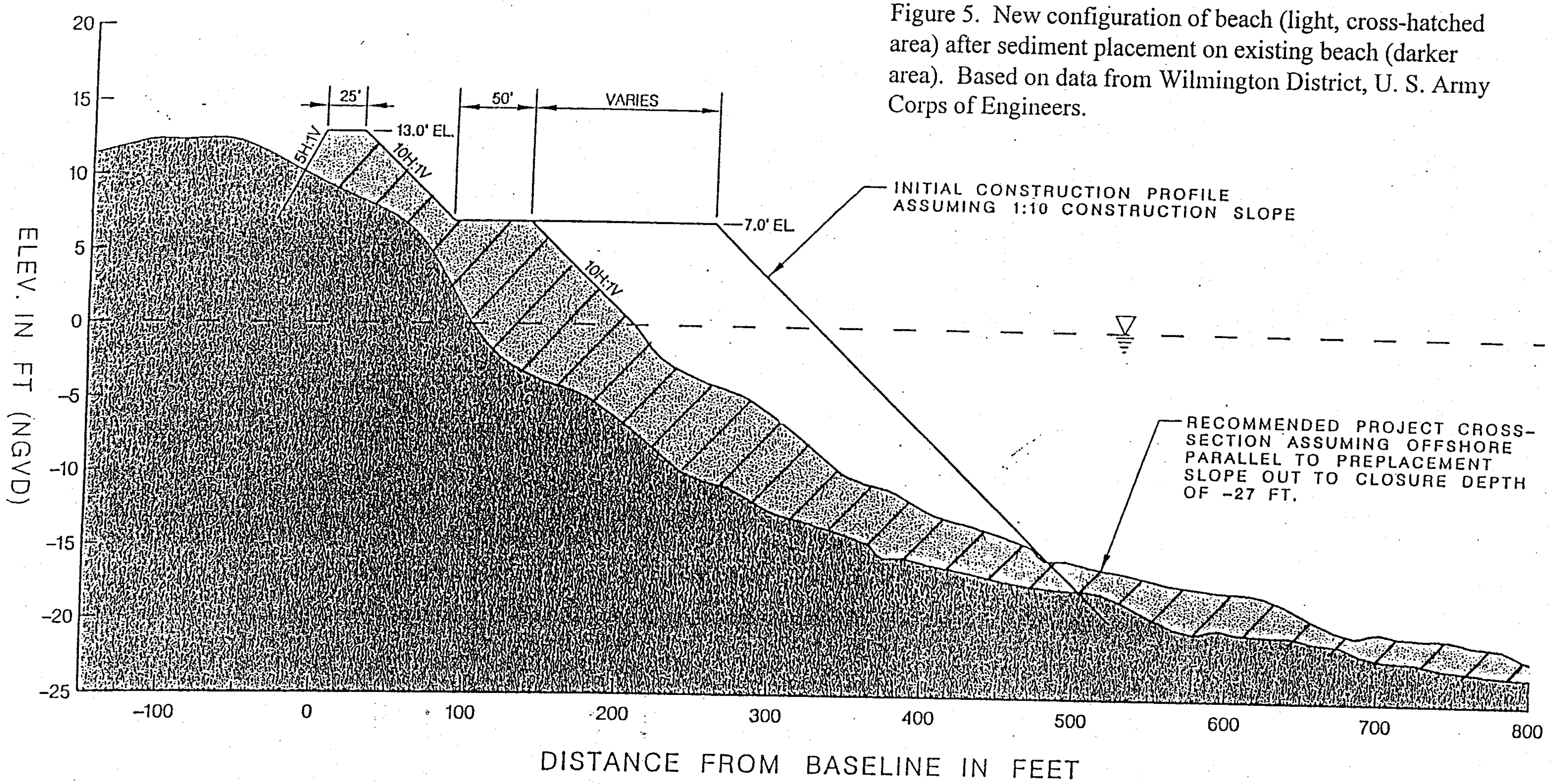


Figure 4 Nourishment Versus Native Beach Sand Size Mid Foreshore

Figure 5. New configuration of beach (light, cross-hatched area) after sediment placement on existing beach (darker area). Based on data from Wilmington District, U. S. Army Corps of Engineers.



last

13.0' DUNE WITH 50' BERM
TYPICAL CONSTRUCTION PROFILE

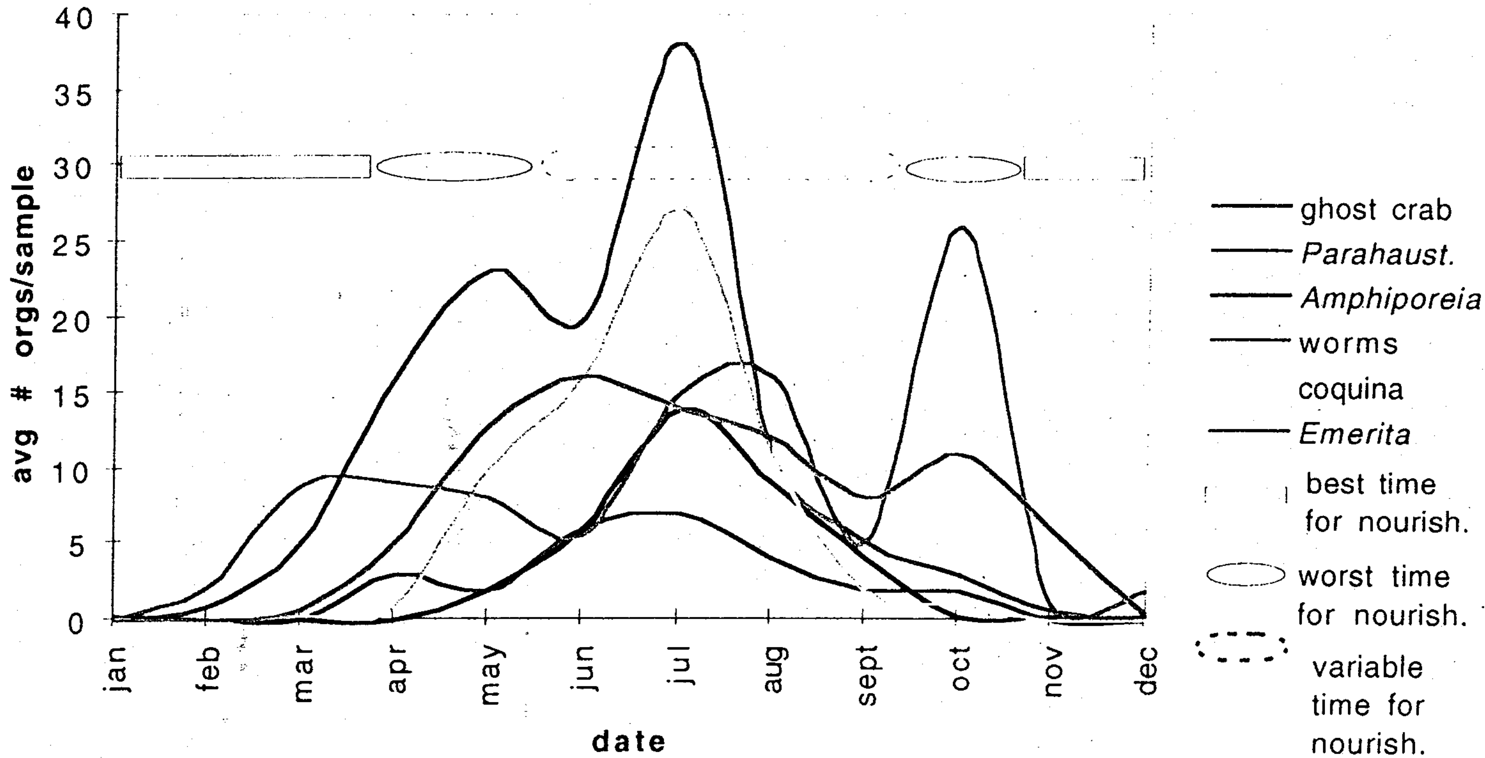


Figure 5. Seasonal abundance of beach and nearshore invertebrates on the Outer Banks and the relationship to best, worst, and variable times for beach nourishment

Memorandum

DATE: June 17, 1999

TO: Keith Watson, National Park Service, Cape Hatteras National Seashore

FROM: Cinde Donoghue, University of Virginia

RE: Dredge disposal impacts along North Carolina coast

CC: Robert Dolan

Timing of dredge disposal is important with respect to swash zone species specifically *Emerita talpoida* (mole crab), *Donax variabilis* (coquina clam), *Scolelepis squamata* (beach worm), *Parahaustorius longmerus* (amphipod) and *Amphiporeia virginiana* (amphipod). It also effects *Ocypode quadrata* (ghost crabs) which live higher on the beach, near the base of the dune and feeds on swash species. Disposals occurring between March and April or September and October can be expected to cause the longest-term significant depletion of populations of these organisms along the North Carolina coast. Disposals in late September through October are most detrimental and can virtually eliminate populations for nearly two years.

Difference between sediment size and the native beach sand is critical. These organisms are classified as "substrate sensitive" meaning their ability to burrow quickly to avoid washing out of the swash varies with sediment size. Sediment that is too fine is too closely packed for the organisms to burrow out of if buried during disposal. Coarser sediment slows their burrowing to such an extent that a disposal region is rendered essentially uninhabitable. Sediment that is finer than the native sand has a more immediate deleterious impact on organism abundances. Disposal material that is just 20% finer than the native sediment will decrease faunal abundances by 60%. In other words, for Pea Island if the average disposal sediment is finer than 250 microns, a depletion of at least 60% of mole crabs and coquina in the region of disposal and immediately downdrift of the area can be expected. A corresponding decrease will also be seen in a primary predator, ghost crabs. The decreases will remain for as long as the sediment is retained in the disposal region. If the average disposal sediment size is 180 microns, a decrease of 80% for mole crabs can be expected and coquina will be entirely eliminated from the area. Change in ghost crabs numbers will mirror this depletion.

Size of the nourishment relative to the longshore placement region is also important. The larger the volume of sediment placement on the beach, the longer the recovery period. On Pea Island, disposals of greater than 75,000 yd^3 of sand resulted in organisms population depletions below 65% of the non disposal region populations until the following season.

Disposal on to the back beach portion on Pea Island along a 1800 ft longshore region of beach with fine grained sediment (<200 microns taken from the region behind the groin) eliminated ghost crabs from the area for 26 months.

Changes to the beach shape (slope, and geomorphic features such as cusps, tidal pools and channels) will change the hydrodynamics of the wave runup and backwash. There is a relatively small window of runup and backwash flows that allow for the habitability of the swash species. Even sediment that is within the range of material the organisms are capable of burrowing into may not be habitable until the waves shape the sediment into features that allow for the proper runup and backwash flow velocities. Sediment that is exactly the same in size and shape characteristics of the native sand therefore will also impact organism abundances particularly if it placed in a concentrated region rather than spread out alongshore. The thinner the disposal wedge the higher the recovery rate. When the ratio of disposal of sediment to longshore beach distance was greater than 10,000 yd^3 per 2000 longshore ft, a significant increase in the time required for recovery occurred on Pea Island.

APPENDIX D

Fish Species Found in Inshore and Offshore Waters in the Project Vicinity. Source: N.C. Division of Marine Fisheries. 1991. Assessment of North Carolina Commercial Finfisheries 1989-1990 Season. Annual Progress Report for Project 2-IJ-16-2.

Dominant species caught in North Carolina inshore waters north of Cape Hatteras by long-haul fishery, sciaenid pound net fishery, and flounder pound net fishery.

Common Name	Scientific Name
Spot	*Leiostomus xanthurus*
Atlantic Croaker	*Micropogonias undulatus*
Weakfish	*Cynoscion regalis*
Bluefish	*Pomatomus saltatrix*
Southern Flounder	*Paralichthys lethostigma*
Striped Bass	*Morone saxatilis*

Species recorded from commercial reef fish fishery landings at Hatteras, North Carolina. Symbol (*) indicates coastal pelagic species caught in the reef fish fishery.

Common Name	Scientific Name
Sea basses	Family Serrranidae
Black seabass	*Centropristis striata*
Blackline tilefish	*Caulolatilus cyanops*
Red porgy	*Pagrus sedecim*
Vermillion snapper	*Rhomboplites aurorubens*
Jacks	*Carangidae*
Leatherjacket	*Oligoplites saurus*
Sharks	*Squaliformes*
Wahoo *	*Acanthocybium solanderi*
Dolphin *	*Coryphaena hippurus*
Bluefish *	*Pomatomus saltatrix*
King mackerel	*Scomberomorus cavalla*
Cobia *	*Rachycentron canadum*
Yellowfin tuna *	*Thunnus albacares*
Blackfin tuna *	*Thunnus atlanticus*
Bigeye tuna *	*Thunnus obesus*

Dominant species caught in offshore waters of the Dare County by deepwater trawl fishery, flynet trawl fishery, nearshore flounder trawl fishery, and commercial reef fish fishery.

Common Name	Scientific Name
Southern flounder	*Paralichthys lethostigma*
Summer flounder	*Paralichthys dentatus*
Bluefish	*Pomatomus saltatrix*
Weakfish	*Cynoscion regalis*
Atlantic croaker	*Micropogon undulatus*
Red drum	*Sciaenops ocellatus*
King mackerel	*Scomberomorus cavalla*
Spanish mackerel	*Scomberomorus maculatus*
Butterfish	*Peprilus triacanthus*
Spotted seatrout	*Cynoscion nebulosus*
Spot	*Leiostomus xanthurus*
Longspine porgy	*Stentomus caprinus*
Silver hake	*Merluccius bilinearis*
Longfin squid	*Loligo pealii*
Requiem sharks	*Carcharhinus* sp.
Spiny dogfish	*Squalus acanthias*
Little tunny	*Euthynnus allerteratus*
Pigfish	*Orthopristis chrysoptera*
Harvestfish	*Peprilus alepidotus*
Striped searobin	*Prinotus evolans*
Northern kingfish	*Menticirrhus saxatilis*
Southern kingfish	*Menticirrhus americana*
Northern puffer	*Spaeorides maculatus*
Scup	*Stenotomus chrysops*
Atlantic sturgeon	*Acipenser oxyrinchus*
Goosefish	*Lophius americanus*

APPENDIX E

Measures That Could Be Taken by the Federal Government to Reduce the Damage Caused by Shoreline Recession (Skidaway Institute of Oceanography 1985):

1. End all federal expenditures, direct or indirect, in support of private coastal development. Require private coastal development to pay its full cost.

2. Replace economic incentives for private development in high risk areas with incentives to relocate and build in other areas.

3. Acquire undeveloped areas to preserve natural features or the recreational beaches important to the public.

4. Discontinue government backed insurance programs for new development and substantial rebuilding and require flood insurance for existing structures to be actuarially sound. Also condition the use of insurance receipts or disaster payments on rebuilding outside coastal hazard areas.

5. Permit the use of offshore sand supplies for beach nourishment only where the value and extent of development outweighs other values and where nourishment would not deprive other communities of natural sand supplies.

6. Encourage research in new technologies for managing beach areas, especially inlets and navigation channels, without disturbing natural processes.

7. Provide special tax incentives and disincentives to limit development in the units of the Coastal Barriers Resources System and V Zones, including the following:

    a. Remove the limits on deductions for gifts of land to government or conservation groups if the land is in a threatened area.

    b. Allow tax deductible gifts with the right of the owner to use improvements until damaged by erosion or storms.

    c. Eliminate casualty loss tax deductions for properties in high risk zones purchased or built after adoption of a new policy.

    d. Eliminate Accelerated Cost Recovery System for property in high risk zones.

    e. Treat gains on property in high risk areas as ordinary income, rather than as capital gains.

f. Put businesses and homeowners on an equal footing by disallowing as business expenses the costs of draining, filling, or building protective measures on properties in the high risk zone.

g. Repeal the deduction for interest paid on loans for properties in the high risk zones.

h. Allow tax exempt financing for the financing of public acquisition of properties in the hazard areas.

I. Give preferential tax treatment to profits made on sales to public bodies or conservation groups.

8. Amend the Interstate Land Sales Act to require the disclosure of the possible consequences of buying or building in hazard zones.

9. Stimulate full disclosure by removing the "private offering" exemption in Section 4(2) of the Securities Act of 1933 for proposed private investment and development in units of the Coastal Barrier Resources System and in V Zones identified by the National Flood Insurance Program.

10. Establish a firm policy that all usable (compatible) sand material from navigation projects be placed on adjacent beaches.

APPENDIX F

Measures That Could Be Taken by State Government to Reduce the Damage Caused by Shoreline Recession (Skidaway Institute of Oceanography 1985):

1. End all state expenditures, direct or indirect, in support of private coastal development. Require private coastal development to pay its full cost.

2. Halt tax free exempt financing of private development on ocean beaches.

3. Acquire undeveloped areas with natural features or recreational beaches important to the public.

4. End state funding for roads and other public works serving high risk areas unless most of the benefits accrue to public coastal areas.

5. Halt stabilization, including sea walls, groins, jetties and other hardened construction, especially since such structures usually set off a chain of greater and greater defenses that typically lead to appeals for public subsidy, while destroying nature's system of beach maintenance.

6. Create a property transfer tax to fund acquisition of important coastal resources, public beaches and beach access, as already done in Florida and Massachusetts.

7. Create a tax check-off system or provide for earmarking tax refunds for public purchase of property in the high risk zones.

8. Allow special favorable tax assessments for land in high risk zones whose owners donate conservation easements or adopt uses compatible with preserving the natural beaches (e.g., fishing camps, some recreational uses, parks, etc.).

9. Establish building set-backs that protect natural beaches and primary dunes and that prohibit permanent structures in threatened areas. Where seasonal changes in beaches create new beach areas, prohibit building on newly accreted land.

10. Require developers and real estate agencies marketing property to disclose in writing the risks of being in the high hazard areas, including the costs associated with such risks during the expected life of their building.

11 Require when recording each change of ownership or new financing, a current plat be filed showing the lot lines, location of buildings and the shoreline location. Deed descriptions might note specific risks of hazard zones.

12. Require a successful applicant for a permit to rebuild in a hazard area to waive their rights to petition government for public aid when future damage occurs.

13. Educate the public about the nature of open ocean beaches, public and private property interests, and the economic consequences of beach management options and about how hardened defenses of private property burdens the taxpayer and denies citizens access to and use of their public beaches.

14. Enact enabling legislation, if necessary, to allow local government to create transferable development rights programs.

APPENDIX G

Measures That Could Be Taken by Local Governments to Reduce the Damage Caused by Shoreline Recession (Skidaway Institute of Oceanography 1985):

Land use planning should guide a variety of specific measures. Local land use plans should identify areas threatened by coastal erosion and flooding. Many coastal management acts already identify these areas. Land use plans and development regulations ought to prohibit unmovable buildings whose life spans will at any time place them in the path of the retreating shoreline.

1. Adopt zoning and land use controls that encourage development in safe areas by providing property owners who have to move back from the shore with development incentives elsewhere - e.g., cluster development, transferable development rights, extra building height, or total area.

2. Assign a non-conforming status to high risk uses of land just as zoning codes consider certain uses non-conforming. Regulations could prohibit non-conforming uses from being rebuilt after a certain level of damage has been sustained.

3. Require new subdivisions to set aside lands in safe areas for those who must retreat from the shore. Where shoreline retreat is likely to threaten buildings, lots could be required to have space for at least one back step large enough to safeguard the relocated building from rising sea level for at least the term of its projected life or require developers to set aside areas of land for future relocation.

4. Remove or require demolition of structures that become a threat to public safety, including seawalls and other structures in the surf zone and high risk buildings.

5. Remove hard stabilization structures that no longer serve their purpose and cause adverse affects to nearby shoreline.

6. Establish a fund to buy up property that should not be built upon. Such a fund would allow government to move quickly to buy storm damaged property when owners are most likely to sell at the lowest prices.

7. Establish a system of Transferable Development Rights in which presently developed or undeveloped oceanfront property is endowed with separable development rights that can be used or sold further inland if the oceanfront areas cannot be rebuilt or developed. If a government were to prohibit building or severely limit the density allowed on a given property, it could provide economic relief to the owner by assigning transferable and thus salable development rights.

8. Develop zoning provisions that have special standards for areas of unstable beaches, including a "floating zone" in which zoning designation and standards move with natural features such as mean high water, dune, or vegetation line.

9. Levy special impact assessments on risky development to provide a reserve fund for buying out damaged properties.

10. Using what is known of long term erosion rates, set time limits on the residential use of certain beach fronts, enabling the owners to plan a realistic depreciation and income projection into their financial plans.

11. Establish building set-backs that protect natural beaches and primary dunes and that prohibit permanent structures in threatened areas. Where seasonal changes in beaches create new beach areas, prohibit building on newly accreted land.