National Park Service
US Department of the Interior

Cape Hatteras National Seashore
North Carolina

Cape Hatteras National Seashore

Sediment Management Framework
Draft Environmental Impact Statement

September 2020

NPS cost associated with developing this EIS: $468,000

US Department of the Interior
National Park Service
Cape Hatteras National Seashore

Sediment Management Framework Environmental Impact Statement

September 2020

The National Park Service (NPS) prepared this draft environmental impact statement (DEIS) for a sediment management framework at Cape Hatteras National Seashore (the Seashore). The purpose of the DEIS is to develop a streamlined framework for permitting sediment management actions at the Seashore, including the methods, locations, and frequency for sediment management actions that may be permitted over the next 20 years. In this context, the DEIS will address certain sediment management activities that may be requested by local jurisdictions, utility companies, state agencies, other federal agencies, and in some cases, the Seashore.

This DEIS presents three alternatives: A, B, and C. The Seashore has received requests and anticipates future requests for sediment management activities to protect critical infrastructure such as roads, bridges, electrical transmission facilities, and other public transportation facilities; to repair island damages, including breaches that also affect transportation; and to restore habitat through the placement of dredged materials along eroded sections of barrier islands.

A sediment management framework is needed to assist the Seashore in addressing these requests in a timely manner, while avoiding and minimizing impacts that may be associated with such actions. Permitted sediment management activities would require consistent mitigation measures to reduce the impacts on park resources and values. The DEIS analyzes the beneficial and adverse impacts that could result from implementing any of the alternatives considered on littoral processes and barrier island morphology; benthic organisms and essential fish habitat; sea turtles; listed shorebird species; and structures and infrastructure. Upon conclusion of the DEIS and decision-making process, one of the alternatives (or a combination of alternatives) will be selected for implementation and will update the approach for permitting sediment management activities at the Seashore.

This DEIS is being prepared in cooperation with the US Army Corps of Engineers (USACE) Wilmington District Regulatory and Planning Divisions, the US Fish and Wildlife Service (FWS), the Bureau of Ocean Energy Management (BOEM), the North Carolina Department of Transportation (NCDOT) Ferry and Highway Divisions, the North Carolina Wildlife Resources Commission (NCWRC), Dare County, and Hyde County.

The review period for this document will end 45 days after publication of the US Environmental Protection Agency Notice of Availability in the *Federal Register*. Comments will be accepted during the comment period through the NPS Planning, Environment, and Public Comment website at https://parkplanning.nps.gov/CAHASediment or in hard copy delivered by the US Postal Service or other mail delivery service or hand-delivered to the address below. Comments will not be accepted by fax, email, or in any other way than those specified above. Bulk comments in any format (hard copy or electronic) submitted on behalf of others will not be accepted. Before including your address, telephone number, electronic mail address, or other personal identifying information in your comments, you should be aware that your entire comment (including your personal identifying information) may be made publicly available at any time. While you can ask us in your comments to withhold your personal identifying information from public review, we cannot guarantee that we will be able to do so.

For more information, visit https://parkplanning.nps.gov/CAHASediment.

Cape Hatteras Sediment Management DEIS
Superintendent, Cape Hatteras National Seashore
1401 National Park Drive
Manteo, NC 27954

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SUMMARY

This sediment management framework and draft environmental impact statement (DEIS) presents three alternatives for sediment management at Cape Hatteras National Seashore (the Seashore). This framework would guide NPS special use permitting over the next 20 years for sediment management activities such as beach nourishment; dune stabilization; emergency breach repair; and habitat restoration. Permitted sediment management activities would require consistent mitigation measures to reduce the impacts on park resources and values. This framework includes mitigation measures to reduce impacts to Seashore resources and visitors that may be associated with proposed projects.

This DEIS assesses the potential impacts of the alternatives on littoral processes and barrier island morphology, benthic organisms and essential fish habitat (EFH), sea turtles, listed shorebird species, and structures and infrastructure (including park recreation, park lands, economics, and visitation). This DEIS is being prepared in cooperation with the US Army Corps of Engineers (USACE) Wilmington District Regulatory and Planning Divisions, the US Fish and Wildlife Service (FWS), the Bureau of Ocean Energy Management (BOEM), the North Carolina Department of Transportation (NCDOT) Ferry and Highway Divisions, the North Carolina Wildlife Resources Commission (NCWRC), Dare County, and Hyde County.

BACKGROUND

The Seashore is located along the Outer Banks of North Carolina and is the nation's first national seashore, authorized in 1937 and reauthorized as Cape Hatteras National Seashore Recreational Area in 1940. Consisting of more than 30,000 acres distributed along approximately 67 miles of ocean-facing shoreline, the Seashore is part of a dynamic barrier island system. Nine villages, including Nags Head, Rodanthe, Waves, Salvo, Avon, Buxton, Frisco, Hatteras, and Ocracoke, are located adjacent to or within the Seashore. The Seashore and villages are accessible by North Carolina Highway 12 (NC 12); private boat; and the Hatteras-Ocracoke, Swan Quarter, and Cedar Island ferries. Given its local and regional popularity, the Seashore draws over 2 million visitors a year with opportunities to experience the ocean and sound beaches. Tourism is the largest industry in the Outer Banks, and Seashore visitors contribute substantially to the local economy (MAI 2015).

At the Seashore, human activities and structures have contributed to the alteration of natural shoreline processes. These activities and structures include dredging of navigation channels, hardened structures such as groins, dune building, overwash scraping (the process of removing/scraping overwash sand deposition off the road or other built features), and relative sea-level rise resulting from the warming temperatures caused by human-driven emissions (NPS 2015c). Sand fencing, grass planting, and dune building occurred in the 1930s and continued into the 1960s at the Seashore. Beach nourishment began in the 1960s and continues today. These human activities are changing the pace, magnitude, timing, and other aspects of natural ecosystem processes at the Seashore (NPS 2016c). Increased storm frequency and intensity have also impacted the natural migration and evolution of the barrier island environments at the Seashore (NPS 2015c). Numerous actions have been taken to protect and repair areas after high water events. Erosion rates are as high at 10 feet (ft) per year in some areas of the Seashore (CSE 2015). Over the next 30 years, approximately 5 to 10 inches (in) of sea-level rise are projected, potentially impacting Seashore resources, private property, and NC 12 (NOAA 2020b). Areas of frequent erosion within the

Seashore that have been identified for potential sediment management are based on repeated observations over the past several decades by NPS staff and state agencies; feasibility studies conducted by the NCDOT; erosion studies; local residents; consulting engineers; geologists; and surveyors. In some locations (e.g., portions of Ocracoke Island and the end of Hatteras Island) these areas of frequent erosion result in the loss of shoreline and upland habitats.

PURPOSE AND NEED

The purpose of taking action is to develop a framework for issuing special use permits for sediment management at the Seashore to mitigate impacts of human-altered shoreline processes, consistent with applicable NPS management policies. This framework will include the method, locations, and frequency for sediment management actions that may be permitted over the next 20 years. By developing a framework, the Seashore can consider the impacts of multiple sediment management actions over many years in a more comprehensive context and cumulative manner. The Seashore has received requests and anticipates future requests for sediment management activities to protect critical infrastructure such as roads, bridges, electrical transmission facilities, and other public transportation facilities; to repair island damages, including breaches that affect transportation; and to restore habitat through the placement of dredged materials along eroded sections of barrier islands. The Seashore needs a sediment management framework to assist in addressing these requests in a timely manner, while avoiding and minimizing impacts that may be associated with such actions.

ALTERNATIVES

The alternatives under consideration must include a “no-action” alternative as prescribed by 40 CFR 1502.14. Alternative A in this document is the “no-action” alternative. “No action” in this case would mean the proposed actions would not take place, and the resulting environmental effects from taking no action would be compared with the effects of permitting the proposed action or alternate action (CEQ 1981). Action alternatives may originate from the proponent agency, local government officials, or members of the public at public meetings or during the early stages of project development. Alternatives may also be developed in response to comments from coordinating or cooperating agencies. The alternatives analyzed in this document, in accordance with the National Environmental Policy Act (NEPA), are the result of internal and public scoping. These alternatives meet the overall purpose of and need for taking action. Alternative elements that were considered but were not technically or economically feasible, did not meet the purpose of and need for the project, or created unnecessary or excessive adverse impacts on resources were dismissed from further analysis. These alternatives are described briefly below and presented in greater detail in chapter 2.

Alternative A (No-Action Alternative)

Under alternative A, the NPS would not permit sediment management activities at the Seashore over the next two decades. NCDOT currently maintains a right of way (ROW) easement through the Seashore for NC 12, and alternative A would preclude NCDOT from implementing sediment management to protect NC 12 outside of its existing ROW. Partners, such as Dare County, would not be permitted to perform beach nourishment projects along the Seashore. Other partners, such as USACE, that may wish to work with the Seashore to implement habitat restoration projects through the placement of sediment would not be permitted to implement those projects. Under alternative A, permits also would not be issued for any sediment management activities on the Pea Island National Wildlife Refuge (NWR) section of the Seashore.

During development of this EIS, unforeseen storm and tidal events may warrant emergency action by agencies such as NCDOT to maintain critical infrastructure (such as NC 12) at the Seashore. These actions may occur outside of the NCDOT right of way and may require a special use permit (SUP) from the NPS. Actions may include sediment management to stabilize dunes, sand scraping, use of sand bags, and emergency breach repair. Under alternative A, the NPS would only issue a SUP for sediment management in extreme situations during the development of this EIS.

Alternative B (Proposed Action / Preferred Alternative)

Under alternative B, the NPS could permit other agencies and municipalities to conduct, with conditions, sediment management in the form of sound side and ocean side beach nourishment, dune restoration, and filling island breaches. Applicants would be encouraged to develop long-term, sustainable strategies that allow for the shoreline to respond dynamically to sea-level rise and erosion. They would also be encouraged to consider alternative management actions (e.g., retreat, relocation, etc.).

Projects on the sound side would probably be smaller in scale than the anticipated ocean side projects, as described under the "Project Parameters" sections below. Projects on the sound side could include beach nourishment, stabilization of existing infrastructure, and habitat restoration (for example, on Green Island). For many of these projects, the sediment source is likely to be trucked in from existing stockpiles.

Monitoring would be implemented before and after beach nourishment projects for the purposes of learning and improving conditions associated with future projects. Additionally, under alternative B, the NPS would set aside 5 sections totaling approximately 13 Seashore miles from consideration for sediment management activities in all cases except for emergencies. The primary purpose of excluding these areas is to study their ecology and provide reference zones that may be used in comparative studies with nourishment study areas. Those comparisons may warrant future modification of the frequency, timing, and other methods associated with nourishment projects.

Sediment Management Actions

Alternative B would permit the following actions along approximately 54 miles of Seashore. Sediment management activities would generally not be permitted along approximately 13 noncontiguous miles of beach set aside for monitoring (as noted above) where beach width or lack of vulnerable infrastructure indicate a low potential for requests to manage sediment.

Beach Nourishment

Beach nourishment would be permitted by the NPS at vulnerable sites along the Seashore oceanfront and sound side. Beach nourishment may include placement of material dredged from offshore waters or trucked in from other locations (anticipated to be outside of NPS property boundaries). The NPS may also undertake beach nourishment on the sound side of the Seashore.

Habitat Restoration

The NPS would work with other agencies to use sediment to restore habitat for nesting wildlife including shorebirds, in locations such as the end of the Hatteras Island area or Green Island in Oregon Inlet. NPS may also consider wildlife habitat restoration elsewhere at the Seashore through the placement of sediment.

Dune Nourishment and Sand Relocation

Alternative B may include dune reconstruction and/or enhancement in some areas, as well as moving or regrading sand in order to protect natural and cultural resources, existing access, and public facilities. Actions that promote dune building processes, such as beach grass planting and installation of sand fencing, are included in alternative B and may be carried out by the NPS or by a permittee.

Emergency Breach Repairs

When storm events create inlets or overwash areas that damage roadways, these geologic features may be addressed by trucking, staging, and pumping sand in from nearby or other locations to fill in the island breach. A breach is the condition where a channel across the island permits the exchange of ocean and sound waters under normal tidal conditions – there can be a partial or full breach (USACE 2016).

Project Parameters

Sediment management actions permitted under alternative B would fall within the general parameters of past, approved sediment management projects (unless improved methods are discovered). Permitted actions would be required to comply with all conditions specifically developed and prepared by state and federal agencies to minimize impacts to natural and cultural resources, recreation, and public access, as well as to promote health and safety near the proposed project.

Sediment Characteristics (Grain Size and Slope)

The grain size, color, texture, and geologic characteristics of the material from the borrow site would be required to be a close match to the native beach or shore conditions found at the proposed project site. Additionally, a beach should generally be designed such that it will be sloped similar to pre-project conditions following natural adjustment of the profile under wave and wind conditions. The “constructed” slope immediately following project completion may be steeper than the pre-project slope, but the “design” slope should be similar to pre-project conditions.

Volume

The volume of material used for projects is assumed to be between 50-250 cubic yards/foot, and scheduled projects would range from less than a mile to a maximum approximately 6 miles in length annually for ocean side sites. Based on past projects, it is expected that 7.92 million cubic yards would be placed along the ocean side of the Seashore at most, annually. In the event an emergency is declared following a severe storm event, an additional 6 miles of sediment management (an additional 7.92 million cubic yards) may be considered after completing necessary regulatory permit processes.

Borrow Areas

Over the last decade, sediment used for projects at the Seashore has been dredged from locations in the North Carolina Exclusive Economic Zone (Nags Head 2011; Buxton 2017; Nags Head 2019), which is the inshore portion of the continental shelf, extending from the shoreline to 3 miles offshore. Sediment for future projects may be sourced from borrow areas located beyond 3 nautical miles offshore, in federal waters on the Outer

Continental Shelf (OCS), where BOEM holds the authority to authorize use of OCS sand. Alternately, projects can consider bringing in sediment from existing stockpiles via trucks or other methods.

Frequency and Extent

The frequency of nourishment projects permitted at a specific site would be limited under alternative B to allow re-establishment of benthic communities following sediment placement. Alternative B would permit sediment management on up to 6 miles of the Seashore annually, recurring at individual sites as frequently as every three years. A nourished area would not be eligible to receive material again within the three-year period unless permitted under an emergency declaration. If an emergency is declared following a severe storm event, an additional 6 miles of sediment management may be permitted.

Time of Year

The NPS would recommend that proposed actions at the Seashore occur between November 16 and April 1 to avoid breeding and migration periods for listed shorebird species and nesting seasons for sea turtles. However, where safety conditions may preclude winter-time activities (e.g., emergency response, projects that require open-ocean dredging), the Seashore may permit summertime work, with the requirement that permittees work closely with other resource agencies to incorporate avoidance and minimization measures.

Alternative C

Alternative C would be similar to alternative B in that it includes beach nourishment, dune nourishment and sand relocation, and emergency breach repairs as described under alternative B. Sediment characteristics, volume, borrow areas, time of year, and mitigation measures would be same as described under alternative B. The frequency and extent of nourishment projects would differ under this alternative; sediment management may occur on up to 6 miles of beach every 5 years. The establishment of exclusion areas for reference monitoring as stated in alternative B would not take place under this alternative. This alternative would not result in the development of a consistent framework for sediment management that meets permitting needs at the Seashore for the next 20 years.

Alternatives Considered but Dismissed

The following alternatives were considered for inclusion within this framework; however, each was dismissed for the reasons described in chapter 2.

- Hardened structures
- New bridges
- Winter-only beach nourishment
- Living shoreline and marsh restoration
- Removal of the Avon Pier
- Unlimited beach nourishment
- Relocation and abandonment of NC 12, coastal retreat, and abandonment of the Seashore
- Dredging within the Seashore boundary

ENVIRONMENTAL CONSEQUENCES

This DEIS evaluates the direct, indirect, and cumulative impacts on the natural and human environment (i.e., physical, natural, cultural, and socioeconomic resources) that could result from the implementation of the alternatives under consideration. It is important to note that emergency work may be permitted while this EIS is under development. This is further detailed in chapter 2. Impact topics analyzed in detail in this DEIS include: littoral processes and barrier island morphology, benthic organisms and EFH, sea turtles, listed shorebird species, and structures and infrastructure. Impacts were assessed using the Council on Environmental Quality (CEQ) and the US Department of the Interior (DOI) regulations, policy, and guidance on NEPA implementation. The following provides a general summary of the impacts compared across alternatives; detailed descriptions are provided in chapter 4.

Littoral Processes and Barrier Island Morphology

Under alternative A, relative sea-level rise, climate change, wind and waves would continue to impact littoral processes and barrier island morphology. Littoral processes and barrier island morphology would continue to evolve, from the previously modified and moderately engineered system to a dynamic barrier island system with increased erosion, island narrowing, and increased overwash events. Under alternative A, the volume of sediment on the visible (sub-aerial) portion of the barrier island would likely continue to diminish over time.

In comparison, alternative B may help maintain the continuity of the barrier island system at a management scale (months to years) by increasing or maintaining the volume of sediments available for erosion along some sections of the beach, dune, and sound side shorelines. This may reduce the frequency of overwash and breach events, which may be potentially beneficial in allowing barrier systems to respond to relative sea-level rise. Habitat restoration, dune nourishment, and sound side sediment placement would likely create additional sources of erodible sediments to help the Seashore mitigate land loss over the lifetime of the proposed framework. It is likely that sediment management activities would slow the effects of chronic erosion along the Seashore at a management scale (i.e., months to years). Under alternative B, up to 158 million cy of sediment placement would be permitted along the Seashore over the 20-year lifetime of this framework. This volume would be used to mitigate erosion of beaches, dunes, and uplands across the Seashore over the lifetime of alternative B.

Alternative C would result in a smaller departure from current conditions than alternative B, because the frequency of projects would be designed to reflect the current status quo along the Seashore. This alternative would permit up to approximately 24 million cy of sediment placement along the Seashore over the next two decades. As is the case under alternative B, alternative C would involve the burial of nearshore and shoreline habitats, but many of these would be eroded naturally under the condition described in alternative A.

While sediment management activities under alternatives B and C would likely cause some temporary impacts (lasting weeks to months) to littoral processes and barrier island morphology, alternative B would likely help maintain continuity of the processes and habitats that have been in place along the Seashore in recent years.

Under alternative A, relative sea-level rise, climate change, and wind and waves would continue to impact littoral processes and barrier island morphology. Under alternative A, littoral processes and barrier island morphology would evolve naturally, from the previously modified and moderately engineered system to a dynamic barrier island system with increased erosion, island narrowing, and increased overwash events. Under alternative A, the volume of sediment on the visible (sub-aerial) portion of the barrier island would likely continue to diminish over time. In comparison, alternative B and alternative C may help maintain the continuity of the barrier island system at a management scale (months to years) by increasing or maintaining the volume of sediments available for erosion along some sections of the Seashore. This may reduce the frequency of overwash and breach events. Under alternative B, up to 7.92 million cy per year of sand placement (assuming up to 6 miles of beach per year, with up to approximately 1.32 million cy of sand per mile) along the Seashore would be a substantial contribution of sand to the system. This volume would be used to mitigate erosion of beaches, dunes, and uplands across the Seashore over the lifetime of alternative B.

Under alternative C, the impacts of each individual project on littoral processes and barrier island morphology would be the same as under alternative B, but the total impact of all sediment management activities would be reduced due to the decreased frequency of actions (only up to 6 miles of project permitted every 5 years). The degree of reduction in the impacts under alternative C as compared to alternative B would be proportional to the reduction in volume of sediment placed under alternative C.

Benthic Organisms and Essential Fish Habitat

Under alternative A, benthic communities and EFH/habitat area of particular concern (HAPC) within the wet beach and nearshore environments on the Atlantic and Pamlico Sound sides of the Seashore and at the inlets may be impacted by continued erosion leading to potential habitat disappearance and degradation including steeper beach profile and recurrent inlet breaches. Although it is difficult to predict the specific consequences of relative sea-level rise and the human activities conducted at the Seashore, modeling studies of relative sea-level rise have predicted a reduction in intertidal habitat and a decline in intertidal benthic communities. Modeling studies have also indicated that relative sea-level rise would reduce certain types of EFH including intertidal mud flats, submerged aquatic vegetation (SAV), and tidal marsh, and would lead to a decline in abundance and diversity of the benthic communities within these habitats. However, unvegetated, subtidal bottom and pelagic EFH, estuarine water column, soft bottom, and hard bottom, could benefit from increased depth of the water column and associated increases in productivity and nutrient uptake of phytoplankton which would improve food resources available in benthic communities and EFH.

Compared to alternative A, alternative B would likely provide a wider dry-sand beach and restore a less steep beach profile through sediment management at specific sites. This may temporarily improve habitat for benthic communities and help to mitigate the effects of relative sea-level rise. Alternative B would result in the burial of benthic communities at the project site, with impacts anticipated to last between six months to several years (Baptist et al. 2009; Rosov et al. 2016; Wilber and Clark 2007). Unlike alternative A, alternative B would temporarily introduce more turbidity into the water column, impacting EFH and HAPCs. Completing a maximum of 6 miles of beach nourishment in a year would involve dredging impacts that would result in a temporarily depleted benthic community over a small area of offshore substrate in the potential borrow areas, but would not impact the overall condition of the EFH or the benthic community offshore of the Seashore as a whole. If an emergency is declared following a severe storm event, an additional 6 miles of sediment management may be permitted every five years. Impacts from this scenario would likely be the same as those mentioned above, but at a slightly larger magnitude. Alternative B would also preserve approximately 13 noncontiguous miles (approximately 20% of the Seashore) as reference areas and remove them from consideration for sediment management activities in all cases except for emergencies. These reference areas may be used to perform comparative studies with nourishment project study areas. Information gained from these studies could further improve conditions associated with future projects, including modification of the frequency and timing of sediment management activities and other project parameters.

Alternative C would also provide a wider dry-sand beach, but sediment management activities would occur at fewer locations, less often than under alternative B. The impacts of each individual project would be the same as those described for alternative B, but the collective impact of all sediment management activities would be much less. Under alternative C, sediment management activities would occur along 6 miles of beach over a period of 5 years, rather than 6 miles each year as assumed under alternative B. It can be assumed that trends discussed in chapter 3 would continue under this alternative since project frequency would be similar to historic frequencies. Alternative C would not incorporate beneficial monitoring or a holistic framework.

Alternative C would result in similar project specific impacts to alternative B; however, projects would occur at a lesser frequency resulting in less disturbance to the benthic community and EFH/HAPC. Over the course of 5 years, it is anticipated that impacts from sediment management activities would not exceed 9% of the Seashore.

While impacts from sediment management activities under alternative B are anticipated to last from six months to several years for benthic communities and EFH, alternative B may help maintain the continuity of the barrier island system at a management scale (months to years) by increasing or maintaining the volume of sediments available for erosion along some sections of the beach, dune, and sound side shorelines, thus creating and maintaining habitat for benthic communities. Because alternative A would not permit sediment management activities beyond emergency actions within the NC 12 ROW and alternative C would continue sediment management activities at a rate similar to current management, it is anticipated they may not maintain the barrier island system as effectively as alternative B.

Sea Turtles

With no future permitted sediment management activities at the Seashore under alternative A, nesting habitat loss could be exacerbated throughout the Seashore and particularly in developed areas where the beach cannot naturally migrate inland in response to relative sea-level rise. An increase in frequency and intensity of storm events may increase the overwash/inundation of sea turtle nests, the loss of nests to erosion, and a decrease of available beach for nesting.

Based on recent nourishment efforts and the mitigation provided, there could be adverse impacts under alternatives B and C, compared to alternative A, but these would likely be temporary. Alternative B would permit sediment management activities along up to six miles of beach annually and up to 12 miles every 5 years for emergency actions, potentially impacting sea turtle habitat selection, nesting, and hatchling emergence through construction related activity and sediment composition. While impacts could last until the second or third nesting season after project completion, it is anticipated that mitigation measures either already in place or required by permits and/or consultation documents would limit adverse impacts and allow most, if not all, sea turtles that desired to nest in the study area an alternate opportunity in nearby locations; thereby improving the chances for the continued use of the Seashore for nesting by sea turtles. Additionally, landowners and localities would continue to use sand bags to protect buildings and private property. However, under alternative B, sediment management activities would potentially reduce the need for sand bags in the villages of the Seashore. Over the course of 20 years, it is possible that alternative B may create or stabilize habitat for sea turtles. FWS also concluded similar beneficial effects could result from an increase in sea turtle nesting habitat; and that a nourished beach designed and constructed to mimic a natural beach system would benefit sea turtles more than an existing eroding beach.

Alternative C would also provide a wider dry-sand beach for turtle nesting, but sediment management would occur at fewer locations and less often (6 miles of beach every 5 years) than under alternative B. The impacts of each individual project would be the same as those described for alternative B, but the collective impact of all sediment management activities would be less.

Listed Shorebird Species

Under alternative A, shorebirds would not be impacted by construction related activity associated with the NPS permitting of sediment management activities. It is likely erosion would continue along the Seashore and in areas where the island is prohibited from migrating landward due to development, there could be a loss of dry sand beach necessary for habitat. This loss could impact nesting, resting, foraging, migrating, and wintering shorebirds, and shorebirds would most likely be displaced elsewhere. Alternative A could increase the chance of overwash fans and inlet breaches in undeveloped areas which, although rare, could create new habitat on the sound side shoreline, which would benefit shorebirds. Alternative B would introduce impacts (lasting hours to several years) associated with construction noise and habitat disturbance, as well as disturbance to benthic communities vital for foraging shorebirds. These impacts would be confined to less than 9% of the total length of the Seashore every year (with construction related impacts affecting less area). Alternative B may also create a wider dry sand beach necessary for nesting and foraging for shorebird species. Additionally, the potential restoration of habitat on Green Island or the south end of Hatteras Island and other areas of the Seashore may increase the total available habitat for shorebirds at the Seashore, generally improving conditions for these species. Under alternative C, 67 miles of the Seashore would remain available at any given time with the exception of every 5 years when 61 miles would be available if sediment management activities are occurring; exclusion areas for reference monitoring would not take place under this alternative. Alternative C would adversely and beneficially impact listed shorebirds similarly, but on a smaller scale than alternative B. Benefits from the monitoring component and holistic framework associated with alternative B would not be seen with alternative C.

Under the alternative A, shorebirds would not be impacted by construction related activity associated with the NPS permitting of sediment management. It is likely erosion would continue along the Seashore and in areas where the island is prohibited from migrating landward due to development, there could be a loss of dry sand beach necessary for habitat. This loss could impact nesting, resting, foraging, migrating, and wintering shorebirds, and shorebirds would most likely be displaced elsewhere. Alternative A could increase the chance of overwash fans and inlet breaches, which, although rare, could create new habitat on the sound side shoreline, which would benefit shorebirds. Alternative B and alternative C would introduce impacts (lasting hours to several years) associated with construction noise and habitat disturbance, as well as disturbance to benthic communities vital for foraging shorebirds. These impacts would be confined to less than 9% of the total length of the Seashore every year under alternative B (with construction related impacts affecting less area). At least 61 miles of the Seashore (91%) would remain available at any point, and of those 61 miles, 13 miles (approximately 20%) of the Seashore would be set aside as reference zones and not considered for sediment management activities (in all cases except for emergencies). Under alternative C, 67 miles of the Seashore would remain available at any given time with the exception of every five years when 61 miles would be available if sediment management activities are occurring. Exclusion areas for reference monitoring would not take place under alternative C. Alternative B and alternative C may also create a wider dry-sand beach necessary for nesting and foraging for shorebird species. Additionally, the potential restoration of habitat on Green Island or the south end of Hatteras Island and other areas of the Seashore may increase the total available habitat for shorebirds at the Seashore, generally improving conditions for these species. Alternative C would impact listed shorebirds in similar ways as alternative B, but on a smaller scale.

Structures and Infrastructure

Under all alternatives, there would be continued adverse impacts on Seashore resources, values, and infrastructure, as well as private property and NC 12 because of the erosion resulting at least partially from human activities, existing hardened structures along the Seashore, and storm and extreme high tide events. Under alternative B and alternative C, these impacts would be temporarily lessened in and near the locations of the sediment management project, while the sediment remains in place. Alternative B would result in the greatest reduction of impacts to structures and infrastructure.

Under all alternatives, NC 12 closures would cause residents and visitors to lose access to the Seashore, and emergency personnel would need to rely on alternate methods of providing relief such as by emergency ferry routes. These adverse situations may be less severe and less frequent under alternative B and alternative C, but they would not be eliminated.

Under all alternatives, beachfront buildings and other infrastructure would continue to suffer damages, requiring closures that would result in loss of revenue from tourism as well as costs incurred by property owners for emergency protection measures and repairs. These adverse situations may be less severe and less frequent under alternative B and alternative C but would not be eliminated.

Alternative B and, to a lesser extent, alternative C may result in beneficial impacts to Seashore access by creating wider beaches. This may have secondary, temporary beneficial impacts on NC 12, other roads, and infrastructure adjacent to the shoreline. Under alternative B and, to a lesser extent, alternative C, access to the Seashore by residents and visitors may be maintained or restored more quickly after storm events because NC 12 may be less vulnerable to storm damages. Emergency personnel and equipment may be better able to access areas in need, more quickly restoring power and other vital services. Beachfront businesses may also experience less damage, allowing them to reopen more quickly after damage does occur, reducing their overall revenue losses. Overall, the improved access to the Seashore may temporarily allow the tourism-based economy to be more resilient under alternative B and alternative C compared to alternative A.

NEXT STEPS

The review period for this document will end 45 days after publication of the US Environmental Protection Agency Notice of Availability in the *Federal Register*. Substantive written comments on the DEIS will be fully considered and evaluated when preparing the final EIS. The final EIS will be available online at the project website (https://parkplanning.nps.gov/CAHASediment). The publication of the final EIS will initiate a 30-day waiting period. Following the 30-day waiting period, one of the alternatives, or a combination of alternative elements, will be documented in a Record of Decision signed by the NPS South Atlantic Gulf Region 2 Regional Director.

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ACRONYMS AND ABBREVIATIONS

BOEM	Bureau of Ocean Energy Management
CAMA	Coastal Area Management Act
CBRA	Coastal Barrier Resources Act
CBRS	John H. Chafee Coastal Barrier Resources System
CEQ	Council on Environmental Quality
CWH	critical wintering habitat
CZMA	Coastal Zone Management Act
DPS	distinct population segment
DEIS	Draft Environmental Impact Statement
EFH	essential fish habitat
ESA	Endangered Species Act
HAPC	habitat area of particular concern
IUCN	International Union for Conservation of Nature
Magnuson-Stevens Act	Magnuson-Stevens Fishery Conservation and Management Act
MBTA	Migratory Bird Treaty Act
MMPA	Marine Mammal Protection Act
MMS	Marine Minerals Service
NC 12	North Carolina Highway 12
NCAC	North Carolina Administrative Code
NCDCM	North Carolina Division of Coastal Management
NCDEQ	North Carolina Department of Environmental Quality
NCDOT	North Carolina Department of Transportation
NCDWR	North Carolina Division of Water Resources
NCEEZ	North Carolina Exclusive Economic Zone
NCWRC	North Carolina Wildlife Resources Commission
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NTU	nephelometric turbidity units
OCS	outer continental shelf
OCSLA	Outer Continental Shelf Lands Act
ORV	off-road vehicle
Pea Island NWR	Pea Island National Wildlife Refuge
ROD	Record of Decision
RMS	root mean square
SARBO	South Atlantic Regional Biological Opinion
SAV	submerged aquatic vegetation
SPBO	Statewide Programmatic Biological Opinion
the Seashore	Cape Hatteras National Seashore
SPL	sound pressure level
SHPO	State Historic Preservation Officer
SUP	Special Use Permit
TSS	total suspended solids
USACE	US Army Corps of Engineers
USCG	US Coast Guard
US EPA	US Environmental Protection Agency
FWS	US Fish and Wildlife Service

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CHAPTER 1: PURPOSE AND NEED

INTRODUCTION

Cape Hatteras National Seashore (the Seashore) is located along the Outer Banks of North Carolina and is the nation's first national seashore, authorized in 1937 and reauthorized as Cape Hatteras National Seashore Recreational Area in 1940. Consisting of more than 30,000 acres distributed along approximately 67 miles of ocean-facing shoreline, the Seashore is part of a dynamic barrier island system (see figure 1 in appendix A). The Seashore was established to preserve the wild and primitive character of the ever-changing barrier islands, protect the diverse plant and animal communities sustained by the coastal island processes, and provide for recreational use and enjoyment that is compatible with preserving the distinctive natural and cultural resources of the Seashore. Nine villages, including Nags Head, Rodanthe, Waves, Salvo, Avon, Buxton, Frisco, Hatteras, and Ocracoke, are located adjacent to or within the Seashore (see figure 2 in appendix A). The Seashore property encompasses a mix of land uses with villages, residences, commercial uses, tourist attractions, and nationally important resources existing within and adjacent to NPS managed areas. The Seashore and villages are accessible by North Carolina Highway 12 (NC 12); private boat; and the Hatteras-Ocracoke, Swan Quarter, and Cedar Island ferries. Given its local and regional popularity, the Seashore draws over 2 million visitors a year with opportunities to experience the ocean and sound beaches.

Pea Island National Wildlife Refuge (Pea Island NWR or refuge) is located within the boundaries of Cape Hatteras National Seashore and jointly managed by the US Fish and Wildlife Service (FWS) and National Park Service (NPS). Executive Order 7864 established Pea Island NWR on April 8, 1938, as a refuge and breeding ground for migratory birds and other wildlife. Presidential Proclamation 2284 closed a 25,700-acre area encompassing the refuge and a portion of the Pamlico Sound west of and adjacent to the refuge to migratory bird hunting. The refuge covers approximately 5,000 acres (reduced by erosion from the original 5,915 acres). The purpose of Pea Island NWR is to protect and conserve migratory birds and other wildlife resources through the protection of wetlands, in accordance with the following: "…as a refuge and breeding ground for migratory waterfowl and other wildlife…" (Executive Order 7864, August 8, 1938). The Department of the Interior (DOI) Secretarial Order establishing the Seashore in 1953 states, "As provided in Section 5 of the Act of August 17, 1937, as amended, the lands comprising the Pea Island National Wildlife Refuge shall continue to be administered as a Refuge by the Fish and Wildlife Service and shall be administered by the National Park Service for recreational uses not inconsistent with the purposes of the Refuge, pursuant to this order." The Pea Island NWR portion of the Seashore is included in this plan through FWS participating as a Cooperating Agency; permitting for projects on Pea Island NWR would be administered by FWS as described in chapter 2.

Natural accretion and erosion processes have been impacted at the Seashore for decades due to anthropogenic activities (e.g., dune building, dune vegetation planting, inlet dredging, and maintenance of dunes) and other changes (e.g., relative sea-level rise[1], increased storm frequency and intensity). As a result, natural migration and evolution of the barrier island environments are impacted. Numerous actions have been taken to protect and repair areas after high water events. Erosion rates are as high as 10 ft per year in some areas of the Seashore (CSE 2015). Over the next 30 years, approximately 5 to 10 in of sea-level rise

[1] Sea level relative to a fixed vertical datum on land, taking into account processes such as subsidence, which is the sudden sinking or gradual downward settling of the ground's surface.

are projected, potentially impacting Seashore resources, private property, and NC 12 (NOAA 2020b). Figures 3 and 4 in appendix A illustrate areas of frequent erosion within the Seashore that have been identified for potential sediment management. These areas of frequent erosion are based on repeated observations over the past several decades by NPS staff and state agencies; feasibility studies conducted by the North Carolina Department of Transportation (NCDOT); erosion studies; local residents; consulting engineers; geologists; and surveyors. In some locations (e.g., portions of Ocracoke Island and the end of Hatteras Island) these areas of frequent erosion result in the loss of shoreline and upland habitats.

The Seashore is developing a framework for authorizing particular sediment management actions within its boundaries, including consistent mitigation measures to reduce the impacts on park resources and values. This framework would provide parkwide guidelines for the Special Use Permit (SUP) applications NPS may receive from entities needing to address transportation maintenance actions and other sediment management requests during the next 20 years. The Seashore has developed alternatives in response to past, current, and anticipated future requests from agencies such as NCDOT, Dare County, and the US Army Corps of Engineers (USACE) for the purposes of:

1) Protecting critical infrastructure such as roads, highway, bridges, ferry terminals, electrical transmission facilities, and other public transportation facilities;
2) Repairing island damages, including breaches, that also affect transportation; and
3) Restoring habitat through the placement of dredged materials along eroded sections of barrier islands.

Sediment management activities are the suite of activities proposed under the action alternatives. These include sound side and ocean side beach nourishment, dune restoration, filling island breaches, and habitat restoration.

BACKGROUND

Sediment management measures have been used periodically at the Seashore to control erosion and stabilize man-made sand dunes (NPS 2013). From the 1930s through the 1960s, active dune building and revegetation efforts occurred along the Seashore. Since the 1970s, localized nourishment has been used to combat severe erosion in some locations such as Ocracoke Island, the Buxton/Cape Hatteras Point area, and Rodanthe. In some places, segments of beach are relatively stable and erosion has not affected transportation or visitor access. In other places, highly eroded beaches result in impacts to dunes and in the ocean waters flooding NC 12, into Seashore facilities, and within adjacent communities.

Historically, the NPS's policy has been to avoid intervention in natural biological or physical processes in park units except:

- When directed by Congress;
- In emergencies in which human life and property are at stake;
- To restore natural ecosystem functioning that has been disrupted by past or ongoing human activities; or
- When a park plan has identified the intervention as necessary to protect other park resources, human health and safety, or facilities (NPS *Management Policies 2006* § 4.1).

This same policy has long applied to shorelines in park units. Where shoreline processes are "natural" (that is, not altered by human activities or structures), the NPS policy is to allow those unaltered processes to continue. However, where shoreline processes have been altered by human activities or structures, the NPS policy is to investigate alternatives for:

- Mitigating the effects of those activities or structures; and
- Restoring natural conditions (NPS *Management Policies 2006* § 4.8.1.1).

At the Seashore, human activities and structures that have altered natural shoreline processes include dredging of navigation channels, hardened structures such as groins, dune building, overwash scraping (the process of removing/scraping overwash sand deposition off the road or other built features), and relative sea-level rise resulting from the warming temperatures. Sand fencing, grass planting, and dune building occurred in the 1930s and continued into the 1960s at the Seashore. Beach nourishment began in the 1960s and continues today. These human activities are changing the pace, magnitude, timing, and other aspects of natural ecosystem processes at the Seashore; therefore, meeting the criteria in the policy statement listed above (NPS 2016c). It is consistent with NPS policy for the NPS to – at the appropriate time and in the appropriate circumstances – intervene in various processes at coastal parks in order to mitigate these human-caused impacts and protect certain park resources and values (NPS 2016c). There is no requirement for the NPS to mitigate or intervene; instead the NPS investigates, or evaluates, potential mitigation or intervention alternatives. Any such intervention would be kept to the minimum necessary to achieve the stated management objectives (NPS *Management Policies 2006* § 4.1 and § 4.8.1.1). In the case of sediment management, the costs associated with trying to mitigate impacts associated with human-influenced erosion are significant and generally beyond the Seashore's capacity. Therefore, actions associated with sediment management have traditionally been carried out and funded by partner agencies.

PURPOSE OF AND NEED FOR ACTION

The purpose of taking action is to develop a framework for issuing special use permits for sediment management at the Seashore to mitigate impacts of human-altered shoreline processes, consistent with applicable NPS management policies. This framework will include the method, locations, and frequency for sediment management actions that may be permitted over the next 20 years. By developing a framework, the Seashore can consider the impacts of multiple sediment management actions over many years in a more comprehensive context and cumulative manner. The Seashore has received requests and anticipates future requests for sediment management activities to protect critical infrastructure such as roads, bridges, electrical transmission facilities, and other public transportation facilities; to repair island damages, including breaches that also affect transportation; and to restore habitat through the placement of dredged materials along eroded sections of barrier islands. The Seashore needs a sediment management framework to assist in addressing these requests in a timely manner, while avoiding and minimizing impacts that may be associated with such actions.

COOPERATING AGENCIES

This DEIS was prepared in cooperation with the following agencies: Bureau of Ocean Energy Management (BOEM), FWS, the USACE Wilmington District (Regulatory and Planning Divisions), NCDOT (Ferry and Highway Divisions), North Carolina Wildlife Resources Commission (NCWRC), Dare County, and Hyde County. Federal cooperating agency partners contributed to the development of this DEIS in accordance with National Environmental Policy Act (NEPA) regulations and may use this DEIS to support future actions related to sediment management activities at the Seashore. Adopting this framework could help streamline agencies' future NEPA efforts and allow them to focus any additional analysis on new information or project-specific activities that are not fully analyzed herein.

Recognizing that outer continental shelf (OCS) sand resources may be identified over the 20 year planning period to support future NPS sediment management actions (i.e., beach nourishment), BOEM has agreed to serve as a cooperating federal agency in the development of this DEIS and may undertake a relevant action (i.e., authorize use of the OCS borrow area) that is related to, but unique from, the NPS proposed action. BOEM's alternate actions are to issue a negotiated agreement pursuant to its authority under the Outer Continental Shelf Lands Act (OCSLA).

The FWS is the primary federal agency responsible for the conservation, protection, and enhancement of the nation's fish and wildlife population and their habitats. Although the FWS shares some conservation responsibilities with other federal, state, tribal, local, and private entities, it has specific trustee obligations for migratory birds, threatened and endangered species, anadromous fish, and certain marine mammals. In addition, the FWS administers a national network of lands and waters for the management and protection of these resources. The National Wildlife Refuge Administration Act of 1966 (16 U.S.C. §§ 668dd et seq.) establishes a unifying mission for national wildlife refuges, outlines a process for determining compatible uses of refuges, and reinforces and expands the compatibility standard. The act states, first and foremost, that the mission of the National Wildlife Refuge System be focused singularly on wildlife conservation. The National Wildlife Refuge System Improvement Act of 1997 (Refuge System Improvement Act; P.L. 105-57) establishes a unifying mission for the Refuge System and a new process for determining the compatibility of public uses on refuges. The act states that the mission of the Refuge System, coupled with the purpose(s) for which each refuge was established, will provide the principal management direction on that refuge. It states that the FWS will manage each refuge to:

- fulfill the mission of the Refuge System;
- fulfill the individual purposes of each refuge;
- consider the needs of fish and wildlife first;
- fulfill the requirement of developing a comprehensive conservation plan for each unit of the Refuge System, and fully involve the public in the preparation of these plans;
- maintain the biological integrity, diversity, and environmental health of the Refuge System; and
- recognize that wildlife-dependent recreational activities including hunting, fishing, wildlife observation, wildlife photography, and environmental education and interpretation are legitimate and priority public uses.

The FWS's Policy on Maintaining Biological Integrity, Diversity, and Environmental Health (601 FW 3) provides guidance on maintaining or restoring the biological integrity, diversity, and environmental health of the Refuge System, including the protection of a broad spectrum of fish, wildlife, and habitat resources in refuge ecosystems. It provides refuge managers with a process for evaluating the best management direction to prevent the additional degradation of environmental conditions and restore lost or severely degraded components of the environment. It also provides guidelines for dealing with external threats to the biological integrity, diversity, and environmental health of a refuge and its ecosystem.

In defining the relationship between the Refuge System mission and refuge purpose(s), the policy states, "we view the System mission, goals, and unit purpose(s) as symbiotic; however, we give priority to achieving a unit's purpose(s) when conflicts with the System mission or a specific goal exist." Biological Integrity, Diversity, and Environmental Health policy mandates, "We will, first and foremost, maintain existing levels of biological integrity, diversity, and environmental health at the refuge scale." Secondarily, the policy requires refuges to "restore lost or severely degraded elements of integrity, diversity, environmental health at the refuge scale and other appropriate landscape scales where it is feasible and supports achievement of refuge purpose(s) and System mission." Refuge management priorities are first for the achievement of refuge-specific purposes with a secondary priority of maintenance, and, where appropriate, restoring biological integrity, diversity, and environmental health, where they do not conflict with refuge purposes.

The FWS has agreed to serve as a cooperating Federal agency in the development of this DEIS and may undertake actions on the Pea Island NWR portion of the Seashore as described in this DEIS. Proposed uses or projects on the Pea Island NWR portion of the Seashore will require a permit from FWS as described in chapter 2.

The other federal, state and, local partners are also participating as cooperating agencies on this DEIS due to their role in reviewing or sponsoring future projects. More information of state and federal permits, licenses, and approvals is included appendix B.

ISSUES AND IMPACT TOPICS RETAINED FOR ANALYSIS

Impact topics identify resources within the study area that could be affected, either beneficially or adversely, by the range of alternatives.

Littoral Processes and Barrier Island Morphology

When natural processes have been impacted by human activities and/or structures, the Seashore must be managed differently than a naturally evolving barrier island, and the NPS is directed by *Management Policies 2006* to investigate alternatives for mitigation and restoration.

The action alternatives would result in changes to onshore and nearshore littoral processes and barrier island morphology. Beach nourishment generally creates a steeper beach profile after implementation, which gradually adjusts to the previous slope over time under the influence of wave action, a major physical force in the nearshore environment (NRC 1995, McLachlan 1996, Greene 2002). Projects that increase dune elevations can reduce overwash frequency on barrier islands like the Outer Banks (Magliocca et al. 2011). Overwash deposits help barrier islands gain elevation through increases in sea level (Riggs and Ames 2003; Moore et al. 2007; Reef et al. 2020). On the sound side, sediment management actions would be used to protect roadways and other infrastructure and restore large areas of habitat-compatible material like sandy flats or shallow muddy bottoms used by migratory waterfowl, as well as sub-aquatic vegetation. The exact construction methods and goals of individual projects on the sound side will likely be more diverse than those along ocean-facing beaches within the Seashore. As a result, the impacts on littoral processes and barrier island morphology will vary as well. Such projects would help provide habitats and increase sound side shoreline elevations, both of which have been reduced over the long term. However, there is a possibility that sound side sediment management activities may damage sensitive, low-energy environments in some locations where there may be a need to protect roadways and infrastructure, if management activities are not executed properly.

Sediment management activities would impact littoral processes and barrier island morphology through the manipulation of large quantities of sediment to mitigate natural erosion processes as well as relative sea-level rise. For this reason, the topic of Littoral Processes and Barrier Island Morphology will be analyzed.

Benthic Organisms and Essential Fish Habitat

The action alternatives could cause adverse impacts on benthic organisms, essential fish habitat (EFH), and habitat areas of particular concern (HAPC) in several ways. The placement of sand on the shoreline could affect intertidal and submarine habitat for benthic organisms by burying areas, either by direct sand placement or with placement sand eroded from the beach. Sediment management activities could indirectly bury benthic organisms or indirectly impact vegetation in tidal marshes and the subtidal submerged aquatic vegetation (SAV), mud bottom, sand bottom, and hard bottom EFHs and HAPCs; temporarily increase turbidity in shallow coastal pelagic EFH; and/or bury sargassum EFH that may be beached or floating in the intertidal area (CSE 2015).

Tidal marsh is a HAPC located along most of the sound side of the Seashore, and it could be impacted by sediment management activities. Activities occurring on the sound side of the Seashore would include habitat restoration, sand placement in sandy bottom areas to slow erosion or protect infrastructure, and breach repair. Natural transport of placement sand following a nourishment event on the sound side and the inlets would depend on the direction of the tide and local currents within the Pamlico Sound. Depending on the transport hydraulics, sediment management activities could cause adverse impacts to tidal marshes in several ways. Sediment management activities could indirectly bury immobile benthic organisms or vegetation, disrupt the normal ecosystem function (CSE 2015), and displace mobile organisms. Deposition of eroded sediment could also raise the elevation of the natural substrate which could alter the composition of the vegetation community. Natural transport of eroded placement sand on the sound side and the inlets would depend on the direction of the tide and local currents within the Pamlico Sound. The addition of sediment could also benefit these habitats by replacing sediment that is routinely transported on barrier islands during storm events but currently is not due to a lack of sediment supply from washover fans.

SAV is another HAPC found along some of the sound side of the Seashore in subtidal areas adjacent to tidal marshes and other sound side intertidal habitats. Deposition of eroded sediment following a nourishment event could bury SAV or raise the elevation of the natural substrate, potentially changing the composition of the vegetation community.

Sediment management activities would impact benthic invertebrate communities, EFH, and HAPC through burying during sand placement or sedimentation or increasing water column turbidity. For these reasons, the topic of benthic organisms and EFH will be analyzed.

Sea Turtles

The action alternatives may occur during any time of the year due to project feasibility and safety concerns caused by rough offshore seas and high winds typically experienced at the Outer Banks during the fall and winter (October to March). Therefore, it is likely that sediment management activities may occur during some part of sea turtle nesting season (May to October). Construction equipment on the beach during sand placement could directly impact nesting sea turtles. Sediment management activities may impact sea turtle reproductive success during construction and continue through the first year after completion of sediment management activities (FWS 2017). Sand placement may result in changes to 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 (USACE 1988b). These changes could result in adverse impacts on sea turtle nest site selection, digging behavior, clutch viability, and hatchling emergence (Nelson and Dickerson 1987 quoted in FWS 2017; USACE 1988a; Ernest and Martin 1999).

Dredging at offshore borrow sites during sediment management activities could potentially impact sea turtles by entrainment in the draghead during dredge operation or increase sea turtle injuries from vessel strikes. Dredging and sand placement activities could also present obstructions to loggerhead and other sea turtles in transit through either the surf zone or the offshore borrow area. Also, the potential borrow areas would be located within loggerhead sea turtle critical habitat as determined pursuant to the Endangered Species Act (ESA) and could impact the quality of that habitat.

Sea turtles considered in the analysis include loggerhead sea turtle (*Caretta caretta*), leatherback sea turtle (*Dermochelys coriacea*), green sea turtle (*Chelonia mydas*), Kemp's ridley sea turtle (*Lepidochelys kempii*), and hawksbill sea turtle (*Eretmochelys runcates*). Additionally, offshore areas are designated critical habitat for loggerhead sea turtles of the Northwest Atlantic Distinct Population Segment (DPS). The critical habitat includes specific areas that contain constricted migratory corridors (NOAA 2014).

Sediment management activities could change sand and beach characteristics, potentially impacting sea turtle nesting. Dredging may entrain sea turtles or result in increased vessel strikes. For these reasons, the topic of sea turtles will be analyzed.

Listed Shorebird Species

Potential impacts to shorebird species from the action alternatives could include disturbance of foraging and nesting during sediment management activities. The loss of preferred nesting habitat along these stretches of shoreline would be temporary, lasting the length of sand placement, which would be completed within a year. Shorebird foraging habitats on the ocean side, sound side, and at the inlets, would be impacted by sand placement. These would include the wet beach habitat, tidal marshes, mud flats, sand bars, and shallow coastal waters; and transport of sediment from sand placement would reduce prey availability by burying immobile benthic organisms and increasing turbidity in the water column. Changes to foraging behavior and nesting as a result of changes in the communities of benthic organisms on which these species feed would take place subsequent to sediment management activities. Sediment management activities may also involve shorebird nesting habitat restoration including possible locations at Green Island in Oregon Inlet and the south end of Hatteras Island adjacent to Hatteras Inlet. It is anticipated that habitat restoration would provide beneficial impacts to nesting and foraging shorebird species at the Seashore.

Several shorebird species protected under the ESA are known to use the study area. These species include piping plover (*Charadrius melodus*), roseate tern (*Sterna dougallii dougallii*), and rufa red knot (*Calidris canutus rufa*). There are several other shorebird species, not protected under the ESA, that nest at the

Seashore, are managed by NPS, and are protected under the Migratory Bird Treaty Act (MBTA). These species are protected as either threatened or special concern species by the State of North Carolina and include gull-billed tern (*Gelochelidon niloctia*), least tern (*Sternula antillarum*), common tern (*Sternula hirundo*), black skimmer (*Rhynchops niger*), American oystercatcher (*Haematopus palliates)*, and Wilson's plover (*Charadrius wilsonia wilsonia*) (NPS 2018c). It should be noted that terns and skimmers are technically categorized as seabirds; however, for ease of refence in this document, they are grouped with the plovers and oystercatcher in general references to shorebirds.

Sand placement from sediment management activities could disturb foraging, resting, and nesting listed shorebird species, as well as nesting habitat. In addition, sand placement would also impact benthic invertebrate communities within areas of potential sediment management. This could impact foraging resources for many listed shorebird species. For these reasons, the topic of listed shorebird species will be analyzed.

Structures and Infrastructure

Public Health and Safety

The range of alternatives may impact public health and safety. The authorization of sediment placement by other agencies may result in a wider sand beach along the Seashore and result in increased protection of roadways and infrastructure, which may reduce the frequency of road closures by protecting NC 12 from overwash and damage during future storm and extreme high tide events. This reduction in closures would allow access to hospitals, grocery stores, and other services accessed via NC 12 to be maintained or restored more quickly after storm and extreme high tide events. Sediment placement may temporarily result in a reduction of road closures, or increased sediment may contribute to overwash which could run onto the NC 12 and cause disruptions.

Visitor Use and Resident Access and Experience

Over the life of the framework, sediment management under alternative B may help reduce road closures, or increased sediment may contribute to overwash and more road closures. Sediment placement is likely to result in wider beaches, albeit temporarily, which is likely to improve visitor use and experience. Improvements to habitat conditions along the sound side shorelines would also be likely to improve visitor use and experience.

Beach nourishment may result in short-term disruptions (e.g.*,* closures, water turbidity, and the sight of dredging or construction equipment) to visitor use and experience at the Seashore, lasting the duration of beach nourishment activities. This disruption would take place during active sand placement, which could occur on 600-800 ft of beach at any given time. Large projects are expected to last less than a year, though the disrupted area may only be impacted for 24 hours or less. Sediment management activities along the sound side shorelines would likely impact a smaller length of shoreline than a typical beach nourishment project, but include similar disruptions to use, access, and experience within the Seashore.

Socioeconomics

Sediment placement may have temporary impacts on the local economy, which is largely tourism and recreation based. Adding more sediment to the beach system may reduce erosion and lessen impacts to roadways and infrastructure when compared to alternative A. Increased protection of roadways and infrastructure is likely to result in more tourism and recreation at the Seashore.

The placement of sediment may temporarily widen the beach and stabilize dunes and may reduce the need for additional emergency sediment management actions. This may benefit private property by creating a wider beach profile and reducing wave runup, which could reduce damage to these properties and infrastructure. This may help temporarily maintain beachfront property values. These impacts would last as long as the widened beach remains in place, which will vary by location. Additionally, because of the protection afforded to local buildings, roadways and infrastructure from the issuance of permits under the action alternatives, Seashore visitation and tourism may be less subject to interruption and may add stability to the local tax base.

Because of impacts to public health and safety, visitor use, and socioeconomics, the topic of structures and infrastructure will be analyzed.

IMPACT TOPICS DISMISSED FROM FURTHER ANALYSIS

The following presents an overview of impact topics that were considered but dismissed from further analysis. An impact topic was considered but dismissed from further analysis if it was determined that the environmental impacts were not of critical importance or central to proposal; the potential impacts to resources were not significant; the environmental impacts associated with the issue are not a big point of contention among the public or other agencies; or a detailed analysis of these impacts was not necessary to make a reasoned choice between alternatives.

Littoral Processes and Wave Action

Specific borrow areas for each project would be identified based on project-specific needs; however, for the purposes of this framework, it is assumed that borrow areas would be located miles from the shoreline, either in the North Carolina Exclusive Economic Zone, or in federal waters managed by BOEM, and would be excavated to a depth of less than 8 ft. Navigational dredging is covered by separate NEPA compliance, as noted in chapter 2. Offshore dredging can alter wave patterns and sea floor topography, potentially interrupting nearshore sediment transport. Repeat dredging events in the same location can compound these effects over time (Dean 2002; BOEM 2013).

Project-specific modeling to support the 2017 Beach Restoration to Protect NC Highway 12 at Buxton Project simulated wave patterns and longshore sediment transport rates before and after the dredging proposed for that project and found no measurable wave-pattern changes at the beach within that project area (CSE 2015). That borrow area was located in a portion of the seafloor that had not been dredged before. A federally sponsored Marine Minerals Service (MMS) study found excavation of four borrow areas off Nags Head would result in a wave height difference on the order of centimeters (e.g., less than 10 cm) (Applied Coastal Research and Engineering, Inc. et al. 2003). In both cases, impacts were concentrated immediately adjacent to the dredged area (see the “Water Quality” section below for details on how quickly sediment would be expected to settle out of the water column). As described in “Collection of Environmental Data Within Sand Resource Areas Offshore North Carolina and the Environmental Implications of Sand Removal for Coastal Beach Restoration” (Applied Coastal Research and Engineering, Inc. et al. 2003), no significant changes to longshore sediment transport are expected from modeled borrow site configurations for BOEM Sand Resource Areas off Nags Head. Overall, the cumulative impacts of sand mining offshore North Carolina on wave propagation and sediment transport processes are expected to be negligible under modeled conditions. Empirical observations following nourishment events at Buxton and Nags Head corroborate the modeled results. Sediment exchange between the beach and offshore environments would not be interrupted, because no structures would be placed in the surf to impede such transport (Kamphuis 2000).

In conclusion, no measurable wave-pattern changes or changes to longshore sediment transport are expected and the sediment exchange between the beach and offshore environments would not be interrupted. As such, impacts on littoral processes and barrier island morphology as they relate to offshore action issues are not significant and do not rise to the level of being central to the proposal. A detailed analysis of these impacts is unlikely to provide substantial differences between the no-action scenario and other alternatives. Therefore, littoral processes and wave actions as they may be affected by offshore actions to borrow sediment is dismissed from further analysis.

The impacts of onshore actions are retained for detailed analysis, as discussed in the “Littoral Processes and Barrier Island Morphology” section above.

Water Quality

Water quality in environmental restoration projects is often evaluated by one or more parameters including water chemistry and turbidity. This is related to the quality of the sediment being placed as compared to the native sediment. That is, if the new sediment has a higher proportion of fine-grain-sized material, placement may result in a more turbid water column and decreased light penetration to lower depths. While the range of alternatives may result in impacts to water quality, the discussion below explains how these impacts would be limited.

Within the water column, constant mixing and exchange occur under the natural processes of wave breaking and currents along ocean-facing beaches well removed (i.e., outside of the inlet zone, which can range depending on wave energy, but is typically a few thousand feet) from inlets and rivers, such as potential borrow areas and beach nourishment sites. The influence of fine-grained sediment from inlets and rivers varies depending on wave and tide conditions, but along the Outer Banks, inlet and riverine sediments are a small fraction of oceanfront material. The dominant sediments are sand-sized with negligible fine-grained material (NPS 2015c).

Along sound side shorelines, however, a larger fraction of fine-sized grains is in place naturally. Moreover, decreased wave energy (as compared to ocean-facing beaches) prevents continuous mixing and exchange of water bodies. This means many of the sound side habitats are more sensitive to variations in water quality, and often must be monitored closely to ensure negative impacts are properly avoided and/or mitigated. With the limited number of projects contemplated for the sound side, variations in water quality would not be of large enough scale or duration to cause noticeable changes in the local ecology. Also, the low wave energy on the sound side would limit resuspension of sediments.

The steps necessary for compliance with NPS Director’s Order #77-1: Wetland Protection, will be assessed for each individual project when the project is proposed.

In the case of emergency breach fill projects, a relatively coarse grain size is desired as this provides enhanced stability for the fill and discourages future island breaches (USACE 2005). While sediment placement for sound side and ocean side shorelines is often accompanied by months or years of environmental review and critique, emergency breach fills are by their very nature fast-moving projects (USACE 2005). As a result, the environmental impacts of breach fills on water quality are less well-studied. However, the relatively coarse nature of many breach fill sediments (as compared to pre-project native sediments) means turbidity would be minimized, compared to other sediment management activities.[2]

Suspended sediment in the surf zone tends to involve short, intermittent suspensions under breaking waves with relatively large grains settling more quickly (Davidson-Arnott 2010). The amount of sediment in suspension is directly proportional to the energy of waves with rougher conditions producing more turbidity (Komar 1998). The same rules apply along sound side shorelines as well. The naturally finer grains along the sound side mean sediments would remain in suspension for longer than in the ocean side surf zone; however, the sound side shorelines are subject to much lower energy when compared to the ocean side surf, as noted above.

Dredging and sediment management would result in a temporary increase in the turbidity of the water in the locations of the action and last the duration of these activities (dredging would take place for less than one year). However, it is unlikely that the action alternatives would result in a violation of state water quality standards or have long lasting impacts to water quality, for the reasons described below.

While turbidity is likely to be elevated locally at the dredge during excavations and loading, the plume associated with the action is expected to be limited in extent (within 1,000 ft of the dredge vessel) and short-lived (e.g., within hours), due to the proposed texture of coarse borrow sediment, which minimizes the spatial and temporal extent of sediment plumes around the dredge or at beach discharge points (CSE 2015). For previous dredging projects along the Outer Banks, sediment plumes disappeared within hours of digging cessation. While operations continued and the plume was in place, wave energy and the coarse grain size of the borrow material kept the disturbance to within 1,000 ft of the dredge vessel. The predominance of sandy material in the proposed borrow areas and oxygen-rich conditions indicate the dredging activities would have a small impact on dissolved oxygen, pH, or temperature because the general lack of fine-grained material in the littoral zone or in the borrow areas suggests existing conditions prevent accumulations of the type of material that is likely to remain in suspension for extended periods. Sediment suspensions in the proposed borrow areas tend to be intermittent with rapid settling of sandy material (Komar 1998). Settling velocities of sand-sized particles (approximately 0.1–2-mm diameter) are roughly in the range 1–20 centimeters per second in quiet water (Komar 1998). Thus, settling occurs in seconds to minutes for sand-sized particles in the range of depths typical of the Seashore including borrow areas (CSE 2015). Therefore, the impact would be highly localized and temporary, returning to ambient conditions within minutes to hours of cessation of pumping.

Because of the rapid resolution of increases in turbidity described above, the impacts of up to 6 miles of project(s) per year are unlikely to have overlapping impacts on water quality. This fairly rapid resolution of project-related turbidity would remain true in the case that an additional 6 miles of sediment management were to be permitted once every 5 years due to an emergency declaration following a severe storm event.

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[2] Settling velocities of sand-sized particles (approximately 0.1 to 2.0-mm (mm) diameter) would roughly be in the range of 1 to 20 centimeters per second in quiet water (Komar 1998).

In addition, the NPS would set aside approximately 13 noncontiguous miles from consideration for sediment management activities (in all cases except for emergencies), for the purpose of studying the ecology of these zones and providing reference zones that may be used in comparative studies with nourishment study areas. Under alternative C, sediment management activities may occur on up to 6 miles of beach every 5 years so the probability of impacts from projects overlapping is even lower than under alternative B.

In conclusion, impacts on water quality are not significant and do not rise to the level of being central to the proposal. Dredging activities would have a small impact on water chemistry and elevated turbidity associated with dredging would likely be short-lived and highly localized; the spatial and temporal extent of plumes would be minimized. For emergency breach fills, the coarse nature of many breach fill sediments would likely result in minimized turbidity, compared to other sediment management activities. On the sound side, variations in water quality would not be of large enough scale or duration to cause noticeable changes in the local ecology, due to the limited number of projects contemplated for this area. Therefore, water quality is dismissed from further analysis as a standalone impact topic; however, water quality (specifically turbidity) is discussed as relevant under the topic of "Benthic Organisms and Essential Fish Habitat."

Marine Mammals

The Marine Mammal Protection Act (MMPA) of 1972, as amended, offers federal protection to marine mammals. Three species of whales are known to occur off the North Carolina coast: finback whales (*Balaenoptera physalus*), humpback whales (*Megaptera novaeangliae*), and North Atlantic right whales (*Embalagen glacialis*). Finback whales and North Atlantic right whales are listed as endangered by the ESA. According to the National Marine Fisheries Service (NMFS), the finback whale is unlikely to occur within the vicinity of proposed borrow areas; therefore, impacts due to dredging activity are unlikely to occur on this species (NMFS 2020b; NMFS 2019a). The *South Atlantic Regional Biological Opinion (SARBO) for the Continued Hopper Dredging of Channels and Borrow Areas in the Southeastern United States* (NMFS 1995) and the *2020 South Atlantic Regional Biological Opinion for Dredging and Material Placement Activities in the Southeast United States* (NMFS 2020b) discuss the effect of vessel strikes from offshore dredging activities on humpback and North Atlantic right whales. In 2016, NMFS delisted the West Indies DPS of the humpback whale (the population that occurs near North Carolina), due to its recovery; it was therefore not included in the 2020 SARBO. As the primary effect discussed in both SARBOs, vessel strikes were due to increased boat traffic near dredging operations, which NMFS concluded may adversely affect the North Atlantic right whale (NMFS 2020b) and humpback whale (NMFS 1995). NMFS also concluded that impacts could be avoided with cooperation between dredge operators and protected species observers (NMFS 2020b). Any sediment management activities at the Seashore involving dredging or discharge of dredged materials would require a permit from the USACE, and project-related dredging would be required to operate within the parameters established by the SARBO. These projects would require qualified and NMFS-approved marine mammal observers be present on project vessels during operation.

Other species of marine mammals are common or abundant in North Carolina waters. Three are found year-round, Atlantic spotted dolphin (*Stenella frontalis*), common bottlenose dolphin (*Tursiops truncatus*), and the short-finned pilot whale (*Globicephala macrorhynchus*), and one is found only during the winter or early spring, short-beaked common dolphin (*Delphinus delphis*) (CSE 2015). There are also occasional sightings of harbor seals, four in 2017, and harp seals, one in 2017 (NPS 2018i). The only marine mammal likely to be affected by both dredge operations and sediment management activities is the common bottlenose dolphin, which can be found close to the beach and nearshore (NPS 2018i). The other marine mammals with potential occurrence in North Carolina waters are oceanic and could be found offshore near potential borrow areas located on the OCS (CSE 2015).

Underwater noise from dredging activities may interrupt or impair communication, foraging, migration, or other behaviors in marine mammals (USACE 2001b). Studies of underwater sound levels from dredging activity indicate the source level of the dredging activity ranges between 160 and 185 decibel (dB) re 1µPa, approximately (USACE 2001b; Jones and Marten 2016).[3] This is above the NMFS established threshold for take for non-impulsive (continuous) noise of 120 dB root mean square (RMS) (NMFS 2019c) but below the injury threshold of 199 dB RMS for the low-frequency cetacean hearing group (whales) and 198 dB RMS for the mid-frequency cetacean hearing group (dolphins, toothed whales, and beaked whales). To mitigate for potential marine mammal takes, an approved protected species observer would be stationed on the dredge at all times and would follow standard reporting and notification protocols should a whale or other marine mammal be observed in the vicinity (NMFS 2012).

Sediment management activities may impact bottlenose dolphins foraging near the Seashore by disturbing the nearshore community structure and removing food sources. The placement of sand at the Seashore could bury benthic organisms (CSE 2015). The localized loss of this foundational food source would reduce the number of fish, the primary prey for dolphins, in the intertidal and subtidal areas adjacent to the nourished beach. Impacts would only occur during sediment management activities and last between six months and several years. Nourishment may also increase turbidity within and immediately adjacent to the area of sand placement (CSE 2015) affecting visibility for foraging bottlenose dolphins. Up to 600–800 ft of beach would be under active sand placement on any given day, and 200–300 ft of placement would be completed per day under normal conditions. As described in the “Water Quality” section, the suspended sediment would consist primarily of sand which would settle out of suspension in a period of seconds to minutes under normal conditions. This effect would only occur during nourishment activities and would last less than a year as the beach erodes and assumes a natural profile.

Although numerous sediment management actions may occur within the Seashore over the 20-year life of this framework, the NPS would only permit up to 6 miles of project(s) in any given year. This amounts to actions taking place along less than 9% of the shoreline at a time and surrounding each of the dredge vessels. If an emergency is declared following a severe storm event, an additional 6 miles of sediment management may be permitted once every 5 years. In addition, the NPS would set aside approximately 13 noncontiguous miles from consideration for sediment management activities (in all cases except for emergencies), for the purpose of studying the ecology of these zones and providing reference zones that may be used in comparative studies with nourishment study areas. Under alternative C, sediment management activities may occur on up to 6 miles of beach every 5 years; therefore, impacts would be even less frequent and not exceed 9% of the Seashore. Because impacts would be limited in duration to the time that projects are taking place, the impacts described above are unlikely to compound upon each other from year to year. This remains the case should an emergency declaration warrant an additional 6 miles of nourishment, which could affect up to 18% of the shoreline in a given year (assumed to take place no

[3] In underwater acoustics, sound is typically described in terms of sound pressure level (SPL), and the standard unit of acoustic pressure is the micro Pascal [µPa]. Therefore, the amplitude of acoustic pressure is referenced to 1 µPa [re 1 µPA], and the units for SPL are dB re 1µPa.

more frequently than every 5 years). This amounts to actions taking place along less than 9% of the shoreline at a time and surrounding each of the dredge vessels. Marine mammal use of the area would be expected to resume, following disturbances in these areas.

The West Indian manatee (*Trichechus manatus*), also known as the Florida manatee, is a federally listed endangered mammal protected under the ESA and the MMPA. The manatee is also listed as endangered under the North Carolina ESA of 1987 (Article 25 of Chapter 113 of the General Statutes). While this species may be present seasonally, or may be transient at the Seashore, the NPS does not expect this species to be adversely affected by actions proposed in this framework. Manatees are not often found on the ocean side of the Seashore which is highly turbid and has little to no vegetation. There have been a few documented instances of manatees near inlets and sound side areas where the manatee is likely to traverse into brackish water for vegetation consumption and to drink. All project proponents would be required to follow the FWS *Guidelines for Avoiding Impacts to the West Indian Manatee-Precautionary Measures for Construction Activities in North Carolina Waters* (FWS 2003b).

In conclusion, projects would require qualified NMFS-approved protected species observers to follow standard reporting and notification protocols should a whale or other marine mammal be observed in the study area, to mitigate for potential takes. Dolphin species are unlikely to be affected by dredge operations and sediment management activities, with the exception of the common bottlenose dolphin. Impacts to this species, however, would likely only occur during nourishment activities and would last less than a year. The West Indian manatee is unlikely to be adversely affected by the range of alternatives because it is not often found on the ocean side of the Seashore. Therefore, the impacts on marine mammals are not significant and do not rise to the level of being central to the proposal; furthermore, the analysis is not pivotal to making a reasoned choice between alternatives. Therefore, the potential for impacts on marine mammals are dismissed from detailed analysis.

Fish and Sturgeon

The Seashore provides habitat for a variety of fish species. There have been 60 fish species documented as present and 236 species documented as probably present in the Seashore (CSE 2015). Individual fish may be disturbed during dredging activities in the vicinity of borrow sites due to the presence and operation of dredging equipment at these sites. Fish may avoid these areas during dredging; however, because fish species are mobile, they would be able to easily find nearby suitable habitat for foraging or other behaviors during dredging activities. Other effects to fish species involve the disturbance of habitat within the vicinity of borrow areas, which would remove benthic invertebrates from the dredged area and reduce a significant food source. These effects would be local (only within the footprint of dredging and the sand placement site), would last between six months to several years[4] before the benthic community would recover, and fish could move to adjacent areas to forage (CZR and CSE 2015b). The impacts of these activities on fish species would be too small to be meaningfully measured, and habitat impacts would be addressed under the topic of “Benthic Organisms and Essential Fish Habitat,” described above.

Two fish species listed as federally endangered, the shortnose sturgeon (*Acipenser brevirostrum*) and the Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), are known to occur in waters of coastal North Carolina (NMFS 2019b). Shortnose sturgeon spend most of their time in freshwater rivers and estuaries and relatively little time in the ocean (NMFS 2010). There have been four unconfirmed occurrences of

[4] For additional detail on benthic recovery times, see discussion in chapter 4.

shortnose sturgeon in Oregon Inlet (Holland and Yelverton 1973; Gruchy and Parker 1980; NMFS 1984b; Gilbert 1989), but this species is rarely documented within the aquatic marine habitat of the Seashore (CZR and CSE 2015a). Also, it rarely occurs in the rivers and sounds between the Chesapeake Bay and Cape Fear River (NMFS 2010). Therefore, the shortnose sturgeon is unlikely to occur within or near the marine waters at the potential borrow areas or areas of likely sediment management. For this reason, it is determined that sediment management activities would not impact the shortnose sturgeon.

The Atlantic sturgeon is documented as occurring within the vicinity of potential borrow areas where it forages most of the year and then moves to inshore freshwaters to spawn in the spring. Juvenile Atlantic sturgeon were consistently captured in January-February bottom trawls from 1988 to 2006 in the shallow nearshore waters of North Carolina north of Cape Hatteras Point, with most of the captures concentrated north of Oregon Inlet (Laney et al. 2007). Kocik et al. (2013) developed an index of the estimated Atlantic coast population abundance for Atlantic sturgeon using data from the Northeast Fisheries Observer Program between the years 2006 and 2011. The location of captures along the North Carolina coast indicated that Atlantic sturgeon were captured most often in ocean side waters near the inlets (Kocik et al. 2013; Dunton et al. 2010). Sediment management activities that would occur near the inlets would be on or near the shoreline in water too shallow or with too much wave energy for sturgeon to inhabit.

Impacts to the benthic community at the offshore borrow site could indirectly impact Atlantic sturgeon by reducing local benthic food sources and forcing the sturgeon to forage in other areas; however, the areas that would be impacted by dredging would be limited in size and similar foraging habitat would be available nearby that could support sturgeon (CZR and CSE 2015a). A study of US Gulf and Atlantic Coast sandy borrow areas within BOEM jurisdiction found that general fauna recovery (total abundance and biomass) varies from 3 months to 2.5 years; however, recovery of diversity and composition may take longer depending on a number of factors (Wilber and Clarke 2007; BOEM 2013). The effects of localized reduction of benthic prey species at the potential borrow areas on Atlantic sturgeon would be too small to be meaningfully measured.

Because of uncertainty about the habits of Atlantic sturgeon, the precise location of dredging, and the timing of sediment management activities, sturgeon may be in the potential borrow areas during dredging. Although it is unlikely, dredging could impact sturgeon by entrainment in the draghead. Historically, entrainment of Atlantic sturgeon by hopper dredges has been rare. The average rate of incidental take of Atlantic sturgeon during all USACE-authorized dredging projects since 1995 was 0.7 per year, with most of those incidental takes occurring while dredging in inlets and harbors, not offshore (CZR and CSE 2015a). Vessel strikes or disruption of sturgeon foraging during dredging operations would have potential short-term impacts (only occurring during dredging activities) during migration or use of offshore waters.

The Atlantic sturgeon was not included in the 1995 SARBO because it was not protected under the ESA at the time. In 2012, however, five separate DPSs of Atlantic sturgeon were listed under the ESA by NMFS (the Carolina DPS was listed as endangered), so this species is therefore included in the 2020 SARBO as a species likely to be adversely affected (NMFS 2020b). As such, when individual dredging activities are proposed and permitted, USACE and/or BOEM would include the project in annual reporting in accordance with the SARBO requirements. The NPS would issue a SUP subject to issuance of a USACE permit for the project. Mitigation measures would be incorporated into the project to prevent sturgeon impacts including: ensure proper installation and function of a rigid draghead deflector; reduce vessel speeds while traveling to, from, and between borrow locations; and use of a qualified NMFS

Protected Resources Division-approved protected species observer on the dredge(s) at all times. The observer would follow standard reporting procedures. These mitigation measures would minimize the potential for impacts to Atlantic sturgeon.

Although numerous sediment management actions may occur within the Seashore over the 20-year life of this framework, the NPS would only permit up to 6 miles of project(s) in any given year. If an emergency is declared following a severe storm event, an additional 6 miles of sediment management may be permitted once every 5 years. In addition, the NPS would set aside approximately 13 noncontiguous miles from consideration for sediment management activities (in all cases except for emergencies), for the purpose of studying the ecology of these zones and providing reference zones that may be used in comparative studies with nourishment study areas. Under alternative C, sediment management activities may occur on up to 6 miles of beach every 5 years. Because impacts would be limited in duration to the time that projects are taking place, the impacts described above are unlikely to compound upon each other from year to year. If more than one project is taking place at the same time, the impacts described above could apply to all offshore locations where project dredging is approved. Use of the area by fish (including sturgeon) would be expected to resume within a year or so, following disturbances in these areas.

In summary, the impacts of the alternatives on fish species would be too small to be meaningfully measured. Any reduction in benthic food sources would be localized and limited in size; similar foraging habitat would be available nearby. The shortnose sturgeon is unlikely to occur within or near the marine waters at potential borrow areas or areas of likely sediment management. Mitigation measures and project design criteria (PDC) would be incorporated into each nourishment project to minimize potential impacts on Atlantic sturgeon during dredging, as required under the SARBO (NMFS 2020b). As such, the potential impacts on fish and sturgeon would not be significant and do not rise to the level of being central to the proposal; therefore, fish and sturgeon are dismissed from detailed analysis. Additionally, dismissal from further analysis is based around recent analysis conducted for the SARBO. Impacts related to fish habitat are discussed under the topic of “Benthic Organisms and Essential Fish Habitat.”

Other Wildlife and Wildlife Habitat

Sediment management activities may disrupt other wildlife including shorebirds and ghost crabs. Shorebirds that are protected at the state and federal level are retained for detailed analysis, as discussed under the “Listed Shorebirds” topic above. Examples of other species that use the beach include various species of gulls, sandpipers, and herons. These shorebirds tend to forage on a variety of invertebrates and fish and do not tend to nest on the beach. They are all relatively abundant.

The Seashore, a designated Important Bird Area (BirdLife International 2019a), is located along the Atlantic Flyway (Ducks Unlimited 2019), and it serves as a major resting, breeding, and feeding ground for migratory birds throughout the year (CSE 2015). Nourishment activities may temporarily displace foraging or resting shorebirds from using the beach when construction equipment is in use and sand placement is taking place. These impacts would only occur during the activity itself (estimated to be less than a year for each of the projects totaling up to 6 miles that may be permitted per year). If an emergency is declared following a severe storm event, an additional 6 miles of sediment management may be permitted once every 5 years. In addition, the NPS would set aside approximately 13 noncontiguous miles from consideration for sediment management activities (in all cases except for emergencies), for the purpose of studying the ecology of these zones and providing reference zones that may be used in comparative studies with nourishment study areas. Under alternative C, sediment management activities may occur on up to 6 miles of beach every 5 years. At any given time, 600–800 ft of beach would be undergoing sand placement for each project as the sand is pumped and bulldozed; ample foraging and nesting habitat would remain available outside of the area of active sand placement along the length of the Seashore and beyond. These birds are highly mobile and easily able to relocate to areas outside the construction zone. Additionally, the invertebrates on which some shorebirds feed may be buried during active construction and would require between six months to several years to recover following construction (CSE 2015; Wooldridge et al. 2016). The reduction of prey availability within localized areas where sediment management activities would occur could cause birds to adjacent beaches where sand placement has not occurred.

The eastern black rail (*Laterallus jamaicensis jamaicensis*) is currently proposed for listing as federally threatened. The eastern black rail is a small secretive marsh bird whose preferred habitat includes brackish or freshwater marshes; the sound side of the Seashore offers suitable marsh habitat. Not much is known about the diet of the eastern black rail, but they have been known to eat aquatic and terrestrial invertebrates. Of the historical stronghold states, North Carolina presently shows a severe decline in the number of occupied sites (FWS 2020). In the unlikely event that any eastern black rails are present within the vicinity of nourishment activities, the birds may experience displacement and disturbance due to construction equipment and activities similar to the impacts described for other shorebirds above. Additionally, invertebrates on which the eastern black rail feeds may be buried during active construction. These impacts would be the same as described for other shorebirds above. In the event the species is listed, the NPS would consult with FWS on any actions that may adversely affect this species.

Atlantic ghost crabs (*Ocypode quadrata*) are abundant within the Seashore. Estimates indicate that close to 2 million ghost crabs occur within the Seashore (NPS 2018h). A study of ghost crab density in North Carolina found 1.5 ghost crab burrows per square meter across all sampling areas, indicating that thousands of ghost crab burrows could be present in under one acre of beach habitat (Seyfried 2017). Burrows are found from near the high tide line up to 0.25 miles landward from the water (Knott 2006), and they can travel up to 328 yards while foraging at night (Izzo and Kothari 2011). Ghost crabs and their burrows could be damaged by sand placement, including crab mortality due to suffocation or crushing (Schlacher et al. 2016). Studies have shown substantial localized declines in ghost crab population density following sand placement, and reduced recruitment has been documented at nourished beaches (Peterson et al. 2000). However, in this study, only one survey was conducted at three months post-nourishment. Bergquist et al. (2008) conducted a post-nourishment study of Folly Beach in South Carolina and found that within one-year post-nourishment, there was no difference in linear densities (individuals per meter of beach) of ghost crabs between nourished and reference beaches. Because ghost crabs are abundant within the Seashore, displacement and/or mortality of ghost crabs within up to 6 miles of nourishment in any given year (less than 9% of the Seashore shoreline) would represent a small fraction of the overall ghost crab population within the Seashore. If an emergency is declared following a severe storm event, an additional 6 miles of sediment management may be permitted once every 5 years. While this may result in impacts as described above covering up to 18% of the Seashore's ghost crab habitat, this remains a relatively small portion of the overall ghost crab population within the Seashore. In addition, the NPS would set aside approximately 13 noncontiguous miles from consideration for sediment management activities (in all cases except for emergencies), for the purpose of studying the ecology of these zones and providing reference zones that may be used in comparative studies with nourishment study areas. Under alternative C, sediment management activities may occur on up to 6 miles of beach every 5 years; therefore, impacts would be even less frequent and not exceed 9% of the Seashore.

In summary, the impacts of the alternatives on other wildlife and wildlife habitat would be too small to be meaningfully measured. Any reduction in benthic food sources would be localized and limited in size, and similar foraging habitat would be available nearby. Also, localized impacts to ghost crab populations would be too small to impact the overall population throughout the Seashore. As such, the potential impacts to other wildlife and wildlife habitat would not be significant and do not rise to the level of being central to the proposal; therefore, other wildlife and wildlife habitat are dismissed from detailed analysis.

Seabeach Amaranth

In 1993, the plant species seabeach amaranth (*Amaranthus pumilus*) was listed as federally threatened under the ESA. At the time, the species had been eliminated from two-thirds of its historic range that extended from Massachusetts to South Carolina. The natural habit of seabeach amaranth makes it vulnerable to both man-made and natural disturbances. The primary threat to the species is habitat destruction. Man-made beach-stabilizing structures (i.e., bulkheads, jetties, continuous barrier dunes) and off-road vehicle (ORV) and pedestrian traffic on beaches have contributed to major habitat loss (FWS 1996b). Barrier islands are extremely dynamic in nature and are constantly being shaped by hurricanes and storm events, resulting in the rapid creation and elimination of potential seabeach amaranth habitat. Other threats to seabeach amaranth include herbivory by insects and mammals, competition from non-native, invasive plants, and sea-level rise.

The Seashore was once heavily populated with seabeach amaranth, hosting 3,000–15,000 individuals per year in the late 1980s. In the last 15 years, numbers were the highest in 2002 with 93 plants. More recently numbers have declined with only one plant found in 2004 and two plants found in 2005. No plants have been observed since that time and the plant may be extirpated from the Seashore. Since populations can be highly variable, Seashore staff continues to perform annual surveys for the species (NPS 2017l). Following the Seashore's *Seabeach Amaranth Monitoring Protocol*, staff begin surveying for plants in mid-July. In the event a species is located during the annual monitoring protocol, the Seashore would consult with FWS on any adverse impacts associated with sediment management before a permit is issued for work in that area.

Beach through nourishment could result in beneficial impacts to the species through creation of additional habitat. In conclusion, impacts on seabeach amaranth are not significant and do not rise to the level of being central to the proposal. This species has not been observed at the Seashore since 2005 and staff continue to survey for its occurrence. A detailed analysis of these impacts is unlikely to provide substantial differences between the no-action scenario and other alternatives. Therefore, seabeach amaranth is dismissed from detailed analysis.

Cultural Resources

There are numerous cultural resources that NPS has identified within the Seashore, both on and offshore. Several of these resources are located within or close to identified areas of potential sediment management.

For cultural resources submerged under water (e.g., offshore shipwrecks), use of borrow areas for sediment management activities would be subject to state requirements for borrow area confirmation

(North Carolina OAH 2014), which would include a survey to characterize each borrow area. The survey would also include the location for the submerged pipe connecting the dredge to the onshore project location. The survey results would provide specific recommendations for buffer zones (i.e., no-work areas) to avoid excavation and placement of the submerged pipe that would directly affect any submerged cultural resources. Should unknown submerged artifacts be encountered during dredging or placement of the pipe, all work in the immediate vicinity would be stopped, the dredge and submerged pipe would be relocated, and Section 106 procedures of the National Historic Preservation Act would be implemented. The State Historic Preservation Officer (SHPO) and any relevant Tribal Historic Preservation Officers would be notified, the resources would be identified and documented, and mitigation strategies would be developed, if necessary, to avoid impacts on these resources. Tribes in the area that may be either directly or indirectly impacted by the action alternatives include the Cherokee Nation, the Eastern Band of Cherokee Indians, the Tuscarora Nation, and the United Keetoowah Band of Cherokee.

Onshore cultural resources (e.g., known shipwrecks) would also be handled sensitively if encountered during proposed activities. Currently, project operators are required to place a buffer around known sites and NPS does not allow heavy equipment through these areas, although sand placement is allowed. If the resource is not covered, project operators may place sand over it to preserve it in situ. Physical protection of the resource, such as with layers of sand, may prevent potential damage to the resource.

In conclusion, measures to protect onshore and submerged cultural resources at the Seashore would be undertaken to prevent impacts from sediment management activities, including surveying and installing a buffer; cessation of work; or physically protecting the resource. Agency coordination for minimizing potential impacts to cultural resources may be conducted through this planning process (unless this would qualify as a streamlined activity) and would also be required during permit acquisition for any proposed sediment management activities. During development of this DEIS, NPS initiated consultation with the SHPO, which allows them to comment and contribute early in the decision-making process and helps NPS to identify key issues or requirements to be considered in the NEPA process. Cultural resources are a fundamental resource at the Seashore, essential to achieving the purpose of the Seashore. Any impacts to cultural resources from the alternatives would be mitigated through avoidance. Therefore, impacts on cultural resources are not significant and do not rise to the level of being central to the proposal, and a detailed analysis of these impacts is unlikely to provide substantial differences between alternatives. For these reasons, cultural resources are dismissed from detailed analysis.

Project-specific consultation with the SHPO would take place during individual permitting. NPS has preliminarily determined that there would be no adverse effect to historic properties within the identified areas of frequent erosion. The NPS will provide the SHPO with notification of this proposed sediment management framework and DEIS and will outline how future compliance would be addressed as part of follow-on Section 404 permitting for individual projects, where detailed project specifics would allow a more complete analysis.

CHAPTER 2: ALTERNATIVES

INTRODUCTION

This chapter describes the various actions that could be implemented to address sediment management at the Seashore. The alternatives under consideration must include a “no-action” alternative as prescribed by 40 CFR 1502.14. Alternative A in this document is the “no-action” alternative. The Department of the Interior regulations for implementing NEPA state that there are two interpretations of the term “no-action.” First, ‘‘no-action’’ may mean ‘‘no project’’ in cases where a new project is proposed for implementation (43 CFR 46.30). Second, ‘‘no-action’’ may mean ‘‘no change’’ from a current management direction or level of management intensity. When the “no project” alternative is used, the no-action alternative represents inaction continued into the future. Alternative A, the "no-action" alternative here serves that purpose.

The action alternatives were developed by the NPS interdisciplinary team, and included feedback received during the agency and public scoping process. Action alternatives may originate from the proponent agency, local government officials, or members of the public at public meetings or during the early stages of project development. Alternatives may also be developed in response to comments from coordinating or cooperating agencies. The alternatives analyzed in this document, in accordance with NEPA, are the result of internal and public scoping. These alternatives meet the overall purpose of and need for taking action.

Action alternatives carried forward for detailed analysis must meet the management objectives of the Seashore and the purpose of and need for taking action. Action alternatives considered to be reasonable (40 CFR § 1502.14, 43 CFR § 46.415) would be technically and economically feasible and show evidence of common sense. All future SUP requests would depend upon available funding. Alternatives or alternative elements that were considered but are not technically or economically feasible, do not meet the purpose of and need for the project, create unnecessary or excessive adverse impacts on resources, or conflict with the overall management of the Seashore or its resources were dismissed from detailed analysis. These alternatives or alternative elements and their reasons for dismissal are discussed at the end of this chapter.

Impacts associated with the alternatives are described in chapter 4.

ALTERNATIVE A

Under alternative A, the NPS would not permit sediment management activities at the Seashore over the next two decades. The NCDOT currently maintains a right of way (ROW) easement through the Seashore for NC 12, and alternative A would preclude NCDOT from implementing sediment management to protect NC 12 outside of its existing ROW. Partners, such as Dare County, would not be permitted to perform beach nourishment projects along the Seashore. Other partners, such as USACE, that may wish to work with the Seashore to implement sediment management-based habitat restoration projects through the placement of sediment would not be permitted to implement those projects. Under this alternative, permits also would not be issued for any sediment management activities on the Pea Island NWR portion of the Seashore outside of NCDOT's existing ROW to protect NC 12.

Local jurisdictions and the State of North Carolina (the state) would not be able to respond to future maintenance needs associated with erosion along the Seashore. Current responses to that erosion, such as sand scraping and road repairs by NCDOT, would continue only within the existing ROW which extends 60-150 ft from the centerline of NC 12 (varying by location) (NCDOT, Corbett, pers. comm., 1999). As erosion progresses and sufficient room to maintain protective dunes no longer exists, the state and property owners would likely implement short-term emergency measures such as the installation of sand bags.

If transportation routes are closed due to major storm events or chronic erosion, communities at the Seashore, as in the past, would be isolated from the mainland until road access was restored. The county (or counties), state, and NPS would have to seek alternative ways of transporting goods, service providers, and residents, including sick or injured persons. Road-based travel would cease and transporting goods and services may occur by boat, ferry, small plane, or helicopter.

If a breach were to occur that affects NC 12, NCDOT may need to cease Southdock ferry operations and only utilize ferry services to Cedar Island or Swan Quarter, to and from Silver Lake on Ocracoke. NCDOT may utilize a route from the Silver Lake Ferry docks to the Hatteras Ferry docks. If a breach were to occur on Hatteras Island that affects NC 12, NCDOT may utilize two routes: 1) from the Hatteras Ferry docks to Stumpy Point (emergency ferry docks) or 2) from Rodanthe (emergency ferry docks) to Stumpy Point. NCDOT would not create new emergency ferry basins or docks for island breaches (NPS, Henry, personal communication, 2020b).

During preparation of this EIS (prior to implementation of whichever alternative is selected), unforeseen storm and tidal events may warrant emergency action by agencies such as NCDOT to maintain critical infrastructure (such as NC 12) at the Seashore. These actions may occur outside of the NCDOT ROW and may require a SUP from the NPS. Actions may include sediment management to stabilize dunes, sand scraping, use of sand bags, and emergency breach repair. Under alternative A, the NPS would only issue a SUP for sediment management in extreme situations during the development of this EIS.

ALTERNATIVE B (PROPOSED ACTION / PREFERRED ALTERNATIVE)

Under alternative B, the NPS could permit other agencies and municipalities to conduct, with conditions, sediment management in the form of sound side and ocean side beach nourishment, dune restoration, and filling island breaches. Applicants would be encouraged to develop long-term, sustainable strategies that allow for the shoreline to respond dynamically to sea-level rise and erosion. They would also be encouraged to consider alternative management actions (e.g., retreat, relocation, etc.). Furthermore, the Seashore and Pea Island NWR would continue to work collaboratively with partner agencies to develop long-term transportation and infrastructure facility plans that may include relocation and alternative transportation options that minimize the need for recurring sediment management activities that result in temporary impacts.

Projects on the sound side would probably be smaller in scale than the anticipated ocean side projects, as described under the "Project Parameters" sections below. Projects on the sound side could include beach nourishment, stabilization of existing infrastructure, and habitat restoration (for example, on Green Island). For many of these sound side projects, the sediment source is likely to be trucked in from existing stockpiles.

Monitoring would be implemented before and after any significant sediment management project for the purposes of learning and improving conditions associated with future projects. General monitoring may include studies of intertidal invertebrates, net shoreline change, storm impacts, wildlife monitoring, and other metrics. This monitoring would be used to evaluate rates of recovery in areas where sediment management activities take place. Information gained from monitoring can be used to further improve conditions associated with future projects, which may include modification of the frequency, timing and other methods associated with nourishment projects.

Additionally, under alternative B, approximately 13 noncontiguous miles (approximately 20% of the 67 total Seashore miles) would be set aside, including a section of the Pea Island NWR portion of the Seashore, from consideration for sediment management activities in all cases except for emergencies. The primary purpose of excluding these areas is to study their ecology and provide reference zones that may be used in comparative studies with nourishment study areas. Sediment management activities, either large scale management actions or small-scale projects (i.e., dune stabilization projects, overwash mitigation), would only be permitted on the Pea Island NWR portion of the Seashore if found compatible with the purposes for which the refuge was established and either in the case of an official declaration of emergency or in advance of planned or scheduled longer term solutions that relocate the highway off the refuge.

Figures 3 and 4 in appendix A illustrate where sediment management activities may be permitted under this alternative (zone 1) and where activities would be avoided to establish reference areas for comparative monitoring (zone 2). Additional information on this alternative is included in the subsections that follow.

Sediment Management Actions

Alternative B would permit the following actions along approximately 54 miles of Seashore. Sediment management activities would not be permitted on the Pea Island NWR portion of the Seashore, except as described above. A section of Pea Island NWR would be excluded from sediment management actions in all cases for monitoring (as noted above).

Beach Nourishment

Beach nourishment consists of placing large (e.g., millions of cubic yards) volumes of sand on the beach and within the surf zone and is one method for temporarily slowing erosion (Dean 2002). The additional volume provided via nourishment places erodible material in between uplands and the ocean, such that the nourishment sand is eroded instead of uplands and dunes. Areas with a greater sand deficit would receive a greater volume of sand via nourishment, ideally, in order to make up for the deficit and provide excess volume for added protection. The excess volume provides a reservoir to accommodate average annual erosion losses for a number of years before the deficit volume is impacted once more.

Beach nourishment may be proposed by other entities and permitted by the NPS to mitigate erosion at various sites along the Seashore. Beach nourishment may include placement of sediment dredged or trucked in from other locations (anticipated to be outside of NPS property boundaries), provided the sediment is a close match or is compatible to the native mean grain size found at the project site and that project plans follow the NPS Beach Nourishment Guidance (NPS 2012). During placement of dredged sediment, a submerged pipeline would cross the surf zone and connect to elbows and valves at the edge of the beach. Portions of this pipeline may be left in place during sand placement. After an initial platform of sand is pumped into place on the existing beach and shaped by bulldozers, lengths of steel shore pipe would be connected parallel to the beach. A splitter placed at the end of the pipe would spray a slurry of sediment and water along the shoreline. This slurry is pumped continuously for the duration of the project's construction, with work stoppages only occurring for weather or mechanical delays. See figures 5, 6, and 7 in appendix A.

During placement of trucked material, dump trucks would transport sand from an upland borrow pit outside Seashore boundaries to the study area. At this time, most beach nourishment projects along the Seashore (and along the Outer Banks in general) contain millions of cubic yards (cy) of sediment within their designs (more detailed background and examples are included in the "Littoral Processes and Barrier Island Morphology" section in chapter 3). Because there are limited upland sand resources within an economical distance to the Seashore it is likely that nearly all beach nourishment projects would be performed via dredge and fill operations.

Figure 8 in appendix A illustrates how profile nourishment is planned. The nourishment would be expected to spread laterally toward unnourished areas where the profiles have more sand (Luijendijk et al. 2017; Elko et al. 2007; Dean 2002). Nourishment volumes are determined by using survey data to calculate the volume needed to reach some minimum ideal beach size. By identifying local deficits in beach volume, project planners may determine the amount of sand to place at particular portions of the Seashore. This method allows planners to compensate for the deficit in beach volume at a site as well as place excess volumes to compensate for future anticipated erosion (Dean 2002).

Locations for anticipated beach nourishment along the Seashore oceanfront include, but are not limited to:

- Bodie Island
- North of Mirlo Beach
- Avon
- Haulover Sound access and areas south towards Buxton
- Buxton
- The Bypass Road (Cape Hatteras Point Area)
- Frisco to Hatteras
- Hatteras Village
- South End of Hatteras Island
- North End of Ocracoke (South Dock)
- Ocracoke Island

The locations listed above include sites where future beach nourishment project requests are considered likely or known based upon NCDOT feasibility studies, discussions with cooperating agencies, and erosion studies.

The NPS may also undertake beach nourishment on the sound side of the Seashore. Sound side nourishment may include placement of dredged material or sediment trucked in from other locations, similar to actions described above.

Based on discussions with Seashore staff, sound side areas that may be subject to sediment management actions include:

- Haulover Day Use Area
- Salvo Day Use Area
- Frisco to Hatteras (NC 12) Sandy Bay "Isabelle Inlet"
- areas near inlets which typically provide valuable nesting habitat for shorebirds

Habitat Restoration

In addition to evaluating and, in appropriate cases, permitting projects that may be proposed by other entities, the NPS would work with other agencies to use navigational dredged material to restore habitat for nesting wildlife including shorebirds at the southern end of the Hatteras Island area and Green Island in Oregon Inlet (see figure 9 in appendix A). This would include the application of dredged material and moving/manipulating sand at the site with heavy machinery. Dredged material for these habitat restoration projects would come from pipeline dredging operations of navigational channels within the Pamlico Sound, provided the sediment is a close match or is compatible to the native mean grain size found at the project site and project plans follow the NPS Beach Nourishment Guidance (NPS 2012). NPS may also consider habitat restoration elsewhere at the Seashore in the future, as necessitated by local conditions. All habitat restoration projects would include continuous monitoring of sensitive areas as well as compliance with other parameters described in this DEIS. No new designated ORV areas would be established in habitat restoration areas. Existing ORV routes and non-motorized public access that do not interfere with habitat restoration would continue to be allowed.

As part of regular maintenance of the navigational channel, the USACE dredges sand from Oregon Inlet on the north end of the Pea Island NWR portion of the Seashore and disposes compatible sand on Pea Island NWR's beaches. The dredged sand is pumped onto the beaches if it is compatible with natural beach sand. All aspects of the Oregon Inlet dredging operations, including the extent of dredging areas, the location for disposal of dredge spoils, and the ability to dredge year-round were previously analyzed in a separate compliance document and therefore are not included in this framework and DEIS.

Dune Nourishment and Sand Relocation

In the areas identified above, alternative B may include dune reconstruction and/or enhancement, as well as moving or regrading sand in order to protect natural and cultural resources, existing access and infrastructure improvements, and public facilities. These actions could include but are not limited to small scale projects to move sand off of NC 12, stabilize dunes along NC 12 including the use of sand bags, and moving sand off of private property and county roads after storms or extreme high tide events. Actions that promote dune building processes, such as beach grass planting and installation of sand fencing, are included in alternative B and may be carried out by NPS or a permittee in consultation with North Carolina Division of Coastal Management (NCDCM), NCWRC, and FWS.

Emergency Breach Repairs

When storm events create inlets or overwash areas that damage roadways, these situations may be addressed by trucking, staging, and pumping sand in from nearby or other locations to fill in the island breach. A breach is the condition where a channel across the island permits the exchange of ocean and sound waters under normal tidal conditions – there can be a partial or full breach (USACE 2016).

Project Parameters

Sediment management actions permitted under alternative B would fall within the general parameters of previously approved sediment management actions (unless improved methods are discovered). Permitted actions would be required to comply with all conditions specifically developed and prepared by state and federal agencies to maximize protection and minimize impacts to natural and cultural resources, recreation, public access, and health and safety in and near the proposed project.

Sediment Characteristics (Grain Size and Slope)

The grain size, color, texture and geologic characteristics of the material from the borrow site would be required to be a close match to the native beach or shore conditions found at the proposed project site, following the NPS Beach Nourishment Guidance (NPS 2012). Additionally, grain characteristic criteria for sediment compatibility would follow the standards outlined in the North Carolina Administrative Code (NCAC), at *15A NCAC 07H.0312, Technical Standards for Beach Fill Projects* (North Carolina OAH 2014). Grain characteristic requirements are also outlined in the *North Carolina Coastal Beach Sand Placement Statewide Programmatic Biological Opinion* (SPBO) (FWS 2017).

Material would be considered for a proposed project from upland or offshore borrow sites, and dredged material sources as long as the material is clean (e.g., similar grain size and no toxic and/or fine-grained material) and meets the grain characteristic requirements. NPS would require that sediment for beach nourishment projects be sourced from outside the active beach profile or the underwater area within which sand moves onto and off of the visible dry beach. This requirement prevents projects from simply recycling material within the beach profile and ensures outside material will be deposited, increasing the total beach volume. FWS would have specific recommendations for beach profiles, in order to avoid and minimize impacts to nesting sea turtles. Constructed dunes should have a relatively steep slope (e.g., 1.5 to 1) to discourage nesting female sea turtles from going up and over the dune. A back slope is not recommended, unless needed to tie into the existing elevation.

The beach should generally be designed to have a slope that is similar to pre-project conditions following post-construction beach equilibration processes. This post construction profile equilibration aspect of projects is described later in this document as the “constructed” dune and berm profile that adjusts to the “design” profile following equilibration of the berm via natural wave and tidal process. It is during this equilibration process that the constructed berm achieves a more natural slope. If projects are constructed in the future where the slope does not adjust accordingly due to compatibility or other issues, NPS would consider revised requirements for future nourishments.

Dune and sound side nourishment projects would require similar quality controls as beach nourishment projects. In general, dunes contain more fine-grained material than most of the beach profile. Sound side shorelines can vary between sand-, silt-, and clay-sized grains depending on site-specific conditions. Sediment characteristics and slope would need to match either “native” pre-project conditions or represent a “restoration” to some previous or desired state.

Volume

The volume of material used for projects is assumed to be between 50-250 cy/foot (measured along the length of the project), and scheduled projects would range from less than a mile to a maximum approximately 6 miles in length annually for ocean side sites. At most, 7.92 million cy would be placed along the ocean side of the Seashore, annually. The 6 miles of nourishment may be allowed as a single project or broken into non-continuous areas with a linear distance no greater than 6 miles total for the year. Distance between study areas may be taken into consideration during permitting to aid in the recruitment and recovery of macroinvertebrates affected by nourishment projects. In the event an emergency is declared following a severe storm event, an additional 6 miles of sediment management (an additional 7.92 million cy) may be considered after completing necessary regulatory permit processes. For analysis purposes, it is assumed that these additional emergency nourishment events may occur once every five years. Individual project volumes and fill characteristics would be determined on a site-specific and project-specific basis, once pre-project surveys have been completed. The 50-250 cy/foot volume estimate is based on previous, locally sponsored project volumes.

Because there are unavoidable volume losses involved in the transport of dredged sediment from a borrow site to a study area, the volume of dredged material would generally be approximately 10% greater than the designed fill volume. For instance, the 2017 Beach Restoration to Protect NC Highway 12 at Buxton Project dredged 2,798,160 cy while the surveyed fill volume on the beach was 2,607,632 cy (93.2%). The 2019 beach nourishment at Nags Head dredged 2,279,604 cy and placed 2,077,732 cy (91.1%).

Other sediment management actions such as dune nourishment and/or sound side nourishment would be expected to require smaller volumes commensurate with the purpose and site conditions. Dune restoration or nourishment projects often fill an eroded gap within a larger pre-existing dune. So, the width and height of the post-project dune would be determined based upon site-specific conditions using historical surveys or photography. Most dune volume changes are at least an order of magnitude lower than volume changes to the entire beach profile, so project volumes for dune nourishment activities would likely vary from approximately 1,000 cy to more than 100,000 cy.

Sound side nourishment volumes would also be determined on a site-specific basis. Beach and dune nourishment projects construct a template for a relatively limited number of habitats within sandy areas like the dry/upper beach, dune ridges, and intertidal beach. However, sound side projects may involve placement of sand, silt, and/or mud in order to promote different habitats along Pamlico Sound. Volumes associated with sound side nourishment would likely vary from approximately 1,000 cy to more than 100,000 cy.

Breach fill operations often require larger volumes of sediment to fill the breach channels. Volumes associated with breach fills can range from approximately 100,000 cy to over 1,000,000 cy (USACE 2005, 2017; NPS 2003), although it is possible some relatively minor breaches could be addressed with thousands of cubic yards.

Borrow Areas

The inshore portion of the continental shelf, extending from the shoreline to 3 miles offshore is within the North Carolina Exclusive Economic Zone (NCEEZ). Over the last decade, sediment used for projects at the Seashore has been dredged from locations in the NCEEZ (Nags Head 2011, Buxton 2017, Nags Head 2019). In circumstances where distances to the borrow area are 2 miles or less, ocean-certified pipeline dredges may be used to dredge. Longer distances may require equipment such as booster pumps, which are used to move sediment through a pipeline longer than approximately 2 miles. In cases where a borrow area is several miles from the project site contractors may elect to use a hopper dredge, which can transport sediment from a borrow area to a project site over longer distances (BOEM 2013). Dredging for breach repairs would have similar requirements.

Sediment for future projects may be sourced from borrow areas located beyond 3 nautical miles offshore, in federal waters on the OCS, where BOEM holds the authority to authorize the use of OCS sand. The Marine Minerals Information System (MMIS), as part of BOEM's National Offshore Sand Inventory, may be used to determine appropriate borrow areas beyond the NCEEZ (BOEM 2019b). As described in "Collection of Environmental Data Within Sand Resource Areas Offshore North Carolina and the Environment Implications of Sand Removal for Coastal and Beach Restoration" (Applied Coastal Research and Engineering, Inc. et al. 2003, pgs. 138 -174), Sand Resource Areas 1, 2, 3, and 4 contain borrow sites with the greatest potential for future use at the Seashore (see figure 10 in appendix A). The primary purpose of this study was to address environmental concerns associated with potential sand dredging from the OCS offshore Dare County, NC for beach nourishment. A copy of this document can be found on the project website (https://parkplanning.nps.gov/CAHASediment).

Additionally, the USACE is in the process of developing a South Atlantic Coastal Study (USACE 2020a), analyzing coastal risk and vulnerabilities along the South Atlantic and Gulf coast shorelines and identifying specific actions to mitigate risks. The Sediment Availability and Needs Determination component of this study will examine all federal and non-federal beach projects from North Carolina to Mississippi to determine the need and availability of sediment to maintain projects for the next 50 years. Preliminary borrow area locations relevant to Dare and Hyde Counties have been identified by USACE and are available in appendix A, figures 10, 11, 12, and 13. Additional information can be found at https://www.sad.usace.army.mil/SACS/.

Frequency and Extent

The frequency of nourishment projects permitted at a specific site would be limited under alternative B to allow re-establishment of benthic communities following sediment placement, except where critical transportation infrastructure that provides access to the Seashore may require more frequent, emergency management. Alternative B would permit sediment management on up to 6 miles of the Seashore annually, recurring at individual sites as frequently as every 3 years. The 6 miles of allowed nourishment may be allowed as a single project or broken into non-contiguous areas with a linear distance no greater than 6 miles total for the year. A nourished area would not be eligible to receive material again within the 3-year period unless permitted under an emergency declaration. If an emergency is declared following a severe storm event, an additional 6 miles of sediment management may be permitted. For analysis purposes, it is assumed these emergencies may occur once every five years.

Re-nourishment may be needed as vulnerable areas throughout the Seashore continue to experience erosion through natural processes and as sand washes away over time. In some circumstances, other permitting agencies such as USACE and BOEM may require the project proponent to determine sediment volume loss or beach width reduction before a subsequent event in the same location is permitted. Project proponents may also determine nourishment frequency based on FEMA funding received after a storm event or loss of sediment. Because benthic communities take time to recover fully after nourishment, a well-defined monitoring plan designed to evaluate benthic recruitment would be used to refine appropriate frequencies of future nourishment projects. This is intended to help identify whether compounding impacts of successional benthic community-wide impacts should be considered in future project plans.

When issuing a permit, the NPS would require placement of sand at 600-800-foot intervals at any given time for Atlantic-facing nourishment projects. This is approximately 0.2% of the overall Seashore length (i.e., 67 miles). In fair weather, more than 300 ft of nourishment could be completed per day. Sound side projects are anticipated to be smaller in extent.

Time of Year

The NPS would recommend that proposed actions at the Seashore occur between November 16 and April 1 to avoid breeding and migration periods for listed shorebird species and nesting seasons for sea turtles. However, where safety conditions may preclude winter-time activities (e.g., emergency response, projects that require open-ocean dredging), the Seashore may permit summertime work, with the requirement that permittees work closely with other resource agencies to incorporate avoidance and minimization measures. Allowance to work within migratory and nesting seasons may include only a portion of the season.

Reference Area Monitoring

As mentioned above, under alternative B, the NPS would set aside 5 segments, totaling approximately 13 Seashore miles (including the Pea Island NWR portion of the Seashore), to provide reference zones that may be used to perform comparative studies with nourishment project study areas. The areas designated for these reference zones are illustrated as zone 2 in figures 3 and 4 in appendix A, and include:

- Pea Island NWR: 2 miles from the start of the Jug Handle Bridge to where it ends at Mirlo Beach
- Between Salvo and Avon: 2 miles from Village of Salvo to 1 mile south of Ramp 25
- Cape Hatteras Point to Frisco: 5 miles from the point to an area west of Ramp 48
- Hatteras Island terminus: 2 miles from ramp 55 to an area near the end of the island but not including the end
- Ocracoke Island terminus: 2 miles from ramp 72 to the intersection with Ocracoke Inlet

The criteria for identifying the reference areas above include (1) locations not adjacent to a highway or village and (2) locations with either low erosion rates or significant beach width, indicating that nourishment is not likely to be proposed over the next 10-20 years; and (3) locations requested to be identified as reference locations by cooperating agencies. Other areas may be considered. Long-term studies of intertidal invertebrates, erosion, storm impacts, and other metrics may be used to evaluate rates of recovery in nourishment areas. Information gained from monitoring can be used to further improve conditions associated with future projects, including modification of the frequency, timing, and other methods associated with nourishment projects.

Ongoing Scientific Review

Every two years following the development of this framework, the Seashore and Pea Island NWR would convene agency regulatory partners to review the results of monitoring, emerging scientific information, new regulatory requirements, and new erosion and transportation management solutions (such as proposed bridge building). A summary of the state of the science and any potential changes to sediment management conditions would also be prepared as a brief report and distributed to the public.

Mitigation Measures

It is expected that specific conditions will be required by regulatory agencies for projects taking place under this framework, including conditions associated with a specific FWS BO and relevant project design criteria (PDCs) of the 2020 SARBO. NPS specifically incorporates all of the terms, requirements, obligations and conditions of the permits, certifications, letters and documents, mitigation and consultation requirements for all the activities before, during and after construction as specifically developed and prepared by state and federal agencies to maximize protection and minimal impact to the physical environment, threatened and endangered species and people in and near the project, as if fully written in their entirety in the SUP. Additional conditions may be required as a result of relevant permitting by other agencies, as described in appendix B. Anticipated conditions include:

- Threatened and Endangered Species Mitigation Terms and Conditions required for an NPS SUP.
- During sediment placement, material shall be qualitatively inspected daily by the contractor or engineer to ensure compatibility. If the inspection process finds that a significant amount of non-compatible material has been placed on the beach, all work shall stop immediately and the Seashore, NCDCM, and the USACE will be notified by the permittee or USACE to determine the appropriate plan of action (FWS 2017). Beach-compatible material would consist of sediments that are similar in composition, grain size distribution, and color to the native sediments of the recipient sites (FWS 2017; NPS 2012; North Carolina OAH 2014).
- The project proponent would not injure, alter, destroy, or collect any object, structure, or site of historical, archeological, or cultural value. Should the action unearth previously undiscovered archeological resources within Seashore boundaries, work would be stopped immediately in the area of such discovery, and the permittee would immediately contact the Seashore. The Seashore would consult with the SHPO and the Advisory Council on Historic Preservation as necessary.
- The applicant is responsible for obtaining all other required State, Federal and Local approvals before application of the project, including those required by but not limited to USACE, BOEM, NCDCM, and FWS. Copies of these approvals must be submitted to the NPS as part of the NPS SUP application package.
- Other modifications to operations may be recommended by federal and state resource agencies during the permitting processes.

ALTERNATIVE C

Alternative C would be similar to alternative B in that it includes beach nourishment, dune nourishment and sand relocation, and emergency breach repairs as described under alternative B. Sediment characteristics, volume, borrow areas, time of year, and mitigation measures would be the same as described under alternative B. The frequency and extent of nourishment projects would differ under this alternative. Sediment management may occur on up to 6 miles of beach every 5 years. The frequency assumption is based on past permitting actions at the Seashore for sediment management and emergency actions to protect NC 12 over the last 10 years. The establishment of exclusion areas for reference monitoring as stated in alternative B would not take place under this alternative (see figure 14 in appendix A). This alternative would not result in the development of a consistent framework for sediment management that meets permitting needs at the Seashore for the next 20 years. Projects on the Pea Island NWR portion of the Seashore would be subject to individual permit review by FWS. For a description of the recent history of sediment management projects permitted by FWS on the Pea Island NWR portion of the Seashore, see appendix C.

ALTERNATIVES CONSIDERED BUT DISMISSED

Hardened Structures

Groin[5] rehabilitation, new groins, jetties,[6] or other hardened structures are not considered in this sediment management framework. No special use permit applications have been received or are anticipated to be received in the near future for new groins or jetties. Additionally, the construction and rehabilitation of groins and jetties along ocean shorelines and outside of Seashore boundaries are currently limited by state law (GS 113A-115.1), and it is unlikely that the State would permit these structures at this time rendering this alternative element technically infeasible.

New Bridges

NPS has considered but dismissed construction of new bridges from the range of alternatives. NPS recognizes bridges as a sustainable option to maintain natural over wash function while allowing access to the Seashore. Dismissal of this alternative does not preclude the NPS from considering permitting new bridging and other sustainable solutions in the future. New bridges are not carried forward for analysis here because they are not a sediment management action. Therefore, new bridging or similar road proposals do not fall within the scope of the framework and have been dismissed. NPS may evaluate future bridge proposals under a separate NEPA review, where appropriate.

Winter-Only Beach Nourishment

The NPS considered a winter-only beach nourishment alternative. Work under this alternative would be completed during the winter months within a particular environmental window for construction prescribed by the FWS and NMFS. NPS evaluated a similar alternative for the 2017 Beach Restoration to Protect NC Highway 12 at Buxton Project. While winter-only nourishment would result in fewer impacts on listed species and Seashore visitors, winter nourishment activities were determined infeasible by the USACE and offshore dredging operators. Dredging can be dangerous when seas are rough. The areas that are likely to be dredged under this framework receive high wind and wave events during winter months making dredging operations during that time particularly dangerous and often infeasible. For this reason, NPS dismissed the winter-only alternative.

Living Shoreline and Marsh Restoration

The NPS considered living shorelines[7] and coastal marsh restoration as alternative elements to reduce erosion on the sound side of the Seashore. Living shorelines are beneficial for some coastal environments as they generally result in sustainable long-term habitat protection. NPS generally supports and would consider requests for these types of restorations. These alternatives require engineering, build, and biotic elements

[5] Groins are a type of hardened structure installed with the intent to capture sediment locally to stabilize shorelines. They are typically installed perpendicular to the shoreline and can be constructed of materials such as sheet piles or stones.
[6] Jetties are hardened structures, similar to groins, that are usually associated with protecting harbors or inlets.
[7] A living shoreline is a protected, stabilized coastal edge made of natural materials such as plants, sand, or rock. Unlike a concrete seawall or other hard structure, which impede the growth of plants and animals, living shorelines grow over time.

specific to the proposed location of the living shoreline and are not a sediment management action. They typically result in a more permanent ecological element to the environment. Because there are currently no proposed locations for living shorelines and future locations are speculative at best, the impacts of these actions cannot be meaningfully analyzed. Therefore, NPS has dismissed living shorelines from this analysis. The NPS would evaluate living shoreline proposals under a separate NEPA review, as appropriate.

Removal of the Avon Pier

During public scoping, a commenter requested that the NPS analyze the removal of the Avon Fishing Pier. The Avon Fishing Pier, located in the Village of Avon, provides a recreational opportunity to Seashore visitors and is not considered a sediment management device or structure. The removal of the Avon Fishing Pier is not carried forward for analysis because it does not meet the purpose and need for taking action nor is it being currently proposed by partner agencies. Therefore, the removal of the pier is outside the scope of this framework and EIS. Dismissal of this alternative element does not preclude the NPS from considering future proposals for the management of the pier.

Unlimited Beach Nourishment

The NPS considered an alternative that would not limit the amount or extent of permits issued each year at the Seashore for sediment management. The Seashore was designated to preserve dynamic barrier islands and its unique vegetation, wildlife and coastal processes, and to provide recreation and enjoyment for the public. Not placing any limits on the amount or extent of sediment management actions permitted at the Seashore could result in unacceptable environmental impacts to Seashore resources, including impacts to natural resources and visitor use and enjoyment. Additionally, those agencies that would be requesting permits for sediment management have indicated that not limiting the amount or extent of projects permitted at the Seashore would be economically infeasible and, therefore, not reasonably foreseeable.

Relocation and Abandonment of NC 12, Coastal Retreat, and Abandonment of the Seashore

During public scoping, commenters requested that the NPS analyze the relocation and abandonment of NC 12, coastal retreat, and abandonment of the Seashore. The relocation or abandonment of NC 12, coastal retreat, and abandonment of the Seashore are not carried forward for analysis because they are neither sediment management actions nor currently being proposed by partner agencies and are therefore outside the scope of this framework and EIS. The Act of Oct. 29, 1951, Pub. L. No. 229, 65 Stat. 662, granted the State of North Carolina a permanent easement to construct, maintain and operate a paved road through the Seashore, including the refuge. The ROW easement extends 60-150 ft on either side of the center line of NC 12. Any adjustments, relocations, or abandonment of NC 12 within the easement are outside the jurisdiction of the Seashore and are managed by NCDOT. The NPS will continue to work closely with NCDOT on any projects related to NC 12, and as stated in alternative B, the NPS encourages park partners to develop long-term, sustainable strategies that allow for the shoreline to respond dynamically to relative sea-level rise and erosion. The NPS will evaluate future proposals by NCDOT under a separate NEPA review, if appropriate.

Coastal retreat or abandonment by the NPS would not allow for recreation and enjoyment by the public at the Seashore. In order to manage and preserve the nation's national park lands, Congress passed the National Park Service Organic Act in 1916. 16 U.S.C. §1. The Organic Act established the NPS as an agency under the direction of the Secretary of the Interior with the stated purpose of promoting use of national park lands while protecting them from impairment. Specifically, the Act declares that the NPS has a dual mission, both to conserve park resources and provide for their use and enjoyment "in such a manner and by such means as will leave them unimpaired" for future generations (16 U.S.C. §1). Coastal retreat or abandonment of the Seashore may constitute impairment and may violate both the Seashore's enabling legislation as well as the Organic Act. For these reasons, coastal retreat and abandonment were not carried forward for detailed analysis.

Dredging within the Seashore Boundary

Dredging within the Seashore boundary would not be considered in this Sediment Management Framework unless it is required for navigational dredging. The Seashore boundary is mean low water line on the ocean side and 150 ft into the Pamlico Sound from mean low water line on the sound side. Oregon Inlet is one example of an area regularly dredged to maintain navigation, and the spoils from that dredging (and other navigational dredging) may be used for habitat restoration as mentioned under alternative B. With the exception of navigational dredging, there are no areas suitable for dredging within these boundaries.

CHAPTER 3: AFFECTED ENVIRONMENT

INTRODUCTION

This chapter describes the current condition of littoral processes and barrier island morphology; benthic organisms and EFH; sea turtles; listed shorebird species; and structures and infrastructure that may be affected by the implementation of a sediment management framework for the Seashore.

The chapter focuses on four primary habitat areas that may be affected by sediment management activities: the ocean side beach, sound side, areas adjacent to inlet channels, and potential borrow areas.

- The ocean side beach consists of the sand dunes at the inland side of the beach, the dry beach environment located above mean high water, the wet beach environment located between mean high water and mean low water, and nearshore subtidal habitats. The ocean side beach is a high energy environment continuously exposed to wind, waves, and currents.
- The sound side habitat area includes shallow estuarine waters, tidal marshes, mud flats, sand bars and sandy bottom areas, submerged aquatic vegetation (SAV), and some sand beaches. Generally, the sound side is a lower energy environment than the ocean side, although sediment transport processes still shift sand in small shoals and bars.
- The habitats adjacent to inlet channels include sandy beaches, sand bars, and channels. The channels were initially created naturally, and regular dredging attempts to maintain their current depths. These areas are exposed to wind and wave energy similar to the ocean side beach environment. However, the channels and adjacent shallow areas also experience stronger currents which cause different types of sediment transport and resulting landforms.
- The offshore bottom habitats consist of sandy shoals offshore of the Seashore on the ocean side from which sand would be dredged for use in sediment management activities. These areas could be located within state or federal waters and may be up to 60 ft in depth. Generally, areas beyond that depth are not subject to the high-energy processes that occur in the beach or inlet environments but are influenced by larger scale hydraulic movements such as tidal flow and ocean currents. As a result, the deposits have a finer mean grain size.

LITTORAL PROCESSES AND BARRIER ISLAND MORPHOLOGY

Coastal Resources Background

Littoral processes and barrier island morphology are the physical characteristics which, in part, make the Seashore a unique natural system. Along ocean-facing shorelines, the Seashore is exposed to deep-water wave energy as well as storm winds from as much as 270 degrees of direction. Because of relatively high wind and wave energy, and a low astronomical tidal range of approximately 3.1-3.5 ft the Seashore is considered a wave-dominated coast (USGS 2004). This means the primary drivers of morphological change are wind, wind-driven waves, and storm surge. In a given year, approximately 772,000 cy of sand is transported south towards Cape Hatteras from the northern Outer Banks (Inman and Dolan 1989).

The Seashore encompasses a string of barrier islands and spits from just north of Oregon Inlet to Ocracoke Inlet along the northern half of the North Carolina Outer Banks. This stretch of coastline contains more than 67 miles of ocean-facing beaches, Cape Hatteras Point, and three permanent tidal inlets (Oregon, Hatteras, Ocracoke) along with multiple areas subject to breaching via storm-driven overwash (the Pea Island NWR portion of the Seashore, Rodanthe, Avon to Buxton Village, Sandy Bay, and Ocracoke Island). The Seashore boundary is mean low water line on the ocean side and 150 ft into the Pamlico Sound from mean low water line on the sound side. The Seashore provides direct vehicular access to much of the shoreline, most of which is undeveloped beach open to the public.

The Outer Banks are a textbook example of a micro-tidal, wave-dominated coast (Hayes 1994; Riggs and Ames 2003), which features elongated barrier islands separated from the mainland by a wide shallow lagoon (sound) (see figure 1 in appendix A). Due to the location of the Seashore between a broad, shallow lagoon – Pamlico Sound – and the Atlantic Ocean, the region is windswept. Strong winds transport beach sands into large (e.g., more than 30 ft above mean sea level [MSL]) dune ridges along much of the Seashore (Havholm et al 2004; Wells and Kim 1989). The specific elevations of dune ridges are dependent on the balance between wind energy, sand supply, and wind-stopping elements like vegetation that can serve to reduce the amount of wind-blown sand (Davidson-Arnott 2010). In lower parts of a dune ridge, high water can transport sand landward into formations known as overwash fans. These deposits are important on wave-dominated coasts with few tidal inlets like the Outer Banks, because they are one of the primary drivers of landward barrier migration (Mallinson et al. 2008). In geological terms, overwash deposits allow the barrier to conserve its sand volume against relative sea-level rise by migrating landward with increasing water levels (Rosati et al. 2013).

On sound side shorelines, winds approaching from the southwest can travel over 60 miles across open water in Pamlico Sound before reaching the Seashore (Wells and Kim 1989). Along northwest-facing shorelines, this distance is greater than 25 miles. In either case this can result in significant water level changes along the sound side shoreline (known as wind tides – see NOAA 2020a for additional information), which can induce erosion of that shoreline just as rough seas remove sand from the ocean-facing beaches. When wind directions change rapidly during high water events (for instance, during the passage of especially strong nor'easter-type storms or tropical systems), rapid changes in water level on the sound side may induce breaching of the barrier island and result in the opening of a channel between the Atlantic Ocean and Pamlico Sound (USACE 2005).

These barrier islands provide shelter to sounds and tidal rivers extending tens of miles across the coastal plain. One notable characteristic of wave-dominated, micro-tidal barrier islands is their tendency to be long and narrow with widely separated inlets. Over a 400-year period, approximately 30 inlets have been documented along the Seashore. Many of the inlet channels are short-lived (e.g., less than 12 months active) but may be the sites of repeat flooding and breach hazards during storm events (Mallinson et al. 2008; Houser and Hamilton 2009; Everts et al. 1983). Only three inlets along the Seashore – Oregon, Hatteras, and Ocracoke – have persisted for decades, in part due to navigational dredging. The influence of dredging within the inlets is just one of many examples of human interference with natural processes at the Seashore.

Hurricane Irene (August 2011) produced several breach inlets; one near Oregon Inlet along Pea Island that closed naturally within weeks of the event. A breach near Rodanthe was closed artificially after the storm. Prior to Irene, a large (e.g., greater than hundreds of feet wide) breach occurred approximately one mile north of Buxton Village in 1962 (USACE 1963), and near Hatteras Village from the Pamlico Sound side of the island during Hurricane Isabel in 2003 (Wutkowski 2004; USACE 2010). Both breaches were closed artificially within a year to restore vehicle access to the area and rebuild NC 12, the only road through the Seashore. Such breaches typically only occur during storm events at the narrowest segments of the barrier island where the dunes are low. Given that globally rising temperatures are linked with increasing confidence to increased tropical cyclone frequency and intensity (Kossin et al. 2020), breaches may occur with increasing frequency in the future.

Net sediment transport along the shoreline is generally directed southward (Inman and Dolan 1989). The northern 40 miles of the Seashore face east and extend from Oregon Inlet to Cape Hatteras Point. The southern 30 miles face south and stretch from Cape Hatteras Point to Ocracoke Inlet, along portions of Hatteras and Ocracoke Islands. At Cape Hatteras Point, similar to Capes Lookout and Fear farther south, the shoreline makes a prominent turn from a north-south orientation (from Oregon Inlet to Cape Hatteras Point) to an east-west orientation (from Cape Hatteras Point to Ocracoke Inlet). Locally, the area around the Cape is referred to as Cape Point (also referred to as Cape Hatteras Point throughout this document), and it represents a zone of sand accumulation from the north and west (see figure 15 in appendix A). Sand moving toward Cape Hatteras Point has accumulated in Diamond Shoals (see figure 1 in appendix A), one of the largest banks of shallow water along the Carolina coast.

Beaches to the north of Cape Hatteras Point are exposed to similar waves from the northeast and routinely experience the largest wave heights on the US Atlantic Coast (USACE 1996b). During Hurricanes Irene (2011) and Sandy (2012), peak wave heights approximately 1 mile off Duck and Nags Head, NC exceeded 27 ft (McNinch et al. 2012; CSE 2013a). These locations are just north of the northern boundary of the area of likely sediment management activities. South of Cape Hatteras Point, wave heights decrease significantly and are dominated by the gentler southerly direction of approach. However, in the area around Cape Hatteras Point, strong deep-sea swells may be observed from three primary directions of approach (e.g., Northeast, Southeast, and Southwest waves all strike Cape Hatteras Point from deep water). This exposure makes the Cape Hatteras Point area more susceptible to erosion from storm passage, when winds may shift rapidly from southerly to northerly directions but remain onshore.

Mean tide range at the Cape Hatteras Fishing Pier in Frisco, near the center of the area of likely sediment management activities, is 3.1 ft with a spring tide range of 3.5 ft (NOAA 2019a). Sea level has risen during the 20th century as well, with the tide gauge at the Oregon Inlet marina (on the north side of the inlet channel) registering a relative change rate of approximately 0.2 in/year since 1977 (NOAA 2020b). This rate has accelerated more recently and is expected to be incrementally higher throughout the lifetime of the proposed framework (NOAA 2020b). Sea level measurements at the Oregon Inlet are comparable back to 1977 because that was the year in which that site record begins.

Seashore beaches exhibit the full spectrum of conditions from accreting (e.g., Waves, Salvo, Cape Hatteras to Frisco) to eroding (e.g., Pea Island, Rodanthe, Buxton) (USGS 2005; NCDENR 2012; NPS 2015c). Chronic beach and/or dune erosion indicates there is an insufficient volume of sand in the beach and dune system to maintain the present arrangement of habitats (Houser et al. 2008; Saye et al. 2005; Stauble 2005; Nordstrom et al. 2000; Dean 1991). The deficit can be driven by a number of factors, including disruption of nearshore sediment transport by hardened structures, a lack of sediment inputs from riverine or inlet-based sources like sand bars and shoals, or changes in the wave climate affecting sediment transport patterns. At decadal to century time scales, sand along Hatteras Island is generally conserved but shifts between segments of the island. According to the North Carolina Division of Coastal Management, shoreline recession rates along the Seashore are highest near Oregon and Hatteras Inlets, where rates reach and even exceed negative 20 ft per year as of 2020 (NCDENR 2020). Away from the influence of dynamic tidal inlets, reaches of shoreline between Avon and Buxton, as well as in the Rodanthe-Waves area are negative 10 to 15 ft per year. There are a handful of locations where the shoreline is not presently moving landward (e.g., west of Cape Hatteras Point, central Ocracoke Island, Salvo), but these are overshadowed by widespread shoreline recession elsewhere.

The combined findings of studies investigating shoreline histories along the Outer Banks document that the islands are generally narrowing, with most (approximately 80%) of the recession occurring on the ocean side (NCDCM 2020; Riggs et al. 2009; USGS 2005; Everts et al. 1983). The discrepancy between oceanfront and sound side shoreline migration may be due to the loss of beach sand volume via transport into inlets, which can serve as a conduit for beach sand being transported into the sounds (Mallinson et al. 2008). With projected relative sea-level rise rates forecast to continue increasing for the Seashore through the lifetime of this framework, it is likely this trend of island narrowing will continue.

Previous Shore-Protection Measures

Previous shore-protection measures adopted along the Seashore include dune construction, beach nourishment, and groin construction. Additionally, the historic Cape Hatteras Lighthouse was relocated to mitigate coastal erosion hazards (NRC 1988; NPS 2013) and a terminal jetty was constructed on the south side of Oregon Inlet to stop the southerly migration of the inlet and stabilize the beach for the first kilometer from Pea Island south of Oregon Inlet (Riggs et al. 2009). This jetty, however, has not stopped the shoreline erosion process along the Pea Island ocean shoreline (Riggs et al. 2009). These previous measures have modified the natural system along portions of the Seashore by affecting (displacing and/or either slowing or exacerbating) natural background erosion rates.

Dune Construction

In collaboration with the Works Progress Administration (WPA) and Civilian Conservation Corps (CCC), the NPS began a massive dune construction project in the mid-1930s along the Seashore (Stratton 1957; USGS 1986; NPS 2007). Brush panels and sand fencing were used to trap windblown sand and encourage dune growth. Afterwards, vegetation was planted to encourage longer-term stability. Figure 16 in appendix A shows present-day grassy dunes at the Seashore. AC Stratton was the field supervisor with the NPS during the dune restoration efforts, and official reports (Stratton 1943, 1957) describe the condition of the Outer Banks in the 1930s as compared to the late 1800s. Stratton (1943) attributed the denudation of Hatteras Island to overgrazing, mainly by hogs, and timber removal by commercial interests. The WPA-CCC work was credited with reducing erosion and saving the Cape Hatteras Lighthouse, which was abandoned in 1936 (NPS 2007). By the 1970s, however, some researchers questioned the wisdom of dune construction in light of increasing evidence for global and regional relative sea-level rise (NPS 1972; Godfrey 1972; Godfrey and Godfrey 1976).

The natural sequence of erosion, overwash, and breach repair can be seen as a feature of barrier island evolution and a necessary mechanism for allowing islands to respond to changes in storminess or sea level (Riggs and Ames 2003; Smith et al. 2008; Riggs et al. 2009; NPS 2013). Many barrier islands have also maintained positional stability over century time scales due to sufficient influxes of sand, natural growth of dunes, and preservation of the sand budget (Hayes 1994; NRC 1995). In other cases, researchers have been able to document the collapse and drowning of barrier islands due to breach inlet formation and sea-level rise (USGS 1992; McBride and Byrnes 1997).

A key point regarding barrier island persistence is that sediment supply to elevations above mean high water must exceed the rate of sea-level rise and losses due to oceanfront erosion or overwash into the back-barrier lagoon. This is why eroded beaches with an artificially high and stable dune ridge were observed narrowing along portions of the Seashore between initial stabilization (1940s) and the 1970s (Godfrey 1972).

The portions of any beach that are more susceptible to overwash tend to be narrower and with discontinuous, lower dunes (Sallenger 2000). Some research suggests a high dune ridge prevents overwash and losses from the beach to sound, preserving localized sand budgets and reducing net erosion rates (USACE 1998; Rosati 2005; Kana 2011; Rosati et al. 2013). This is because when a storm impacts beaches backed by high broad dunes or bluffs, the beach profile is likely to adjust by scarping the uplands and transporting sand offshore. Except in the most extreme cases, a majority of the eroded sand would remain within the active littoral zone and be available to help rebuild the beach under ‘normal’ conditions after storm conditions subside (Shepard 1950; Bascom 1954; Hayes and Boothroyd 1969; Seelig and Sorensen 1974; Larson et al. 1999; Jackson and Nordstrom 2011; Liu et al. 2019).

Beach Nourishment

Several nourishment projects have been conducted within the Seashore boundaries since the 1960s. These projects have collectively added approximately 7.5 million cy of sand across 8.6 miles of shoreline beginning in 1966, at a non-adjusted cost of $83.2 million (NPS 2013; CSE 2013b; WCU 2019, Seashore staff). The projects, time periods, volumes, costs, and applicable lengths of shoreline are listed chronologically in table 1. In total, there have been 18 nourishment events at the Seashore.

Sand placed within the Pea Island NWR portion of the Seashore is not included in this list. Pea Island NWR has received dredged material from USACE on 19 occasions since 1990. These projects have collectively placed 9.7 million cy of sand along the NWR at a non-adjusted cost of $56.2 million (WCU 2019). This material is sourced from ebb-tidal shoals located off Oregon Inlet, and tends to contain a higher portion of fine-grained sediments than an ideal nourishment borrow area along the Outer Banks (Boss and Hoffman 1999).

TABLE 1. CHRONOLOGICAL LIST OF BEACH NOURISHMENT PROJECTS PERFORMED WITHIN THE BOUNDARIES OF CAPE HATTERAS NATIONAL SEASHORE

Location	Year	Volume (cy)	Cost (USD)	Length (ft)
Cape Hatteras	1966	312,000	N/A	N/A
Cape Hatteras	1971	200,000	N/A	N/A
Cape Hatteras	1973	1,300,000	$22,471,910	7,920
Hatteras Island	1974	135,293	$836,640	1,353
Hatteras Island	1977	97,029	$1,026,946	970
Hatteras Island	1984	29,972	$375,000	300
Hatteras Island	1986	90,114	$692,226	901
Ocracoke Island	1986	167,755	$1,076,279	1,687
Hatteras Island	1988	74,646	$760,805	746
Ocracoke Island	1988	90,773	$889,685	908
Ocracoke Island	1989	113,229	$1,124,657	1,132
Hatteras Island	1992	18,147	$329,483	181
Ocracoke Island	1992	100,000	$1,165,326	1,000
Ocracoke Island	1995	44,305	$238,317	N/A

Location	Year	Volume (cy)	Cost (USD)	Length (ft)
Hatteras Island	2003	442,600	$8,423,913	1,500
Rodanthe	2014	1,620,000	$21,436,114	11,250
Ocracoke Island	2016	20,000	$350,000	600
Buxton	2018	2,600,000	$22,000,000	15,312
Total	**-**	**7,455,863**	**83,197,301**	**-**

N/A: (not available)

Note: Table 1 does not include projects at Nags Head, Pea Island NWR. Due to multiple nourishments along certain reaches, the impacted shoreline totals approximately 30,000 ft or about 8% of the Seashore oceanfront. Data assembled from Western Carolina University Program for the Study of Developed Shorelines; costs presented in 2018 USD (http://beachnourishment.wcu.edu/), and Seashore staff.

The first beach nourishment occurred in 1966, when 312,000 cy were pumped from Pamlico Sound onto the beach around Buxton and the US Naval Facility north of the lighthouse (NPS 1980; USACE 1996a; NPS 2013). This project was designed to mitigate sand losses incurred during the March 1962 (Ash Wednesday) nor'easter, but the NPS reported "the borrow material…was too fine and did not remain on the subaerial beach" (NPS 1980). Between 1970 and 1973, two additional beach nourishment projects were completed in the Buxton-Cape Hatteras Point area to combat erosion and land loss around the lighthouse. These projects consisted of approximately 200,000 cy of sand placed in 1970 near the Hatteras Court Motel (adjacent to the shoreline at the north end of the Buxton Village) and a nearly 1.3 million-cy project obtained from an upland borrow pit in 1973. The 1973 project widened the beach by approximately 500 ft, and the dry-sand portion of the beach was widened by nearly 70 ft (NPS 1980).

Between 1974 and 2003, seven additional beach nourishment projects were completed along Hatteras Island. These projects collectively added approximately 888,000 cy to the beach along nearly 6,000 ft of shoreline. The largest of these projects occurred in 2003, when 442,600 cy were placed along approximately 1,500 ft of shoreline. Ocracoke Island received five inputs of nourishment sand between 1986 and 1995, totaling approximately 516,000 cy over 4,700 ft of shoreline. The most recent projects (Rodanthe 2014 and Buxton 2018) used sediment dredged from offshore borrow areas.

The two largest projects have been completed within the study area, at Rodanthe (2014) and Buxton (2017-2018). NCDOT, with assistance from the USACE, implemented a remedial nourishment north of Rodanthe in response to critical erosion within the Pea Island NWR section of the Seashore. In 2014, 1.7 million cy were pumped from offshore borrow areas and placed along 2.1 miles of oceanfront in the refuge. This was the first nourishment project along Hatteras Island to use offshore borrow areas (NPS 2013). At Buxton, Dare County sponsored the placement of nearly 2.6 million cy along 15,300 ft in 2017-2018 to provide protection for a portion of NC 12. Nearly 55% of all nourishment volume to date along the Seashore oceanfront has been placed since 2014.

Because there have only been two substantial nourishment events since 2003 along the Seashore, there is a lack of data on the longevity of projects following completion. Earlier studies (Fisher et al. 1975) tracked the performance of historical projects using profiles across the visible beach, but not underwater. This precludes accurate analysis of performance because it does not capture underwater adjustments to the profile that are ubiquitous around beach nourishment projects. One recent project (e.g., Buxton 2017-2018) has experienced volume losses exceeding 50% of the project volume within 2-3 years of project completion (CSE 2019). However, the location of the Buxton Project near Cape Hatteras Point, as well as a jog in the shoreline around shore protection structures at the abandoned Cape Hatteras Lighthouse site, is exposed to a higher erosion rate than many locations along the Seashore. The Cape Hatteras Point – Buxton area is vulnerable to wave approach from nearly 270 degrees of direction, and the protruding shoreline around the old groins concentrates wave energy due to refraction. Moreover, that project was followed by a relatively active winter storm season in 2017-2018. Another recent project outside the Seashore, but close enough for comparison (Nags Head 2011), did not exceed 50% losses for 7 years following project completion (CSE 2018). Therefore, the variability in erosion rates between sites and between years makes predicting project longevity uncertain because it is difficult to determine whether this pattern would carry through to other sites within the study area.

Groins

Groins are a type of hardened structure installed with the intent to capture sediment locally to stabilize shorelines. They are typically installed perpendicular to the shoreline and can be constructed of materials such as sheet piles or stones. There are three groins located within the study area, around the old Cape Hatteras Lighthouse site in Buxton Village (see figures 17, 18, and 19 in appendix A). Persistent erosion in the vicinity of an adjacent US Naval Facility spurred various shore-protection measures over the past half century. Following a breach and subsequent closure in 1963 and small-scale nourishment commencing in 1966, the US Navy installed sand bags along 1,100 ft of shoreline in 1967. These geotextile bags deteriorated rapidly and proved short-lived (NPS 1980). The Navy then installed three groins to stabilize the beach along their facilities (Machemehl 1979; USACE 1996a). The groins reportedly slowed erosion updrift of the structures and for a few years caused accretion along the US Naval Facility. This was likely aided by the 1973 nourishment of 1.3 million cy of sand at Buxton Village, described above. Dolan et al. (1974) reported the positive impact of the 1973 nourishment; however, the USACE later suggested "the impact of the fill is believed to be minor compared to that of the groins, which have been influencing the shoreline for more than 25 years" (USACE 1996a).

The area south of the old Cape Hatteras Lighthouse site continued to erode with the resulting shoreline, forming a salient (or bulge) in the vicinity of the lighthouse (pictured in figure 19 in appendix A (USACE 1996a). During the 1980s, erosion around the southernmost groin (fronting the lighthouse) was threatening to flank the landward end of the groin despite a protective sheet pile wall, which was installed to prevent such a situation. Because of the deteriorated condition of the groins, they are not as effective at trapping alongshore sediment transport as designed. A detailed survey of the beach surrounding the groins has not been completed, so it is impossible to determine the percent volume of sand that passes through the groins due to their condition.

Lighthouse Protection and Relocation

The original Cape Hatteras Lighthouse, completed in 1802 approximately 1 mile inland from the location of the beach, was deemed inadequate because of its limited height and setback from the ocean (NPS 1980; NRC 1988). A new lighthouse—the tallest in the United States—was completed in 1870, positioned nearly 1,500 ft from the ocean. According to NPS records, by 1919, the ocean was within 300 ft of the structure. By 1936, the US Coast Guard abandoned the lighthouse due to erosion and ownership was transferred to the NPS. The NPS reported that the ocean had advanced to within 100 ft of the lighthouse by 1935. This implies that between 1870 and 1919, the shoreline eroded 1,200 ft (approximately 25 ft/year), but erosion slowed between 1919 and 1935 to a rate of 12.5 ft/year (note: the high rate of retreat between 1870 and 1919 could also reflect inaccuracies of early surveys which were made difficult by the remoteness of Hatteras Island from control monuments on the mainland). Erosion apparently lessened or reversed between 1936 and 1950 when the US Coast Guard reactivated the lighthouse (NPS 1980). Shore-protection measures to protect the lighthouse resumed in the 1960s as previously described (i.e., sand bags, nourishment). After the USACE completed a series of emergency repairs to the groins and sand bag revetment during the 1990s, funds were finally acquired, and the lighthouse was moved 2,900 ft southwest in 1999 (completed September 14, 1999) (Booher and Ezell 2001).

NC 12

Prior to the 1950s, NC 12 was an intermittent paved road and unpaved trail between Oregon Inlet and Buxton. In 1952, a fully paved, two-lane highway was completed. Certain sections of NC 12 along Hatteras Island have been subject to erosion, washovers, and inlet breaching from the beginning (Riggs et al. 2009). Three hurricanes in 1955 (Connie, August 12; Diane, August 17; Ione, September 19) resulted in severe erosion and damages to NC 12 between Buxton and Oregon Inlet (USACE 1996a). The Ash Wednesday Storm (March 1962)—the nor'easter of record in the mid-Atlantic states—breached the barrier island between Buxton and Avon (NPS 1977), causing emergency repairs to close the channel and rebuild the highway. In 1973, the Lincoln's Birthday Storm produced considerable erosion, including severe overwash into Pamlico Sound just north of Buxton (NPS 1980).

In the early 2000s, NCDOT conducted extensive reviews of alternatives for the protection of NC 12 in the Rodanthe area (NCDOT 2008; Parsons Brinckerhoff 2008). NCDOT, with assistance from USACE, implemented a remedial nourishment north of Rodanthe in response to critical erosion within the Pea Island NWR section of the Seashore. In 2014, 1.7 million cy of sand were pumped from offshore borrow areas and placed along approximately 2.1 miles of oceanfront in the refuge. In the Buxton Village area, Coastal Science & Engineering (CSE) in 2013 and NCDOT in 2015, conducted feasibility studies to evaluate alternatives for road maintenance and protection of NC 12 (CSE 2015). Dare County, the sponsor for the CSE study, worked in close coordination with the NPS and implemented beach nourishment during 2017-2018 as the preferred method of protection.

BENTHIC ORGANISMS AND ESSENTIAL FISH HABITAT

Benthic Organisms

Benthic organisms (organisms living on, or in, the bottom sediments) are a resource of concern because they play a foundational role in coastal ecosystems. Since they occupy the base feeding level of the ecosystem food chain, they also serve as indicators of habitat quality for species that feed on benthic organisms (such as species of fish and shorebirds). Coastal and offshore bottom habitats near the Seashore are host to abundant and diverse benthic communities.

Ocean Side Beach

In the study area, coastal benthic habitats on the ocean side consist of substrates located primarily within the wet beach environment. This habitat is characterized by high wave and tide energy present within this environment. The wet beach environment is also subject to wet and dry periods corresponding to the local tides. This is a particularly inhospitable condition for aquatic animals and would be available only to organisms adapted to the tidal cycle (Rosov et al. 2016). The core intertidal groups of organisms present within the wet beach environment of the Seashore include polychaetes (bristle worms, a type of segmented worm) (primarily *Scolelepis squamata*), bean clams (primarily *Donax variabilis*), amphipods (a type of crustacean) (Order *Amphipoda*), and mole crabs (*Emerita talpoida*) (Rosov et al. 2016). These benthic macro-invertebrates constitute the prey base for surf fish, shorebirds, and other benthic invertebrates (Greene 2002). Beach invertebrate populations exhibit patchy distributions within the beach zone with densities in some areas approaching thousands of individuals per square meter (McLachlan 1996). These populations typically follow a seasonal pattern in which they move offshore during the winter months and reduce their presence in the intertidal and subtidal beach environments (Rosov et al. 2016; Wooldridge et al. 2016).

The current condition of benthic macrofaunal communities at the Seashore is unknown, and the effects of increased storm events and relative sea-level rise due to climate change or past sediment management actions at the Seashore are unknown. A two-year study was completed to monitor the recovery of the benthic community at Nags Head after the 2011 beach nourishment project. The study determined that within the beach environment, abundance (or numbers) and diversity of benthic invertebrates recovered within two years so that there was not significant statistical difference between the impact site and the reference site (CZR Incorporated and CSE 2014). A similar timeline for benthic recovery is supported by other studies that focused on recovery rates of benthic communities subsequent to impacts (Wilber and Clark 2007; Baptist et al. 2009; Rosov et al. 2016). It is assumed that communities of benthic organisms on the beach recovered after these nourishment projects similarly to the recovery documented at Nags Head; however, no post-nourishment monitoring was completed to confirm this assumption. In addition, multiple studies indicate that recovery of the benthic community after impacts from beach nourishment is highly variable and can take from six months to several years (McLachlan 1996; Rakocinski et al. 1996; Essink 1999; Peterson and Manning 2001; Greene 2002; Speybroeck et al. 2006; Colosio et al. 2007; Baptist et al. 2009; Wilber et al. 2009; Manning et al. 2014; Rosov et al. 2016; Wooldridge et al. 2016)

Benthic organisms can be affected by settling suspended sediments. Due to the higher energy environment of the subtidal beach and wet beach swash zone, turbidity (a measure of suspended sediments) is typically high within these environments. Although no turbidity readings from beaches at the Seashore are available, one study determined turbidity at a beach on Bogue Banks to vary between approximately 10 nephelometric turbidity units (NTUs)—which are the standard unit for measuring turbidity in water— and 40 NTUs (Manning et al. 2013), with background total suspended solids (TSS) up to a maximum of 34 milligrams/liter (mg/L) (Wilber et al. 2006). The variation in readings at Bogue Banks was caused by wind speeds with low turbidity occurring during calmer periods and high turbidity occurring during stronger winds (Manning et al. 2013). For comparison, Wilber et al. (2006) determined TSS maximum levels at beaches after storm events to be 425 mg/L.[8]

Sound Side

The sound side has a diversity of habitats not present on the ocean side including tidal marsh, SAV, mud flats, and oyster reef, as well as habitats similar to the sand and hard bottom habitats present on the ocean side. Sound side habitats are generally less energetic and therefore more suitable to a diverse community of benthic organisms. Many benthic invertebrate species present within Pamlico Sound are important to

[8] For reference, the World Health Organization (WHO) recommends drinking water be 1 NTU or less, although 5 NTUs is acceptable if it can be purified (Fondriest Environmental, Inc. 2014; WHO 2020). As provided in Chapter 15A of the North Carolina Administrative Code (NCAC), Subchapter 2B, the State of North Carolina requires non-trout freshwater streams to be less than or equal to 50 NTUs, and non-trout freshwater lakes to be less than or equal to 25 NTUs and trout streams and lakes to be less than or equal to 10 NTUs (Osmond et al. 1995; North Carolina OAH 2014; Fondriest Environmental, Inc. 2014).

the ecosystem function of species' estuarine habitats or are valuable fisheries resources. The quality of the benthic community in the Albemarle-Pamlico Estuarine Complex rated fair using the Southeast Coast Benthic Index with 65% of the area rated in good condition, 16% of the area rated fair, and 16% of the area rated poor. None of the fair or poor locations are within the study area, and the Neuse River Estuary contained most of the sites rated poor. Many of the degraded sites exhibited degraded water and/or sediment quality (EPA 2006).

Dominant benthic invertebrate species present on the sound side of the Seashore include the eastern oyster (*Crassostrea virginica*), blue crab (*Callinectes sapidus*), bay scallop (*Argopecten irradians*), hard clam (*Mercenaria mercenaria*), Atlantic ribbed mussel (*Geukensia demissa*), and multiple shrimp species. These species are important both economically and ecologically to the ecosystems present on the sound side of the Seashore. Oysters typically attach to hard bottom substrates or structures, often in association with barnacles and hooked mussels (*Ischadium recurvum*) (Chesapeake Bay Program 2019). The other dominant species commonly use SAV and/or tidal marsh at some period during their life cycle. Larval blue crab generally first settle in areas of complex habitat such as SAV, tidal marsh, and oyster reef where they become juveniles and begin to migrate to lower salinity waters of upper estuaries and rivers to mature (NCDEQ 2018). Bay scallops are found primarily in SAV, or more specifically sea grass beds. Bay scallops use sea grass almost exclusively for initial attachment sites during larval stages, and upon reaching a length of approximately 1 inch, they drop to the substrate and remain within the sea grass bed (NCDEQ 2018). Atlantic ribbed mussel inhabits tidal marshes, typically in association with smooth cordgrass (*Spartina alterniflora*). The two species exhibit a relationship that is beneficial to both species but is not required by either to survive (Bertness 1984). Shrimp rely on SAV and tidal marsh for virtually all life stages (NCDEQ 2018).

Coastal Inlets

The coastal inlet benthic community is similar to the ocean side benthic community present in the wet beach and subtidal environments. The coastal inlets are particularly important for shrimp species and are considered a shrimp HAPC (SAFMC 1993). The current condition of the benthic community within the inlets at the Seashore is unknown, and no studies have been completed to determine the effects of sand placement in intertidal communities or dredging. Recovery of benthic invertebrates in areas of sand placement is assumed to have occurred similarly to the results reported for Nags Head in CZR Incorporated and CSE (2014). A study of inlet dredging effects on the benthic community determined that benthic recovery depends on the specific hydraulic and sediment transport processes occurring at the inlet (Sanchez-Moyano et al. 2004). Therefore, the current status of the benthic community within the coastal inlets at the Seashore, and its potential recovery following sand placement or dredging projects, is unknown.

Offshore Bottom Habitats

When compared with nearshore marine habitats affected by the active wave breaking within the surf zone, offshore bottom habitats are exposed to lower energy hydraulics (water velocity and force) from waves and offshore currents at the seabed. Within the potential borrow areas, benthic communities consist of an array of amphipods, crustaceans, cumaceans (a type of shrimp), echinoderms, gastropods, isopods, polychaetes, and bivalves (Cerame-Vivas and Gray 1966; Dexter 1969; CZR Incorporated and CSE 2014). Similar to the beach community described above, subtidal seabed invertebrate community composition and distribution vary greatly due to differences in physical site characteristics and fluctuations in hydraulics (Greene 2002).

The current condition of the benthic community within the potential borrow areas has been documented by previous monitoring of offshore sandy shoals in association with prior beach nourishment projects; and recovery following dredging was documented in the biological monitoring study completed for the Nags Head Beach 2011 nourishment project (CZR and CSE 2014). This study conducted pre-impact sampling at multiple borrow site locations and began post-impact sampling in the fall immediately following dredging activities. The study determined that the post-dredging benthic community abundance and diversity at the borrow area sampling locations were similar to or exceeded the pre-dredging control community for each sampling event, including the fall event immediately following dredging (CZR and CSE 2014). These results were similar to the recovery reported in other post-dredging studies in recently dredged borrow areas (Roman-Sierra et al. 2011; BOEM 2013). These studies indicate that benthic community abundance and diversity recovers in less than two years following dredging. Therefore, benthic communities impacted by dredging for other beach nourishment projects at the Seashore (e.g., Rodanthe-Pea Island NWR and Buxton) are likely to have recovered within a period of six months to several years.

Essential Fish Habitat

EFH includes all waters and substrates needed for the spawning, breeding, foraging, and growth of species managed under the Magnuson-Stevens Act. Many of the habitats that are important for benthic organisms are also considered EFH for managed species under the Magnuson-Stevens Act including soft bottom and hard bottom (rock outcrops, artificial reefs, and shipwrecks). Additional habitats near the Seashore include pelagic (water column or open water), shallow coastal waters, and sargassum. Within the category of EFH are HAPC that exhibit one or more of the following traits: rare, stressed by development, provide important ecological functions for federally managed species, or are especially vulnerable to anthropogenic (human impact) degradation. HAPC near the Seashore include sandy shoals (e.g., Diamond Shoals and Wimble Shoals), hard bottom, sargassum, coastal inlets (e.g., Oregon Inlet and Hatteras Inlet), SAV, tidal marsh, and nursery and pupping grounds for sandbar shark (NOAA Fisheries 2018). Table 2 provides details on the habitats managed as EFH within and near the areas of likely sediment management activities or potential borrow areas at the Seashore.

TABLE 2. ESSENTIAL FISH HABITAT WITHIN THE STUDY AREA

Habitat	Species
Pelagic waters	Albacore tuna[1], Atlantic angel shark[1], Atlantic butterfish[2], Atlantic sharpnose shark (Atlantic stock)[1], Bluefin tuna[1], Bluefish[3], Common thresher shark[1], Monkfish (eggs, larvae)[4], Sailfish[1], Sand tiger shark[1], Sargassum[5], Smoothhound shark complex (Atlantic stock)[1], Snapper-grouper[6], Spinner shark[1], Spiny dogfish[7], Summer flounder (larvae)[8], Tiger shark (adult)[1], Wahoo[9], Windowpane flounder (larvae)[10], Yellowfin tuna[1]
Shallow coastal	Atlantic angel shark[1], Atlantic butterfish[2], Blacktip shark (Atlantic stock)[1], Bluefish[3], Coastal migratory pelagics[11], Dusky shark (neonate)[1], Sand tiger shark[1], Sandbar shark[1], Scalloped hammerhead shark[1], Spinner shark[1], Tiger shark (juvenile)[1]

Habitat	Species
Soft bottom	Brown shrimp (mud)[12], Clearnose skate[13], Pink shrimp (mud)[12], Rock shrimp (sand)[12], Scup[14], Slipper lobster (sand)[15], Spiny lobster (sand)[16], Summer flounder (adult)[16], White shrimp (sand)[12]
SAV	Brown shrimp[12], Pink shrimp[12], Scup[14], Slipper lobster[15], Snapper-grouper[6], Spiny lobster[15], Summer flounder (adult)[16], White shrimp[12]
Hard bottom (rock, epibenthic, coral, shell, gravel)	Clearnose skate[13], Coastal migratory pelagics[11], Scup[14], Snapper-grouper[6], Spiny dogfish[7], Summer flounder (adult)[16]
Tidal marsh	Brown shrimp[12], Pink shrimp[12], Rock shrimp[12], White shrimp[12]
Sargassum	Coastal migratory pelagics[11], Wahoo[9]
Sandy shoals (Cape Hatteras shoals)	Coastal migratory pelagics[11]
Inlets	Dusky shark (neonate)[1]

Sources: [1]NOAA Fisheries 2017; [2]MAFMC and NOAA Fisheries 2011; [3]MAFMC and ASMFC 1999; [4]NEFMC 2016; [5]SAFMC 2002; [6]SAFMC 1983; [7]MAFMC 2014; [8]MAFMC 1987; [9]SAFMC 2003; [10]NEFMC 2016; [11]SAFMC 1998; [12]SAFMC 1993; [13]NEFMC 2016; [14]MAFMC 1996; [15]CFMC 1981; [16]MAFMC 1987

HAPCs can be specific locations, or they can include habitats found in many locations (NOAA Fisheries 2018). HAPCs are managed under the regional fishery management councils (Councils) and do not convey additional restrictions or protections on an area – they simply focus increased scrutiny, study, or mitigation planning compared to surrounding areas because they represent high priority areas for conservation, management, or research and are necessary for healthy ecosystems and sustainable fisheries (NOAA Fisheries 2018). HAPCs located in or adjacent to the Seashore are provided in table 3.

TABLE 3. EFH-HAPCS WITHIN OR ADJACENT TO THE STUDY AREA

Species or Fishery	Habitat or Location
Penaeid shrimp	Coastal inlets; tidal marshes
Snapper-Grouper	Coastal inlets; medium- to high-profile offshore hard bottoms where spawning normally occurs; nearshore hardbottom areas; sandy shoals of Cape Hatteras; SAV
Sargassum	Benthic and pelagic, wherever found
Sandbar shark	Nursery and pupping grounds
Coastal migratory pelagics	Sandy shoals of Cape Hatteras
Summer flounder	SAV; tidal marshes

Source: NMFS 2020a

EFH and HAPCs present near the Seashore on the ocean side include shallow coastal and pelagic waters (i.e., water column), soft (mud and sand) bottom, (nearshore) hard bottom (including artificial reefs), sargassum, and Cape Hatteras sandy shoals. Sound side EFH and HAPCs include estuarine water column, soft bottom, SAV, tidal marshes, intertidal flats, and a few areas of hard bottom consisting of oyster reefs, artificial reefs, and shipwrecks (NCDEQ 2019a). EFH and HAPCs present at the inlets include water column, soft bottom, and coastal inlet. Descriptions of these habitats are provided below.

Water Column (Pelagic and Shallow Coastal EFH)

The water column is present throughout the study area and includes shallow coastal (nearshore) and pelagic (offshore) habitats on both the ocean and sound side of the Seashore. It connects all marine and estuarine habitats within the study area and provides a corridor through which fish and other marine species travel between habitats. It is particularly important for species that occupy different habitats during different life stages (NCDEQ 2016). The marine water column is EFH for many species and life stages managed under the Magnuson-Stevens Act. Specifically, the marine water column is a broad EFH that includes ocean high-salinity surf zone and barrier island ocean-side waters, from surf to shelf break zone and from Gulf Stream shoreward, for coastal migratory pelagics (SAFMC 1998); and it provides additional pelagic EFH for Atlantic highly migratory species (NOAA Fisheries 2017), snapper-grouper complex (SAFMC 1983), and shrimp (SAFMC 1993), as well as many other managed species. Cape Hatteras Point is located where marine currents from the north and the south collide, generating offshore mixing zones that, combined with the varied winds and shifting bottom topography characteristic of Cape Hatteras shoals, cause nutrient-rich upwelling. This upwelling supports a large diversity of larval to adult stages of managed fish species, and the currents concentrate pelagic fauna and flora, from the temperate biogeographic region to the north and tropical to sub-tropical biogeographic region to the south (Cerame-Vivas and Gray 1966; Briggs and Bowen 2012).

The condition of the water column is typically described by physical and chemical properties and is dependent on the number of monitoring agents; monitoring site location and distribution; frequency of sampling events; and parameters measured, making comprehensive water quality assessments difficult. Currently the Tar-Pamlico Basin and the Neuse Basin, both of which drain into Pamlico Sound, are classified by the North Carolina Department of Environmental Quality (NCDEQ) as nutrient sensitive waters (NSW). Nutrient sensitive waters are subject to wastewater discharge limitations and more stringent nutrient management policies to reduce their nutrient loads. The Tar-Pamlico River Basin has reduced total nitrogen by 30% since it was classified as NSW in 1989, although total phosphorus has not increased during that time. Data for the Neuse River Basin indicated total nitrogen and total phosphorus fluctuate annually based on flow, and the water quality does not always fall below the total maximum daily load targets for these nutrients (NCDEQ 2016). The condition of the water column on the ocean side of the Seashore has not been characterized by water quality sampling or monitoring.

Soft Bottom (Sand and Mud Bottom)

Soft bottom habitat within the study area consists of soft marine sediments inhabited by a diverse assemblage of invertebrates upon which fish living close to the substrate (demersal) forage. Soft bottom habitats at the Seashore include sandy and mud bottom areas in the sound without vegetation or structure, sand bars on the sound side, intertidal and subtidal areas of the beach, and borrow areas where dredging would occur. Typically, the sediments in this habitat are very mobile in response to wave and current conditions and lack stable surfaces for extensive vegetation or animal attachment. Changes in type or amount of sediment supply, energy of waves and currents, and water quality chemistry drive the biodiversity within this EFH. The offshore component of this EFH is typically more taxa rich than the surf zone and nearshore components because of differences in sediment transport forces and the dynamics of breaking waves in the surf zone (CZR and CSE 2015b). Marine EFH of this type is found both within the study area and the potential borrow areas.

Soft bottom habitat is fairly resistant to changing environmental variables and is the most abundant submerged coastal fish habitat. Although mapping of soft bottom habitats has not been completed in North Carolina due to shifting sediments, they have most likely increased in size as hard bottom, shell bottom, SAV, and wetland habitats have declined (NCDEQ 2016). The condition of soft bottom habitat is usually characterized by contaminant concentration in the sediment. Studies conducted in the sounds and major rivers of North Carolina have indicated that most contaminants are concentrated in the rivers, particularly the Neuse and Pamlico, and the Pamlico Sound has low levels of sediment contaminants (NCDEQ 2016). Recreational beaches are regularly tested for bacterial contamination, although levels for other toxins are not determined. Since 2015, one alert and no advisories have been issued for beaches at the Seashore (NCDENR 2020).

Hard Bottom

Hard bottom habitat, often referred to as “live bottom,” includes areas of exposed rock, relic reef, and shipwrecks or artificial reef. Studies of hard bottom areas on the continental shelf from North Carolina to northern Florida identified three hardbottom habitat types:

1) Emergent hardbottom dominated by sponges and gorgonian corals;
2) Sand bottom underlain by hard substrate dominated by anthozoans, sponges, and polychaetes, with some hydroids, bryozoans, and ascidians; and
3) Softer bottom areas not underlain with hardbottom (SAFMC 2018; NCDEQ 2016; NMFS 1984a).

Hard bottom provides refugia (or protective cover) for many fish and invertebrate species and increases surface relief and irregularity, providing additional surface area for colonization by macroalgae and sessile (attached to the substrate) species. These habitats are usually colonized to some extent by algae, sponges, soft and hard corals, and other sessile invertebrates (SAFMC 1998; SAFMC 2018). The structural complexity of the rock or reef increases the abundance and diversity of fish and invertebrates occupying the habitat (Carr and Hixon 1997). Nearshore and inner shelf hard bottom areas serve as settlement and nursery habitat for early life history stages for many managed fisheries species (SAFMC 2018). Species within the snapper-grouper complex commonly use hard bottom for refuge and spawning (SAFMC 1983).

Figure 21 in appendix A provides a map of hard bottom resources compiled from the results of several habitat surveys conducted along the North Carolina coast (NCDEQ 2019a). Although little information exists on the status of hard bottom habitat in North Carolina waters (Udouj 2007; NCDEQ 2016), the South Atlantic Fishery Management Council (SAFMC) considered nearshore hard bottom habitat to be generally in good condition in 1998 (SAFMC 1998). However, anecdotal information from fishermen in coastal North Carolina indicate that several nearshore hard bottom sites are now covered by sand, reducing the abundance of fish in these areas. For example, hard bottom habitat near Wrightsville beach has been buried under 2–6 in of sand through erosion from nourished beaches (NCDEQ 2016).

Cape Hatteras Shoals

Cape Hatteras shoals are EFH for many managed species and fisheries, and the shoals are HAPC for coastal migratory pelagics and the snapper-grouper complex (SAFMC 1983; SAFMC 1998). Diamond Shoals encompass over 15,000 acres of shoal habitat. It is fed by sand from adjacent beaches and it maintains an underwater extension of the coastline (CZR and CSE 2015b). The shoals, particularly Diamond Shoals, were formed by the confluence of the Labrador Current and the Gulf Stream. Due to the intersecting currents, upwelling of nutrients occurs at the shoals providing a highly productive environment for fish and other species. The current condition of the shoals is unknown because they are continuously moving and unstable. However, they remain highly productive environments for numerous fish species.

Sargassum

Sargassum is pelagic brown algae concentrated as small patches, large rafts, or lines, and it typically occurs where water masses converge in the coastal ocean (e.g., tide lines near coastal inlets or the intersections of oceanic currents). The largest concentrations of *Sargassum* are found in the Sargasso Sea and on the OCS of the South Atlantic (NCDEQ 2016). The most common species in coastal North Carolina near the study areas and potential borrow areas are *Sargassum natans* (floating), *S. fluitans* (floating), and *S. filipendula* (benthic). Pelagic *Sargassum* supports a diverse community of marine organisms, including at least 145 species of invertebrates, 100 species of fish, 4 species of marine turtles, and numerous marine birds (SAFMC 1998). Pelagic adult fish (e.g., dolphin [*Coryphaena hippurus*] and Atlantic sailfish [*Istiophorus albicans*]) feed on the small prey living in and around floating masses of *Sargassum*. In the Gulf Stream off North Carolina, a higher diversity of species living in and around *Sargassum* mats has been documented relative to unvegetated open water habitat (Casazza and Ross 2008).

The SAFMC considers the *Sargassum* as both EFH and as a managed species under the Magnuson-Stevens Act (SAFMC 2002). *Sargassum* is designated EFH and/or HAPC for snapper-grouper complex and coastal migratory pelagics (SAFMC 1983; SAFMC 1998). The Sargasso Sea is also known to be the spawning grounds for all American and European eels (Munk et al. 2010). It is a major source of biological productivity in nutrient-poor regions of the ocean; however, unregulated commercial harvest of *Sargassum* has prompted concerns over the potential loss of this important resource (CZR and CSE 2015b).

Studies conducted to characterize the condition of existing *Sargassum* communities off the shore of North Carolina indicate that the abundance and distribution of *Sargassum* is highly variable and dependent upon the Gulf Stream; but the population has persisted continuously for at least decades and probably for a period of thousands of years (Butler and Stoner 1983; Casazza and Ross 2008). However, unregulated commercial harvest of *Sargassum* has prompted concerns over the potential loss of this important resource (SAFMC 2002). In addition, *Sargassum* continues to be an important habitat for numerous fish, invertebrates, and sea turtle species. Recently, concerns have been raised that floating plastic, which collects in *Sargassum* beds, may be degrading the value of the habitat (Law et al. 2010), and plastic trash is commonly ingested by sea turtles (Wabnitz and Nichols 2010). The effect of trash on the value of *Sargassum* habitat has not been fully determined.

Coastal Inlets

Coastal inlets in the Seashore are HAPC for the snapper-grouper complex and penaeid shrimp complex. Inlets present within or near the study areas include Oregon Inlet and Hatteras Inlet. The coastal inlet HAPC includes both the throat of the inlet as well as its associated delta complexes. These deltas typically include flood tidal shoals created by water moving landward through the inlet and ebb tidal shoals formed as water moves seaward through the inlet (SAFMC 2016). Sand may be placed within the inlets for beach nourishment or shorebird habitat restoration; and although the channels would not be used as borrow areas, material generated during maintenance dredging may be used for beneficial purposes.

Coastal inlets naturally migrate in the downcoast direction according to net nearshore sediment transport direction. They are also subject to strong tidal flows, wave action, undertows, and other forces that act to erode or accrete the land forming the border of the inlet. The inlets at the Seashore include Oregon Inlet, Hatteras Inlet, and Ocracoke Inlet, although Hatteras and Ocracoke Inlets are not technically a part of the Seashore. Between 1846 and 1989, Oregon Inlet migrated approximately 2.2 miles south resulting in NCDOT's construction of a terminal groin to stabilize the southern shoulder of the inlet and protect the Bonner Bridge (Joyner et al. 1999). Extensive monitoring of the hydraulic and sedimentation dynamics of the channel has occurred since the construction of the groin, but little study of the biological effects of the groin on the channel has been completed. Currently, the channel appears to be stable, and no degradation of the inlet habitat has been observed. At Hatteras Inlet, the Hatteras Island spit forming the northern shoulder of the inlet has eroded significantly over the last 10 years. Based on available aerial photography, the spit has lost approximately 4,300 ft from 2009 to 2019. The erosion of the Hatteras spit has created a wide flood tidal delta on the sound side of the island providing additional habitat for species that use inlets. The current health of the inlet is unknown, but no degradation of the habitat is apparent.

SAV

SAV is characterized by plants that are rooted in the substrate and generally remain under the surface of the water during all tidal stages. SAV includes sea grasses which are generally found in marine or high salinity estuarine habitats and submerged vascular plant beds located in freshwater or low salinity estuarine habitats. In the South Atlantic Region, SAV is primarily located in Florida and North Carolina. It is designated as EFH for penaeid shrimp, spiny lobster, and snapper-grouper complex; and it is a HAPC for the snapper-grouper complex. At the Seashore, SAV is a dominant feature along the sound side of the islands beyond the tidal marshes. It is critically important to numerous state- and federally managed species and their prey (NCDEQ 2016). SAV provide food and shelter for multiple species resulting in a complex and dynamic system that provides nursery habitat for many organisms important to the overall system ecology; commercial and recreational fisheries; and other species including shellfish, manatees, and sea turtles. The three dominant SAV species found in North Carolina are shoalgrass (*Halodule wrightii*), eelgrass (*Zostera marina*), and widgeon grass (*Ruppia maritima*) (see figure 27 in appendix A). There is a large SAV concentration in eastern Pamlico Sound, adjacent to areas of potential sediment management activities at the Seashore (SAFMC 1998; SAFMC 2013). The northernmost occurrence of shoalgrass, which is a subtropical species, is in Oregon Inlet between the Pea Island NWR portion of the Seashore and Bodie Island.

Natural events, human activities, and climate change influence the distribution and quality of SAV habitat. Natural events may include drought or excessive rainfall, storm events, varying temperatures, or disease which may trigger shifts in salinity, light availability, or water quality. Human activities can impact SAV through physical disturbance, alteration of habitat, or water quality degradation (SAFMC 2013). These activities may include dredging, propeller scarring, bottom-disturbing fishing activities, and shoreline alteration. SAV is also vulnerable to increases in suspended sediments and eutrophication due to its need for high levels of light transmission through clear water (SAFMC 1998; SAFMC 2013). The majority of SAV in North Carolina is located on the sound side of the Outer Banks (NCDEQ 2016). There were considerable losses of SAV in North Carolina up until the 1980s when conservation measures enacted at the local, state, and federal level helped slow or reverse these declines in some areas (NCDEQ 2016). The North Carolina Division of Marine Fisheries (NCDMF) maintains an inventory of SAV mapping on the coast, and the results of SAV surveys on the sound side of the Seashore indicate that there has not been a large change in seagrass coverage since the 1980s (see figure 27 in appendix A) (SAFMC 2013; NCDEQ 2016).

The NCDCM oversees the management and permitting of projects within SAV. Although development within SAV is not strictly prohibited, it requires a CAMA permit. The activities in SAV regulated by CAMA include, but are not limited to, channel or basin dredging; structures over or within (e.g., bridges and docks); placement of fill material including dredge spoil and beach nourishment; and disturbance, such as clam raking or trawling to harvest benthic or fish species. As provided in Chapter 15A NCAC, Subchapter 7H, to qualify for a permit, the project needs to be designed and located to cause the least possible damage to the productivity and integrity of SAV. It also must not significantly increase siltation or erosion that may smother or block sunlight from SAV (North Carolina OAH 2016, 2012, 2006, 1998; NCDCM 2014).

Tidal Marshes

Tidal marshes are transitional zones between the land and water along intertidal estuarine shorelines. They are present along the entire sound side of the Seashore, and the Albemarle-Pamlico Sound is the estuarine drainage area along the southeast Atlantic coast with the largest areal coverage of marsh habitat. Tidal marshes at the Seashore are generally high-salinity salt marshes. Although marsh elevations at the Seashore are not known, these salt marshes are divided into two zones: low marsh and high marsh (SAFMC 2009a). Low marsh is regularly inundated during the normal tidal cycle. The species composition is limited due to high salinity and regular tidal inundation. Smooth cordgrass (*Spartina alterniflora*) is the primary plant species found within low marsh at the Seashore, with smaller amounts of needlerush (*Juncus roemerianus*). High marsh is typically above the normal tide line and is inundated only during spring or storm tides. Species common to high marsh at the Seashore include saltmeadow cordgrass (*S. patens*), big cordgrass (*S. cynosuroides*), needlerush, sawgrass (*Cladium jamaicense*), and southern cattail (*Typha angustifolia*) (NCDEQ 2016).

Tidal marshes provide diverse functions for fish species including forage and refuge. It is estimated that over 95% of the finfish and shellfish species harvested commercially in the US are dependent on wetlands. These organisms use the marsh structure including stems of emergent vascular plants, macroalgae, substrate materials such as shells and sediments, attached oysters and mussels, and accumulated woody flotsam. Many species feed directly on the vegetation, especially decapods and gastropods. Some species are not found within the marsh but derive substantial food resources from marsh plants as detritus. Also, the protection afforded by the stem structure and intertidal water levels provides spawning habitat for fish species, such as killifish, atherinids, and gobiids (SAFMC 2009a). The Seashore completed a vegetation community mapping study in 2014, with an update in 2018 (NPS 2014, 2018f). Five types of salt or brackish tidal marsh were identified totaling 2,635.1 acres. The same results were provided in the 2018 update. The study also identified 41 acres (or 1.5%) of marsh within the Seashore in which monocultures of the invasive exotic common reed (*Phragmites australis*) was present (NPS 2014, 2018f), and the NPS reported that approximately 800 acres of brackish tidal marsh had been impacted by common reed invasion (NPS 2016a). Common reed has been spread primarily by human activities that cause disturbance of tidal marshes such as pollution, sedimentation, changes in hydrologic regimes, and changes in salinity (Saltonstall 2002). In 2012 and 2013, the NPS began treating isolated patches of common reed with aquatic-safe herbicide to prevent spreading and the creation of monoculture conditions. Treatments occur during summer and early fall months when plants are actively growing (NPS 2016a).

Tidal marshes are considered wetlands by the NPS. As such, activities conducted or approved by the NPS would comply with Director's Order #77-1: *Wetland Protection* and the NPS Procedural Manual #77-1: *Wetland Protection*.

Potential Threats to EFH and HAPC

Potential threats that may affect EFH and HAPC at the Seashore include similar inland and water-based sources of impact, and threats are present both on beaches and in offshore waters. In water and on land threats to EFH/HAPC in the South Atlantic Region are detailed by the South Atlantic Fisheries Management Commission in the *Fishery Ecosystem Plan of the South Atlantic Region, Volume IV: Threats and Recommendations*, pages 1 to 143 (SAFMC 2009b), which is incorporated herein by reference. The plan is available at https://safmc.net/wp-content/uploads/2017/07/VolIV-Intro-and-Non-Fishing-impacts.pdf.

Potential threats include aquaculture; residential and commercial development; transportation projects and navigation support activities; nuisance/exotic species introduction; offshore sand mining and beach fill; and natural catastrophes and climate change. Aquaculture impacts EFH with the installation of pens, nets, and other containment devices; and operation of aquaculture projects introduces waste products, toxic chemicals, and exotic organisms into EFH. Residential and commercial development impact EFH by converting wetlands to upland; direct and non-point source discharge in streams, rivers, and estuaries; and hydrologic modifications. Threats from transportation projects include fragmentation of EFH, stormwater discharges and increased runoff, and shading of habitat from bridges. Navigation support activities that impact EFH include excavation and maintenance of channels, construction and operation of ports and mooring facilities, construction and operation of ship repair facilities, and construction of channel stabilization structures including jetties and revetments. Exotic species or nuisance species threaten EFH by consuming native populations, outcompeting native species for resources, or replacing prey species with an inedible food source. Sand mining and beach fill can remove habitats, increase turbidity, and bury habitats. Coastal and inland storms can cause severe habitat erosion, burial of habitat and organisms by sediment deposition, creation of strong currents that alter habitats and remove biota, and damage by wind and waves.

SEA TURTLES

The Seashore contains ecologically important habitats for federally listed sea turtles. Sea turtles nest annually from May to October at the Seashore and occur within the waters adjacent to the Seashore on the ocean side, sound side, and within the inlets. The species found at the Seashore include the loggerhead sea turtle (*Caretta caretta*), green sea turtle (*Chelonia mydas*), Kemp's ridley sea turtle (*Lepidochelys kempii*), leatherback sea turtle (*Dermochelys coriacea*), and the hawksbill sea turtle (*Eretmochelys imbricata*) (NPS 2019d). Non-breeding sea turtles of all five species can be found within the waters near the Seashore for much of the year (Epperly et al. 1995), and the Seashore is near the northern extent of the nesting ranges for the loggerhead, green, Kemp's ridley, and leatherback sea turtles. Hawksbill sea turtles are only known through strandings or very rare nesting activity.

Loggerhead Sea Turtle

The loggerhead sea turtle was initially listed as threatened throughout its range under the ESA in 1978. Since that time, nine DPS have been identified, based on genetic, physical, or behavioral discreteness, population uniqueness, and conservation status (NMFS and FWS 1996; FWS 2017). The Northwest Atlantic DPS, which uses both nesting and offshore habitats in and near the Seashore, is federally listed as threatened. The International Union for Conservation of Nature (IUCN) lists the loggerhead as vulnerable due to the continuing decline in the extent and quality of habitat (Casale and Tucker 2017). Loggerhead sea turtles are also listed as state special concern species in North Carolina.

Critical habitat designated for the North Atlantic DPS occurs in coastal North Carolina offshore of the Seashore. The ESA defines critical habitat as specific areas occupied by the species at the time it is listed, which contain physical or biological features essential to the conservation of the species and which may require special management considerations or protection. It may also include areas outside the geographical range of the species at the time it is listed upon a determination by the Secretary that such areas are essential for the conservation of the species (16 USC 1532(5)(A) 1973). The critical habitat at the Seashore is constricted migratory habitat, which is identified as a physical and biological feature that is essential to the conservation of the loggerhead sea turtle. As provided in 79 FR 39755, a constricted migratory corridor is described as a high-use corridor that is constricted, i.e., limited by width, by land on one side and the edge of the continental shelf and Gulf Stream on the other side. The primary constituent elements that support the habitat include the following:

- Constricted continental shelf area relative to nearby continental shelf waters that concentrate migratory pathways; and
- Passage conditions to allow for migration to and from nesting, breeding, and/or foraging areas.

Constricted migratory habitat extends north to south along the entire length of the Seashore and east to west from the Atlantic shoreline of the Seashore to the outer edge of the continental shelf. Dredging for beach nourishment would occur within this habitat.

Juvenile and adult loggerheads occur year-round in the shallow continental shelf waters off the coast of the Seashore. Pamlico Sound is regularly used by juvenile loggerheads for refuge and forage, but these areas are only occasionally used by adults. The loggerhead diet consists primarily of benthic invertebrates, particularly hard-shelled organisms such as mollusks and crabs. Habitats within or near the Seashore frequented by loggerheads include sandy shoals, hard bottom, and sea grass beds (NMFS and FWS 2008).

At the Seashore, loggerheads typically nest on sandy, wide, open beaches, backed by low dunes, along the Atlantic coast (ocean side). Factors that determine nest site selection include beach slope, temperature, distance to ocean, sand type, and moisture, although there are occasional inconsistencies in site choice. The process of nest site selection is not well understood, but successful nests are located in low salinity, high humidity, well-ventilated substrates, where temperatures are optimal for development. Also, females tend to place nests in areas with low risk of flooding or burying due to tides and storms (Miller et al. 2003). Nesting season at the Seashore is typically from May to October, peaking in June and July, and eggs incubate for approximately 45 to 65 days. Loggerheads are known to lay between 1 and 7 nests per season, approximately 14 days apart over an interval of 2 to 3 years between migrations to nesting beaches.

Table 4 provides nest and false crawl numbers for sea turtle species at the Seashore (excluding the Pea Island NWR portion of the Seashore) from 2014 to 2019. Recorded loggerhead sea turtle nests averaged around 221 nests per year with a low of 122 nests in 2014 and a high of 437 nests in 2019. Recorded false crawls were somewhat lower than successful nests for each year, and the pattern from year to year mirrored the nest numbers (NPS 2017j, 2017k, 2017c, 2018d, 2019d). False crawls occur when a female sea turtle crawls onto the beach to nest but crawls back to the water without digging a nest and laying eggs (USACE 1988b). Although the causes of false crawls are not fully understood, they are generally attributed to unsatisfactory nesting conditions on the beach including sand compaction, unnatural sediment grain size distribution, unnatural beach profiles, or the presence of artificial light or obstacles such as escarpments (USACE 1988b; Nelson and Blihovde 1998; Ernest and Martin 1999).

TABLE 4. NESTING AND FALSE CRAWL TRENDS FOR SEA TURTLES MONITORED AT CAPE HATTERAS NATIONAL SEASHORE

Sea Turtle Species	2014 Total Nests	2014 False Crawls	2015 Total Nests	2015 False Crawls	2016 Total Nests	2016 False Crawls	2017 Total Nests	2017 False Crawls	2018 Total Nests	2018 False Crawls	2019 Total Nests	2019 False Crawls
Loggerhead	122	103	277	238	313	300	240	208	155	135	440	405
Green	2	1	10	3	11	9	10	9	5	1	32	12
Kemp's Ridley	0	0	0	0	1	1	0	0	6	1	1	0
Leatherback	0	0	0	0	0	0	0	0	0	0	0	0
Hawksbill	0	0	2	0	0	0	0	0	0	0	0	0
Unknown	-	-	-	-	-	-	-	-	-	-	0	1
Totals	**124**	**104**	**289**	**241**	**325**	**310**	**250**	**217**	**166**	**137**	**473**	**418**

Source: NPS 2017c, 2017j, 2017k, 2018d, 2019b; Seaturtle.org 2020

TABLE 5. NESTING ACTIVITY AND HATCHLING EMERGENCE FOR ALL SEA TURTLE SPECIES NESTING AT CAPE HATTERAS NATIONAL SEASHORE FROM 2014 TO 2019

Year	Nests	False Crawls	Relocated Nests[1]	Total Eggs	Eggs Hatched	Emerged Hatchlings	Mean Clutch Count	Mean Incubation Time (days)	Mean Hatch Success[2]	Mean Emergence Success[3]
2014	124	104 (45.6%)	33 (26.6%)	12474	6988	6172	105.3	62.2	50.6%	44.6%
2015	289	242 (45.6%)	56 (19.3%)	30168	18644	15960	116.5	56.9	56.6%	48.7%
2016	325	329 (50.3%)	85 (26.1%)	34122	23541	20380	118.6	53.6	62.3%	53.9%
2017	250	219 (46.7%)	72 (28.8%)	27313	17531	15365	112.8	59.5	60.2%	53.1%
2018	166	137 (45.2%)	61 (36.7%)	16282	10390	9062	108.1	57.8	58.5%	51.0%
2019	473	418 (46.9%)	128 (27.0%)	50716	33733	28093	116.8	55.4	60.5%	50.4%

Source: NPS 2017c, 2017j, 2017k, 2018d, 2019b; Seaturtle.org 2020

[1] Number of relocated nests (percentage of total nests)

[2] Average of hatching success (percentage of eggs in a nest that produce hatchlings)

[3] Average of emergence success (total number of hatchlings that emerged unaided from the nest cavity relative to the total number of eggs in the nest)

At the Seashore, threats to loggerhead populations are loss or degradation of nesting habitats, increased human presence, nest depredation, relative sea-level rise, and incidental capture in nets or longline fisheries (NMFS and FWS 2008). Lighting associated with development has had substantial impacts on hatchling dispersal and may cause disorientation, elevating depredation risk due to increased exposure time. The recovery plan for the Northwest Atlantic population identifies minimizing nest predation as an objective for the recovery of loggerheads (NMFS and FWS 2008). In its most recent five-year review, the FWS did not recommend delisting or reclassifying the species (NMFS and FWS 2007a).

Green Sea Turtle

Green sea turtles occurring at the Seashore belong to the North Atlantic DPS, and this DPS is federally threatened (NOAA Fisheries 2019). The IUCN lists green turtles as endangered due to extensive subpopulation declines in all major ocean basins over the last 60 years (Seminoff 2004). The green sea turtle is listed as threatened by the State of North Carolina.

Both adult and juvenile green sea turtles occur in waters off the Atlantic coast (NMFS and FWS 2007b), and regularly nest at the Seashore (NPS 2019d). Green sea turtles primarily occur in three habitats: high-energy oceanic beaches, convergence zones in the pelagic habitat, and benthic feeding grounds in relatively shallow, protected waters. Common foraging habitats include sea grass, algae, or other SAV, but green turtles also frequent coral reefs, worm reefs, and hard bottom habitats. The diet of juvenile green turtles while in pelagic, oceanic habitats is poorly understood, but once juveniles shift to benthic feeding grounds, they are herbivorous. The adult diet primarily consists of sea grasses and algae, or other SAV.

Nesting at the Seashore occurs primarily from June through October. Females nest at night, and eggs incubate for approximately 45 to 70 days depending on incubation temperatures. Females deposit between 1 to 9 clutches in a nesting season with an average of around 3.3 nests. The interval between nesting events within a season varies with an average of 13 days, and intervals between migrations to nesting areas range from 2 to 4 years (NMFS and FWS 1991; NOAA Fisheries 2019; FWS 2017). Documented green sea turtle nests at the Seashore averaged around 8 nests per year with a low of 2 nests in 2014 and a high of 31 nests in 2019, see table 4. False crawls ranged from 1 (in 2014 and 2018) to 12 in 2019, and numbers increased or decreased in proportion to nesting numbers (NPS 2017j, 2017k, 2017c, 2018d, 2019d).

In the US, threats to this species include loss or degradation of nesting habitat, depredation of eggs and hatchlings, entrapment or entrainment in net fisheries, and the disease fibropapillomatosis (NMFS and FWS 2007b; FWS 2017). Recovery criteria are outlined in the green sea turtle recovery plan (see NMFS and FWS 1991, 2007b), and the North Atlantic DPS was downlisted from endangered to threatened in 2016.

Kemp’s Ridley Sea Turtle

The Kemp’s ridley sea turtle is federally endangered and is listed as critically endangered by the IUCN due to steep populations declines after 1945 (Wibbels and Bevan 2019; NMFS and FWS 2015). It is also listed as endangered in North Carolina.

The Kemp’s ridley sea turtle has one of the most restricted distributions of any sea turtle species, and its range includes the Gulf coast of Mexico and the US, and the Atlantic coast of North America as far north as Nova Scotia and Newfoundland (FWS 2017). Adult turtles are thought to primarily inhabit the Gulf of Mexico, while juveniles and subadults also regularly occur in shallow, coastal habitats along the eastern seaboard of the US. Pamlico Sound is a key developmental habitat for juvenile Kemp's ridleys along the Atlantic coast (NMFS and FWS 2015). Northern juveniles tend to migrate south in November to gather in wintering areas on the continental shelf offshore of Cape Hatteras Point indicating that Atlantic waters near the Seashore are an important wintering habitat for Kemp's ridleys (Epperly et al. 1995).

In the US, most nesting takes place in Texas (FWS 2017), but infrequent nesting has been documented at the Seashore (NPS 2019d). Nesting occurs primarily from April to July, and usually occurs during the day. Adult females lay an average of 2.5 clutches within a season with an interval of 14 to 28 days between deposition of clutches within the same season. Eggs incubate for approximately 45 to 58 days before hatching. The average migration interval for adult females is two years, although intervals of one and three years are common (FWS 2017). Kemp's ridley sea turtles rarely nest at the Seashore. As detailed in table 4, only one nest and one false crawl were documented from 2014 to 2017, both in 2016; however, in 2018, six Kemp's ridley sea turtle nests (a record number) and one false crawl were documented at the Seashore. In 2019, no Kemp's ridleys nested at the Seashore (NPS 2017j, 2017k, 2017c, 2018d, 2019d). The reason for the increase in 2018 is unclear, although overcrowding at historical nesting beaches has been proposed as a cause (NPS 2019d).

Kemp's ridley populations are threatened by the public harvesting of eggs from nests, accidental capture in fishery trawls, loss or degradation of nesting habitat, and relative sea-level rise (NMFS and FWS 2015). Nest depredation by mammals and ghost crabs poses a serious threat to marine turtle populations at the Seashore (NPS 2019d). In its most recent five-year review, the FWS notes that the population is not projected to grow at former rates. Downlisting criteria as detailed in the species recovery plan (NMFS, FWS, and SEMARNAT 2011) are unlikely to be attained by 2024, unless survival rates improve (NMFS and FWS 2015).

Leatherback Sea Turtle

Leatherback sea turtles are listed as federally endangered across their range and as "vulnerable" by the IUCN due to an overall global population decline (Wallace et al. 2013). They are also listed as endangered by the State of North Carolina. At the Seashore, leatherback sea turtles occur offshore in waters of the Atlantic, and their presence is documented primarily from strandings and rarely from nesting (NPS 2017j, 2017k, 2017c, 2018d, 2019d). Sea turtle relocations, which occurred in association with the 2017 Dare County beach nourishment project, indicated a similar pattern. Relocations were completed using a trawler modified to safely capture sea turtles present in the path of dredges mining nourishment sand. A total of 74 sea turtles were relocated, ten of which were leatherbacks (Coastwise Consulting, Inc. 2017). This is a much larger proportion of the sea turtle community than is indicated by nesting data.

Leatherbacks spend most of their lives at sea in the pelagic habitats of the open ocean and within offshore sargassum communities, but they are also found in coastal areas when breeding, nesting, or foraging on seasonally abundant jellyfish populations (NMFS and FWS 1992). During the period from 2014 to 2019, no leatherback sea turtle nests or false crawls were documented at the Seashore, see table 4 (NPS 2017j, 2017k, 2017c, 2018d, 2019d).

Threats to leatherbacks are loss or degradation of nesting habitat and nest depredation. At the Seashore, raccoons and ghost crabs are primary nest predators in the area (NPS 2019d). Hatchlings are also subject to depredation, and misorientation can greatly increase their exposure to predators (NMFS and FWS 1992).

Hawksbill Sea Turtle

Hawksbill sea turtles are listed as federally endangered throughout their range and as critically endangered by the IUCN due to continued population decline (Mortimer and Donnelly 2008). They are also listed as endangered by the State of North Carolina. At the Seashore, hawksbill sea turtles occur rarely, and their presence is documented primarily from strandings and very rare nesting events (NPS 2017j, 2017k, 2017c, 2018d, 2019d).

Hawksbills occur in tropical and subtropical waters, and the Seashore is the northern extent of their range. They typically inhabit coral reefs where they forage on sponges, coral, sea anemones, and other organisms that require hard substrate for attachment. They nest at night on sandy beaches, primarily from April through October, and eggs incubate for 45 to 65 days. Females lay an average of 4.5 clutches during a nesting season, with an inter-nesting interval of 14 days. The interval between nesting migrations is typically two to three years (FWS 2017). Hawksbill nesting in the continental US has only been documented in Florida and North Carolina (at the Seashore). At the Seashore, two nests were recorded in 2015. Both nests were originally identified as loggerhead nests due to the similarity of the two species' tracks, but they were determined to be hawksbill nests after DNA testing of the eggshells. Hawksbill nesting and false crawl data are provided in table 4 (NPS 2017j, 2017k, 2017c, 2018d, 2019d; FWS 2017).

Threats to hawkbills are loss or degradation of nesting habitat and nest depredation. At the Seashore, raccoons and ghost crabs are primary nest predators in the area (NPS 2019d). Hatchlings are also subject to depredation, and misorientation can greatly increase their exposure to predators (NMFS and FWS 1992).

Sea Turtle Monitoring and Management

The NPS has monitored its beaches at the Seashore for sea turtle nests since 1987. Standard protocols for sea turtle monitoring and management at the Seashore follow management guidelines defined by the NCWRC in the *Handbook for Sea Turtle Volunteers in North Carolina* (Handbook) (NCWRC 2006), US Fish & Wildlife Service species recovery plans (NMFS and FWS 1991, 1992, 1993, 2008; NMFS, FWS, and SEMARNAT 2011), and the *Cape Hatteras National Seashore Off-Road Vehicle Management Plan/Environmental Impact Statement*, as amended by the *Review and Adjustment of Wildlife Protection Buffers Environmental Assessment* (NPS 2010a, 2010b, 2015a, 2015b). The *Cape Hatteras National Seashore Sea Turtle Monitoring and Management Program 2018 Annual Report*, pages 3 to 7 (NPS 2019d), which is incorporated herein by reference, provides the methodology used by NPS staff to survey for, document, mark, and monitor sea turtle nesting activity. A copy of report is available at: https://www.nps.gov/caha/learn/nature/upload/2018_CAHA_Sea-turtle-report_final_report.pdf.

As part of their protocol, NPS staff demarcate exclusion zones to protect nests from recreational beach users and to protect emergent hatchlings migrating to the ocean. Monitoring staff also record the loss of nests, eggs, hatchlings, and adult sea turtles, and the cause of the loss, if known. Since 2010, the Seashore, along with all other North Carolina, South Carolina, and Georgia beaches, has participated in a genetic mark-recapture study of Northern Recovery Unit nesting female loggerheads using DNA derived from eggs. Georgia Department of Natural Resources, the University of Georgia, and the NCWRC coordinate the study. One egg from each nest is removed and sampled for maternal DNA; the team records losses caused by collecting the permitted research samples (NPS 2019d).

Sea Turtle Nesting Trends

Sea turtle nesting at the Seashore from 2014 to 2019 is summarized in table 4. Please note that the data provided in tables 4 through 10 do not include sea turtle nesting at the Pea Island NWR portion of the Seashore. Although the number of sea turtle nests documented at the Seashore varies annually, the general trend is that the number of sea turtle nests laid at the Seashore is increasing over time. Currently, no data exist to characterize site selection, digging behavior, and energy expenditure by nesting female sea turtles at the Seashore. Reproductive success, clutch viability, and hatchling emergence are discussed below. Annual nest numbers at the Seashore have fluctuated greatly over the last 30 years ranging between 11 nests in 1987, the lowest number, and 473 in 2019, the highest number. Generally, the number of sea turtle nests laid at the Seashore has increased from an average of 77.4 nests between 2000 and 2007, to an average of 192.2 nests between 2008 and 2016 (NPS 2017f). Annual variation in nesting numbers is generally attributed to synchronicity, or lack thereof, of inter-nesting migration periods (Solow et al. 2002), but in general, the populations of sea turtles within the recovery units that nest at the Seashore appear to be increasing as suggested by the nest numbers (Mazaris et al. 2017).

A summary of nesting activity and hatch success from 2014 through 2019 compiled for all sea turtle species nesting at the Seashore is provided in table 5. The average number of sea turtle nests laid during this period was 271 nests per year with a minimum of 124 nests in 2014 and a maximum of 473 nests in 2019. The average number of false crawls was 241 per year with a minimum of 104 in 2014 and a maximum of 418 in 2019. False crawls mirrored the annual variability exhibited by the nest totals. The annual percentage of false crawls was generally between 45% and 46% for each of the years presented in table 5, although false crawls comprised the majority (50.3%) of sea turtle emergences onto the nesting beach in 2016. No reason for the increase in false crawls in 2016 is apparent from the sea turtle nesting data. Mean clutch count (number of eggs per nest), was determined using total eggs counts from relocated nests at the time of relocation. Mean clutch count for the years 2014 to 2019 was generally consistent with some variability, ranging between 105.3 and 118.6. Mean hatch success (percentage of eggs in a nest that hatched) and mean emergence success (percentage of hatchlings that emerged unaided from the nest relative to total eggs in the nest) generally remained steady from 2014 to 2019, with some natural variability.

GPS data collected at nest locations at the Seashore during the 2018 and 2019 sea turtle nesting season indicate sea turtle nests were nearly evenly distributed throughout the Seashore with some natural variation, as illustrated in figure 22 in appendix A. Nest density appeared to be somewhat lower in areas within the villages of Buxton, Avon, and Rodanthe, where development directly abuts the beach, and higher nest densities appeared to occur in areas where a dune system buffered the beach from nearby development. Nests also appear to be evenly distributed within the areas of likely sediment management activities and reference monitoring preservation areas. Monitoring staff documented a large number of nests on the ocean side beach between the Haulover Day Use Area and Cape Hatteras Point, and much of that beach was nourished in 2017. This area is also included as an area of likely sediment management, and planning for a nourishment project is currently underway.

Genetic Testing

As described in the monitoring methodology above, each year, one egg is removed from almost every nest to identify and assign each nest to a particular nesting female. The results of the genetic mark-recapture study of the Northern Recovery Unit nesting female loggerheads at the Seashore from 2014 to 2019 are provided in table 6. In general, the number of nesting females at the Seashore exhibits similar variability, as the number of nests and nests per female averaged around 2.5 (NPS 2017c, 2017j, 2017k, 2018d, 2019b; Seaturtle.org 2020). 2019 appears to be an outlier as nesting females exhibited higher reproductive output averaging 3.43 nests per female (highest recorded since the beginning of the program in 2010 (NPS 2019d)). No cause for the high nest productivity of 2019 has been proposed, although the phenomenon was observed throughout the Atlantic coast from Georgia to North Carolina (Bynum 2019).

TABLE 6. NUMBER OF NESTS, NUMBER OF INDIVIDUAL NESTING FEMALES, NUMBERS OF NESTS PER FEMALE, AND MEAN INTER-NESTING PERIOD AT CAPE HATTERAS NATIONAL SEASHORE BASED ON DNA RESULTS FROM 2014 TO 2019

Year	Number of Nests	Individual Nesting Females	Nests per Female	Mean Inter-Nesting Period (days)
2014	124	64	2.06	14.83
2015	289	131	2.52	14.50
2016	325	142	2.61	13.92
2017	250	105	2.80	14.81
2018	166	94	1.97	14.50
2019	473	132	3.43	14.23

Source: NPS 2017c, 2017j, 2017k, 2018d, 2019b; Seaturtle.org 2020

Nest Relocation

Each year at the Seashore, sea turtle nests have been evaluated for relocation, and some were moved to improve nest success or protect the nest from damage. Most of the relocated nests were moved due to natural factors including nests located at or below daily high tide lines or nests that were laid in areas susceptible to high erosion or flooding. However, in 2017 all sea turtle nests laid within the beach nourishment project area at Buxton Village were relocated. One nest was laid within the active work zone, and 14 nests were laid within the nourishment project area outside of the active work zone. These relocations represent 22.2% of the 72 relocated nests at the Seashore in 2017 (NPS 2018d). Mean hatch success; mean emergence success; and nest success (percentage of nest producing hatchlings) of in situ nests (nests left in place) and relocated nests are provided in table 7. For years 2014, 2015, 2016, and 2018, mean hatch success, mean emergence success, and nest success, is higher for relocated nests than for in situ nests. In 2017, mean hatch success and mean emergence success were lower for relocated nests, but nest success was higher for relocated nests. Currently, there are not enough data to determine the reason for the lower success exhibited by relocated nests in 2017 (NPS 2017c, 2017j, 2017k, 2018d, 2019b).

TABLE 7. MEAN HATCH SUCCESS, MEAN EMERGENCE SUCCESS, AND NEST SUCCESS FOR IN SITU AND RELOCATED NESTS AT CAPE HATTERAS NATIONAL SEASHORE FOR THE YEARS 2014 TO 2018

Year	Number of Relocated Nests	Mean Hatch Success In Situ	Mean Hatch Success Relocated	Mean Emergence Success In Situ	Mean Emergence Success Relocated	Nest Success[1] In Situ	Nest Success[1] Relocated
2014	33	48.0%	58.9%	44.0%	47.0%	57.1%	60.6%
2015	56	55.4%	62.7%	47.4%	55.1%	63.0%	73.2%
2016	85	59.3%	70.5%	52.3%	58.3%	68.2%	89.4%
2017	72	61.1%	59.2%	54.3%	51.1%	67.2%	69.4%
2018	61	53.7%	66.8%	47.9%	56.2%	68.2%	80.3%

Source: NPS 2017c, 2017j, 2017k, 2018d, 2019b

[1] Percentage of nests producing emergent hatchlings

Beach Nourishment

In 2017, beach nourishment occurred along a 2.9-mile stretch of beach at Buxton Village. As described above under “Nest Relocation,” during the 2017 nesting season, all nests laid within the nourishment project area were relocated regardless of whether they were located in an active work area. No loss of nests, eggs, or hatchlings due to nourishment or relocation activities was documented. In 2018, 15 nests were laid within the footprint of the 2017 Beach Restoration to Protect NC Highway 12 at Buxton Project. Of those 15 nests, 5 were relocated due to being laid at or below the high tide line or within a known high erosion zone. The remaining 10 nests were left in place. Hatch and emergence success rates of the nests within the nourishment project area were 68.4% and 56.3%, respectively, higher than the overall (Seashore-wide) hatch and emergence success rates of 58.5% and 51.0%, respectively (NPS 2019b). Nest location GPS data indicate nesting within the nourishment area at Buxton beach remained consistent before, during, and after nourishment activities (NPS 2017c, 2017j, 2017k, 2018d, 2019b).

Depredation/Loss

The Seashore sea turtle monitoring and management program documents the loss of eggs and hatchlings due to depredation, misorientation/disorientation, incidental take (human, including research), and storms/tides/erosion. The causes of sea turtle egg loss during the 2014 to 2018 nesting seasons at the Seashore are provided in table 8. The causes of sea turtle hatchling loss during this time period are provided in table 9.

Over the period from 2014 to 2018, depredation resulted in a relatively low loss of eggs (combined total of 567 out of a total of 120,359 eggs laid [less than 0.5%]) and hatchlings (128 out of a total of 77,094 hatched eggs [less than 0.2%]). The majority of egg and hatchling depredation was by ghost crabs, which account for 57.3% of documented eggs lost to predation and 93% of documented hatchlings lost to predation. Other documented predators at the Seashore include birds, canine/fox (coyote, domesticated dogs, foxes), opossums, racoons, domesticated cats, mink, and fire ants (NPS 2017c, 2017j, 2017k, 2018d, 2019d).

TABLE 8. SEA TURTLE EGG LOSS SUMMARY FOR THE YEARS 2014 TO 2018 AT CAPE HATTERAS NATIONAL SEASHORE

Year	Research[1]	Depredation Canine/Fox	Depredation Birds	Depredation Ghost Crab	Tide/Storm	Broken Egg/Human	Unknown	Totals
2014	121	0	5	55	50	5	19	255
2015	281	0	6	76	14	1	6	384
2016	308	40	6	133	0	26	0	513
2017	246	124	61	41	193	4	0	669
2018	162	0	0	20	350	0	2	534

Source: NPS 2017c, 2017j, 2017k, 2018d, 2019b

[1] Egg loss for research refers to the eggs collected from each nest for genetic sampling as part of the genetic mark-recapture study of the NRU nesting females, as described above.

TABLE 9. SEA TURTLE HATCHLING LOSS SUMMARY FOR THE YEARS 2014 TO 2018 AT CAPE HATTERAS NATIONAL SEASHORE

Year	Misorientation	Depredation Birds	Depredation Ghost Crab	Depredation Ants	Human	Unknown	Totals
2014	2	0	12	0	0	1	15
2015	235	0	28	0	0	1	264
2016	235	0	45	8	0	9	297
2017	442	1	13	0	2	3	461
2018	488	0	21	0	0	7	516

Source: NPS 2017c, 2017j, 2017k, 2018d, 2019b

Disorientation, loss of direction, and misorientation (incorrect orientation) are common occurrences during sea turtle hatchling emergence. The compiled total of disoriented and misoriented hatchlings documented for the years 2014 to 2018 was 1,402 (2.1%) of the 66,939 emerged hatchlings, and the annual totals appear to be increasing. However, the full extent of hatchlings affected is not fully known because disorientation and misorientation are identified by tracks left in the sand by hatchlings and evidence is often erased by winds, overwash, rain, or human or animal activity (NPS 2017c, 2017j, 2017k, 2018d, 2019d). Adult nesting female sea turtles can also become disoriented or misoriented while traveling to or from nesting on the beach. Generally, this does not lead to adult mortality at the Seashore.

Incidental take and disturbance by humans may affect nesting females and hatchling emergence; however, the extent to which human activities have disrupted sea turtles is unknown due to the inability to monitor the entire Seashore 24 hours per day. From 2014 to 2018, egg loss from human disturbance/incidental take totaled 36 eggs (0.03%) of 120,359 eggs counted from 2014 to 2018. These losses include loss of eggs during excavation to confirm nest presence and collection of eggs for research (NPS 2017c, 2017j, 2017k, 2018d, 2019d).

Storms and Tides

Erosion or repeated inundation during storm or high tide events has led to the loss of many nests at the Seashore. Table 10 provides a summary of the nests and eggs lost to storm and tidal erosion or inundation at the Seashore from 2014 to 2018. Nests lost to erosion means the nest was completely washed away and did not remain in the ground. Nests lost to repeated inundation are nests that experienced multiple overwash events and failed to result in any hatching activity (i.e., 0% hatch success). Nests lost to inundation remained, at least partially, in the ground (NPS 2017c, 2017j, 2017k, 2018d, 2019d). The nest losses provided in table 10 are not necessarily represented by egg losses provided in table 8. Generally, egg loss due to storm or tide events is significantly underestimated because clutch counts are not determined for in situ nests, and the estimated annual egg losses provided in table 8 are calculated using 80 eggs per nest as the "minimum" and 120 eggs per nest as the "maximum." Also, nests that were lost to repeated inundation were not included in the egg loss totals provided in table 6 (NPS 2017c, 2017j, 2017k, 2018d, 2019d).

TABLE 10. SEA TURTLE NEST LOSS SUMMARY FROM STORM AND TIDAL ACTIVITY AT CAPE HATTERAS NATIONAL SEASHORE FROM 2014 TO 2018

Year	Nests Lost to Erosion	Nests lost to repeated	Estimated Total Egg Loss	Estimated Total Egg Loss
2014	12	0	960	1,440
2015	20	0	1,600	2,400
2016	24	27	4,080	6,120
2017	13	41	4,320	6,480
2018	19	8	2,160	3,240
Totals	**88**	**76**	**13,120**	**19,680**

Source: NPS 2017c, 2017j, 2017k, 2018d, 2019b

[1] Base on a lower estimate of 80 eggs per lost nest (NPS 2019d)

[2] Based on a higher estimate of 120 eggs per lost nest (NPS 2019d)

From 2014 to 2018, a total of 164 sea turtle nests at the Seashore were lost due to erosion or frequent or prolonged overwash/inundation; and a total of 142 nests exhibited low hatch success, less than 30%, due to multiple overwash or inundation events. The Seashore experienced nest loss from tropical storms in 2014 (Arthur, Bertha, Cristobal, Edouard), 2015 (Joaquin), 2016 (Hermine, Michael), 2017 (Tropical Storm #10, Gert, Jose, Maria), and 2018 (Chris, Florence). In addition to tropical storms, other high tide events often paired with strong winds have led to nest loss from erosion or frequent/prolonged overwash or inundation (NPS 2017c, 2017j, 2017k, 2018d, 2019d).

Potential Threats

Potential threats to sea turtles are generally the same for all sea turtle species that nest or inhabit the waters near the Seashore, and threats are present both on nesting beaches and in offshore waters. In water and on land, threats to sea turtles are detailed in the 2020 SARBO, pages 179 to 211 (NMFS 2020b); the *Recovery Plan for the Northwest Atlantic Population of the Loggerhead Sea Turtle*, pages I-31 to I-67 (NMFS and FWS 2008); and the *North Carolina Coastal Beach Sand Placement Statewide Programmatic Biological Opinion*, pages 163 to 170 (FWS 2017), which are herein incorporated by reference. The SARBO is available at https://www.fisheries.noaa.gov/webdam/download/105447245. The loggerhead recovery plan is available at https://www.fisheries.noaa.gov/resource/document/recovery-plan-northwest-atlantic-population-loggerhead-sea-turtle-caretta-caretta. The SPBO is available at https://saw-reg.usace.army.mil/PN2017/NC_SPBO.pdf.

Threats to sea turtles in the water, as described in the above references, include vessel traffic, dredging operations, fisheries, pollution, bathymetric surveys, and disposal of dredged material in marine or estuarine environments including beach nourishment. Threats on nesting beaches include human presence, beach furniture and recreational equipment, beach vehicular driving, beach nourishment, shoreline armoring, beach erosion and accretion, artificial lighting, predation, and climate change. These threats and activities can impact sea turtles directly (e.g., entrapment, injury, mortality), change sea turtle behavior (e.g., false crawls, nest abandonment, disorientation), or modify habitat (e.g., nourishment of nesting beach, beach erosion, dredging of hard bottom).

LISTED SHOREBIRD SPECIES

The Seashore, a designated Important Bird Area (BirdLife International 2019a), is a critical natural landform along the Atlantic Flyway (Ducks Unlimited 2019), serving as major resting, breeding, and feeding grounds for migratory birds throughout the year (CSE 2015). Barrier island ecosystems are also important nesting and foraging grounds for many shorebird species. Shorebirds are most abundant at the Seashore while mating and nesting, from late spring through the summer months, and many species of shorebirds are actively monitored at the Seashore to track population trends and ensure continued breeding success. Patterns in breeding success and population size vary by species, and details regarding the current conditions of federally and state-listed species are included in the following sections.

Three federally listed shorebird species protected under the ESA are known to use the study area. These species are piping plover (*Charadrius melodus*), roseate tern (*Sterna dougallii dougallii*), and rufa red knot (*Calidris canutus rufa*) (CZR Incorporated and CSE 2015a). The federally endangered red-cockaded woodpecker was excluded from further review because no habitat is present within or near the areas of likely sediment management activities. State-listed shorebird species carried forward for analysis include the American oystercatcher (*Haematopus palliates*), the black skimmer (*Rynchops niger*), the common tern (*Sterna hirundo*), the gull-billed tern (*Gelochelidon nilotica*), the least tern (*Sternula antillarum*), and Wilson's plover (*Charadrius wilsonia*). Many of these species exhibit similar preferences for nesting habitat and share nesting locations within the sediment management areas. The highest concentrations of these nesting sites exist at the northern and southern tip of Ocracoke, the southern shore at Cape Hatteras Point, the ocean side beach between the Haulover Day Use Area and Buxton, the beachfront south of Salvo, the northern shore of Oregon inlet, and Green Island (figure 23 in appendix A). Generally, shorebird nesting has historically occurred in areas that do not correspond to the areas of likely sediment management activities, as depicted in figure 23. The notable exceptions include the ocean side beach between the Haulover Day Use area and Cape Point, along which shorebird nesting has occurred, and the south end of Hatteras Island on which sediment management activities are proposed to restore piping plover nesting and wintering habit due to erosion caused by repeated dredging of the inlet navigation channel and boat traffic in Hatteras Inlet. Table 11 below summarizes important time periods for breeding and migrating listed shorebirds at the Seashore. Overall, there is some type of shorebird activity occurring throughout the year.

TABLE 11. OCCURRENCE OF LISTED SHOREBIRD SPECIES AT CAPE HATTERAS NATIONAL SEASHORE

Shorebird Species	Time Period
Piping Plover Breeding Season	March 1 to August 1
Piping Plover Migration Period (Spring)	March 1 to May 1
Piping Plover Migration Period (Fall)	July 1 to October 15
Red Knot Migration Period	May 1 to February 1
Roseate Tern Migration Period	May 1 to October 1

Source: NPS, Johnson, personal communication, 2019e

Piping Plover

The piping plover is a small shorebird that is endemic to North America. Piping plovers breed in North America in three geographic regions: the Atlantic Coast from Newfoundland to South Carolina, the Great Lakes, and the northern Great Plains. The Great Lakes breeding population is designated as endangered, and the Atlantic Coast and northern Great Plains breeding populations are designated as threatened. All migrating or wintering, piping plovers are considered threatened (FWS 2003a). Piping plovers are also listed by the State of North Carolina. Wintering occurs from July to January, with the highest non-breeding populations visiting the Seashore during migration from July to August. There have been a few instances of piping plovers nesting in South Carolina, but generally, North Carolina is the only state where the piping plover's breeding and wintering ranges overlap and where the birds are present year-round (National Wildlife Federation n.d.).

Piping plovers feed on marine worms, crustaceans, mollusks, and other small invertebrates found in the wet beach environment. Due to their physical size and relatively short bills, piping plovers require shallow or unflooded foraging areas and food items that are unburied or only shallowly buried beneath sediment (less than 2 in). These areas include foreshores, intradunal swales, mudflats/algae flats, overwash, salt marshes, and sand flats.

Breeding Habitat

Piping plovers use sandy beach habitat at the Seashore for nesting (Atlantic population) and foraging (both the Atlantic and Great Lakes populations) (FWS 1996a, 2003a). Atlantic Coast nest sites for the species are confined to flat and gently sloping areas with sand, gravel, and cobble substrates in open to sparsely vegetated beaches and similar habitats (Cairns 1982). Like other beach-nesting species, piping plovers prefer wide fields of view, or shelter beneath detritus or vegetation where they have been observed nesting alongside least terns. Additionally, nearby foraging habitat is important to nesting piping plovers, and wrack lines are preferred foraging habitat for chicks (Elias et al. 2000). The Atlantic Coast population of piping plovers breeds on coastal beaches from Newfoundland and southeastern Quebec to North Carolina, which is considered the southernmost nesting area for the Atlantic Coast population. The overall size of the Atlantic population is approximately 8,000 birds (BirdLife International 2019b; Partners in Flight 2019), but numbers fluctuate, reflecting the quantity and quality of suitable foraging and roosting habitat. Within the likely sediment management areas, concentrated nesting areas are present at four separate locations: the south point of Ocracoke, the southern shore of Hatteras Inlet, the south-facing edge of Cape Hatteras, and the northern shore of Oregon Inlet. Because of their reliance on specific, often localized, habitats and their strong breeding-site fidelity, piping plovers are still dependent on intensive conservation efforts at these locations (BirdLife International 2019b).

Critical Wintering Habitat

Piping plover nesting and wintering grounds overlap in coastal North Carolina and particularly within the Seashore. North Carolina is the northernmost extent of the piping plover's wintering range, and the Seashore represents a significant portion of the available foraging and wintering areas in the state. As such, there are five areas of designated critical habitat for wintering piping plovers located within the Seashore, as shown in figure 23 in appendix A. Critical habitat corresponds with the areas of likely sediment management on the north side of Cape Hatteras Point and at the south end of Hatteras Island. During wintering, piping plovers frequent sand flats, algae flats and mud flats rather than using open beaches (Drake et al. 2001). Roosting habitats consist of sparsely vegetated backshores and dunes (areas above the high tide mark).

Critical habitat for wintering piping plover is defined as:

- Intertidal sand beaches (including sand flats) or mud flats (between the mean lower low water [MLLW] line and annual high tide) with no or very sparse emergent vegetation for feeding. In some cases, these flats may be covered or partially covered by a mat of blue-green algae.
- Unvegetated or sparsely vegetated sand, mud, or algal flats above annual high tide for roosting. Such sites may have debris or detritus and may have micro-topographic relief (less than 20 in above substrate surface) offering refuge from high winds and cold weather.
- Surf-cast algae for feeding.
- Sparsely vegetated backbeach, which is the beach area above mean high tide seaward of the dune line, or in cases where no dunes exist, seaward of a delineating feature such as a vegetation line, structure, or road. Backbeach is used by plovers for roosting and refuge during storms.
- Spits, especially sand, running into water for foraging and roosting.
- Salterns, or bare sand flats in the center of mangrove ecosystems that are found above mean high water and are only irregularly flushed with sea water.
- Unvegetated washover areas with little or no topographic relief for feeding and roosting. Washover areas are formed and maintained by the action of hurricanes, storm surges, or other extreme wave actions.
- Natural conditions of sparse vegetation and little or no topographic relief mimicked in artificial habitat types (e.g., dredge spoil sites). (NPS 2010a)

The four Critical Wintering Habitat (CWH) units likely to be affected by sediment management activities at the Seashore include NC-1, NC-2, NC-4, and NC-5. Within these units, CWH includes sandy areas that lack dense vegetation. Where densely vegetated dunes are present, the CWHs extend from those dunes to MLLW on the Atlantic side of the island. In areas that lack densely vegetated dunes, the CWHs extend from MLLW on the Atlantic side to MLLW on the sound side. At Oregon and Hatteras Inlets, the CWHs include the tidal fans and associated islands, including Green Island in Oregon Inlet.

Monitoring

Nesting

Piping plovers nest within the Seashore and Pea Island NWR annually. They arrive at breeding grounds between late March and early April, and they nest in May and June (FWS 1996a). As part of standard annual management practices, NPS personnel patrol the Seashore, excluding the Pea Island NWR portion of the Seashore, and evaluate all potential breeding habitat for this species by March 1 and recommend pre-nesting closures based on that evaluation. Surveys continue three times/week and closures are adjusted accordingly throughout the nesting season until July 31. If breeding activity occurs, pre-nesting closures remain until two weeks after all chicks have fledged. NPS personnel conduct surveys seven days a week once nesting has begun. These surveys identify species; count eggs, hatchling, and fledglings; and determine probable and observed causes of nest or chick mortality (NPS 2019c). The results for the 2014 to 2018 breeding seasons can be found in table 12. The FWS implements different strategies to administer shorebird nesting closures and monitoring at the Pea Island NWR portion of the Seashore than NPS uses at the rest of the Seashore.

The numbers of piping plover nests and chicks fledged within the Seashore (excluding Pea Island NWR) from 2014 through 2018 is provided in table 12. The number of piping plover nests does not appear to indicate a trend with 14, 17, and 12 nests in 2014, 2015, and 2017, respectively, and three nests in 2016 and 2018. The number of fledged piping plover chicks recorded for the Seashore has remained between two and five for each year from 2014 to 2018 (NPS 2017a, 2017b, 2017c, 2018c, 2019c).

Migrating and Wintering

Tracking the population of wintering piping plovers at the Seashore is a difficult task, as migrant birds stop over for short periods of time, and resident wintering birds frequently move between habitats based on environmental conditions, prey availability, disturbance, and other factors. Significant stopover sites for migratory plovers are not evenly distributed throughout the Seashore. South Point at Ocracoke Island is recognized as a globally important stopover refueling site for piping plovers, hosting an estimated 10% of the global population during fall migration (Weithman 2018). During the non-breeding season, piping plover abundance typically peaks in late August, then tends to decline through December. Low numbers remain consistent from December through the onset of the breeding season the following spring (Cameron et al. 2020).

Two separate survey efforts were conducted annually from 2015 to 2018 to quantify non-breeding piping plover populations at the Seashore. NPS personnel completed one effort, which involved sampling from April to March (excluding June when all piping plovers are assumed to be breeding) along random transects positioned in high and low-intensity areas along the seashore. The number of individual surveys conducted varied based on personnel availability. A second, volunteer-based survey effort recorded the number of piping plovers observed during fall migration in July and August at South Point. In 2018, the volunteer data collection effort included surveys at Oregon Inlet and Green Island as well, but the vast majority of piping plover were observed at South Point on Ocracoke Island during the 2018 migration. As provided in table 13, during the 2015-2016 NPS monitoring, 130 surveys (excluding Ocracoke Island) detected 20 piping plovers; in the 2016-2017 season, 91 surveys detected 49 piping plovers; and in the 2017-2018 season, 66 surveys across the Seashore detected 62 birds (NPS 2017a, 2017b, 2017c, 2018c, 2019c).

The volunteer surveys conducted in July and August from 2016 to 2018 focused on Ocracoke Island and yielded much higher numbers than surveys conducted by the Seashore. In 2016, volunteers conducted six weekly surveys during which they counted from 155 to 188 piping plovers. They conducted ten weekly surveys in 2017 and counted between 125 and 182 piping plovers. In 2018, 22 surveys were conducted by volunteers during which they counted between seven and 211 piping plovers (NPS 2017c, 2018c, 2019c).

TABLE 12. NESTING AND FLEDGING TRENDS FOR SHOREBIRDS MONITORED AT CAPE HATTERAS NATIONAL SEASHORE

Shorebird Species	2014 Total nests	2014 Chicks fledged	2015 Total nests	2015 Chicks fledged	2016 Total nests	2016 Chicks fledged	2017 Total nests	2017 Chicks fledged	2018 Total nests	2018 Chicks fledged
Piping Plover	14	5	17	2	3	3	12	2	3	3
Roseate Tern[1]	-	-	-	-	-	-	-	-	-	-
Rufa Red Knot[1]	-	-	-	-	-	-	-	-	-	-
Black Skimmer	95	59	85	15	169	26	214	32	368	116
Common Tern	38	2	16	6	91	42	90	10	72	12
Gull-billed Tern	1	0	3	0	23	3	14	25	50	10
Least Tern	469	134	291	26	295	30	189	17	475	15
American Oystercatcher	38	9	43	12	41	12	53	2	40	20
Wilson's Plover	3	0	3	0	3	0	2	0	0	0

Source: NPS 2017a, 2017b, 2017c, 2017d, 2017e, 2018g, 2017g, 2017h, 2017i; 2018c; 2019c

[1] Species that do not breed at the Seashore

TABLE 13. FORAGING AND WINTERING PIPING PLOVERS AT CAPE HATTERAS NATIONAL SEASHORE

Year	April-March (excluding June) Number of surveys	April-March (excluding June) Number of birds observed	July-August Number of surveys	July-August Number of birds observed (High, Low)
2013-2014	Not reported	137	N/A	N/A
2014-2015	Not reported	Not reported	N/A	N/A
2015-2016	130	20	6	(188, 155)
2016-2017	91	49	5	(182, 125)
2017-2018	66	62	22	(211, 7)

Source: NPS 2017a; NPS 2017b; NPS 2017c; 2018c; 2019c

Potential Threats

Habitat destruction is the primary threat to piping plovers, and current habitats across the US may not be sufficient to support the existing population (Robinson et al. 2019). Several forces, both natural and anthropogenic, influence the availability of high-quality habitat for the species. Degradation and contamination occur from development, and erosion and flooding due to relative sea-level rise can exacerbate these effects. Natural oceanic currents transport sediments along coastlines, and the deposition of those sediments on the beach limits overgrowth vegetation. Piping plovers cannot see potential predators when vegetation is dense, and their risk of predation increases. Gradual accretion of sediments in nesting and foraging areas also promotes balance between dry beach for nesting and wet beach with an abundance of marine invertebrates for foraging. The addition of permanent structures such as buildings, roads, groins, sea walls, and jetties alters the transport of sediment and prevents the development and maintenance of habitats to which the piping plover is adapted (Seavey et al. 2010). These effects apply to both nesting and wintering piping plovers as well as other protected shorebirds that rely on open beach habitat for foraging, wintering, and/or nesting. Placement of sand on beaches can also affect piping plovers as sand placement often favors fine-grained sandy beaches which are less favorable for nesting than naturally formed beaches with a diversity of particle sizes (Cohen et al. 2008).

Degraded and sparsely distributed habitats intensify naturally occurring threats to nesting and wintering piping plovers. Severe weather resulting in disturbance of nesting areas can often be avoided by mature birds if other appropriate nesting locations are available nearby. However, habitat scarcity can force plovers to nest in areas with lower elevations, thereby increasing the potential for nest mortality due to overwash and flooding. Both adult piping plovers and their young are susceptible to predation during nesting (Roche et al. 2010). Predation by species such as ghost crabs, raccoons, foxes, and gulls, can also occur as a result of low-quality habitat, especially habitats exposed to acoustic disturbance or those with limited fields of view that could limit predator detection by piping plovers. Disturbance can also result in nest abandonment by breeding birds or flushing of foraging and wintering birds. A single isolated case of infanticide has also been documented by piping plovers as a result of territorial behavior toward chicks and fledglings, but the cause of such behavior is unknown. Frequency and cause of piping plover chick and egg mortality documented at the Seashore is provided in table 14.

TABLE 14. CAUSES OF PIPING PLOVER NEST MORTALITY AT CAPE HATTERAS NATIONAL SEASHORE

Year	Eggs Lost to Overwash	Eggs Lost to Predation	Eggs Lost to Abandonment	Eggs Lost to Infanticide	Eggs Lost to Unknown Causes	Estimated Total Egg Loss
2014	8	3	4	0	21	36
2015	2	3	1	0	48	54
2016	7	13	5	0	15	40
2017	>1	>1	>1	4	>1	31
2018	0	>1	0	0	>1	8
Totals	**~18**	**~19**	**~11**	**4**	**~84**	**169**

Source: NPS 2017a, 2017b, 2017c, 2018c, 2019c

Roseate Tern

The roseate tern is a federally endangered migratory seabird. Roseate terns are generally observed at the Seashore while migrating along the Atlantic coast. Preferred habitat for resting and foraging includes sheltered estuaries, inshore waters, and creeks. Roseate terns typically feed on small, schooling marine and estuarine fish, by diving into the water from above and catching prey in their bills. There are two roseate tern nesting populations, one located in the Caribbean and one located along the Atlantic coast in the northeast US (FWS 1993). It nests in widely but sparsely distributed colonies, usually among colonies of common terns.

While global populations have reportedly stabilized since sharp declines in the 19th century (American Bird Conservancy 2017), the roseate tern is exceedingly rare in North Carolina and, most likely, would only be observed at the Seashore as it passes through the area during migration from May to September. Due to the rarity of this species in the area, population trends at the Seashore have not been documented (CZR

Incorporated and CSE 2015a; NPS 2018a, 2018c, 2019c). Offshore sightings over the continental shelf and Gulf Stream occur occasionally, and expert birdwatchers from North Carolina consider roseate terns a rarity in the state, estimating that there is less than 10% chance of seeing the bird during optimal times of year in prime offshore habitats (LeGrand 2020b). Due to lack of information about the species, effective planning to minimize impacts specifically to roseate terns may not be possible at the Seashore.

Potential Threats

Potential threats to the species include habitat loss due to human development of barrier islands, nest or colony abandonment due to human disturbance, and prey competition from gulls (FWS 2011).

Rufa Red Knot

The rufa red knot (hereafter "red knot") is listed as a federally threatened species under the ESA. This species migrates annually from the Canadian arctic to wintering grounds between the southeast US and southern Argentina. It is observed at the Seashore while migrating and foraging. Because of the expansiveness of its range, the red knot is incredibly difficult to track, and population trends for the red knot at the Seashore are unknown. Surveys from Virginia's barrier islands showed no trend over time in the species' population (FWS 2013a). However, along the Delaware Bay, red knot populations have declined by 75% since the 1980s (FWS 2013a). The number of red knots along the Seashore varies from year to year based on available food resources, and this species does not nest in North Carolina (Island Free Press 2014). At the Seashore, the largest populations of red knots are observed around the end of April and into May during their migration to breeding grounds in the north. During peak migration in 2017, greater than 600 individuals were observed at Cape Lookout (NPS 2018e). For the remaining months in 2017, between zero and 200 individuals were observed on each sampling date within the same study area (NPS 2018e). There is not a consistent population of red knots at the Seashore, although some birds spend the summer in North Carolina before migrating farther north and some overwinter in North Carolina rather than continuing to fly south (Island Free Press 2014).

Habitat and Behavior

Like many shorebirds, red knots use open shorelines for foraging. FWS has not established critical habitat for the red knot, but preferred habitats include mudflats for foraging, and high beaches and sand flats for roosting. Prey species include small mollusks, crustaceans, marine worms, and horseshoe crab eggs, all of which must be in high abundance to maintain energy during the long migration (Baker et al. 2013). Red knots forage on a tidal basis, rarely wading into flooded areas to feed (Schneider and Harrington 1981), and they are limited in their ability to dig for buried prey. Therefore, prey and other forage items must be exposed or shallowly buried in the substrate.

Potential Threats

Overharvesting of horseshoe crabs and other marine invertebrates and development in coastal areas are all affecting the forage availability for the red knot, and climate change is changing the timing of red knot migration (FWS 2014). Upon arrival in foraging areas, birds are often emaciated, leading to small deviations from expected foraging areas which can expend extra energy and be detrimental to an individual's survival. Because of this, human disturbance and disruption of foraging habitats can be particularly harmful to the red knot. Threats to red knot are similar to threats to piping plover as they relate to habitat and prey availability, but red knots have an immediate urgency for resources as birds forage during migration (FWS 2013a, 2019a).

American Oystercatcher

American oystercatchers are not listed under the ESA, but they are federally protected under the MBTA. In North Carolina, the oystercatcher is listed as a special concern species. As the name indicates, this species feeds almost entirely on shellfish, including oysters, limpets, clams, mussels, crabs, sea stars, and sea urchins, along with polychaetes, occurring in the wet beach, mud flat, and tidal marsh habitats (Cornell 2017c). Oystercatchers are strictly coastal and inhabit large, open sandy areas, sand dunes, and tidal marshes. During summer months, the oystercatcher can be seen along the Atlantic Coast from New England to the Gulf Coast, Mexico, Central America, parts of South America, and the Caribbean. It is typically considered non-migratory, but most oystercatchers from New England to Maryland head south for the winter around late September. American oystercatchers occur at the Seashore year-round (Cornell 2017c).

Habitat use and foraging requirements for non-breeding and breeding oystercatchers is similar at the Seashore, as roosting typically occurs in former nesting areas and foraging habits do not change throughout the year. Hard-substrate areas such as docks and shell rakes are notable additions to suitable wintering habitat that are not used for nesting. Unlike piping plovers, American oystercatchers are not monitored by the NPS outside of the breeding season, but they are reportedly uncommon to rare at the Seashore during the winter months (LeGrand 2020c).

Nesting

Oystercatchers nest in shallow scrapes on beaches, open sandy flats, and sandy areas in tidal marshes, typically in colonies with terns, plovers, and other shorebird species (LeGrand 2020c). They may also use gravel rooftops in developed areas where natural nesting habitat is limited (Cameron 2008). American oystercatchers are commonly seen in Dare County throughout the year. Nesting numbers for American oystercatchers at the Seashore from 2014 to 2018 are provided in table 12. American oystercatcher nests remained consistently between 38 and 53 nests and averaged 43 nests per year. However, the number of fledged chicks varied between a low of 2 in 2017 and a high of 20 in 2018 (NPS 2018g, 2017g, 2017c, 2018c, 2019c). The resultant fledge rate for American oystercatchers ranged from 0.08 fledglings per breeding pair in 2017 to 0.8 fledglings per breeding pair in 2018, with an average of 0.44 fledglings per breeding pair for the period from 2014 to 2018 (NPS 2019c).

Potential Threats

Causes and numbers of egg and nest mortality are provided in table 15. Predation is the primary cause of nest mortality identified at the Seashore. Predators at the Seashore include coyotes, foxes, feral cats, minks, various bird species, possums, raccoons, and ghost crabs. Populations of predator species may be increasing on beaches frequented by people as humans provide corridors for movement between barrier islands and introduce anthropogenic food sources such as garbage to beach areas. Habitat destruction due to land development poses an additional threat leading to a decline in the oystercatcher population (Cornell University 2017c).

As with other shorebirds, severe weather and extreme tidal events account for some of the variation in nesting success of American oystercatchers. From 2014 to 2019, seven named storm events impacted the Seashore. Of those events, only Hurricane Arthur (2014) definitively caused adverse effects to American oystercatchers. The dynamic and unpredictable nature of storm events often has variable repercussions for shorebirds. For example, Arthur destroyed a single oystercatcher nest (NPS 2017d), but other hurricanes, such as Hurricane Isabel (2003), increased the available nesting habitat for shorebirds, leading to greater nest success in subsequent years (Schulte and Simons 2016).

TABLE 15. CAUSES OF AMERICAN OYSTERCATCHER NEST MORTALITY AT CAPE HATTERAS NATIONAL SEASHORE

Year	Eggs Lost to Overwash	Eggs Lost to Predation	Eggs Lost to Abandonment	Eggs Lost to Unknown Causes	Estimated Total Egg Loss
2014	2	15	3	0	20
2015	3	8	4	9	24
2016	4	13	2	9	28
2017	11	15	4	14	44
2018	0	10	2	10	22
Totals	**20**	**61**	**15**	**42**	**138**

Source: NPS 2017c, 2018g, 2017g, 2018c, 2019c

Wilson's Plover

Wilson's plover is not listed under the ESA, but it is federally protected under the MBTA. It is listed as a special concern species in North Carolina. Wilson's plovers inhabit sparsely vegetated coastal areas, including beaches, sand bars, barrier and dredge spoil islands, lagoons, tidal mudflats, and river mouths where fiddler crabs, their main food source, occur. North Carolina is near the northern extent of the range of Wilson's plover.

Wilson's plovers build nests in areas with open to dense vegetation but prefer to nest on sparsely vegetated sites. They nest in groups, often with terns and other shorebirds (LeGrand 2020a). Wilson's plover nesting and fledging numbers for the years of 2014 to 2018 are provided in table 12. Wilson's plover nesting activity at the Seashore has remained low, with zero to three nests recorded each year and no fledged chicks in any year from 2014 to 2018 (NPS 2017h, 2017i, 2017c, 2018c, 2019c).

Potential Threats

Nesting habitat for Wilson's plover is similar to that of piping plover and other shorebird species. Similar impacts occur from habitat destruction, severe weather, predation, anthropogenic disturbance, and reduction in forage availability (NPS 2017a).

Colonial Shorebirds

State-protected colonial shorebird species at the Seashore include gull-billed terns, least terns, common terns, and black skimmers. These species nest in large colonies and obtain their food primarily from the water. Due to similarities in behavior and habitat use, NPS staff monitor these species simultaneously to determine abundance and location of nesting pairs at the Seashore. Threats to these shorebirds are the same for all four species and are discussed below.

NPS staff establish pre-nesting closures at the Seashore (excluding Pea Island NWR) in April for locations where nesting had occurred within the last five years and in suitable habitat recently created by storms or tidal overwash. At the Seashore, active colonies are identified during regular walkthroughs and protected with barriers during the breeding season. Shorebird colonies are defined as areas with two or more nests within 200 meters. Colony buffers differ by species based on breeding behavior. Least terns receive a 100-meter buffer for breeding behavior, nests, and unfledged chicks. A 180-meter buffer is applied to breeding behavior, nests, and unfledged chicks for all other colonial shorebirds. These buffers are applied to the outermost resource (e.g., nest, fledgling, and scrape). Once buffers are established, NPS staff conduct abundance surveys at least twice daily. Additionally, at least two walkthrough surveys were conducted during peak nesting (June) to more accurately collect data on the colony. FWS uses different strategies to administer closures and surveys for nesting colonial shorebirds on the Pea Island NWR portion of the Seashore.

Nesting Habitat

Colonial shorebirds nest on open beaches, sand spits, sea wrack in marshes, and shell or gravel bars on relatively undisturbed islands (Cornell University 2017a). They dig shallow depressions that are occasionally lined with beach materials such as shells and pebbles. Under ideal circumstances, shorebird nesting locations exclude terrestrial predators and allow colonial shorebirds to nest in the open without risking nest predation (Florida Audubon Society 2016). By nesting in large colonies in these habitats, shorebirds are capable of detecting and defending against predators, such as gulls, crows, and small mammals (Cornell University 2017b).

The NPS determines critical nesting habitat based on the areas where colonial shorebirds have nested during the previous five years (NPS 2017d, 2017e, 2017c, 2018c, 2019c). Disturbance of colonial shorebird habitat can result in lower chance of recolonization in the future, and birds react similarly to disturbances in areas surrounding the colony. For this reason, NPS staff establish buffers around shorebird colonies to avoid disruption of nesting activities. Another factor that influences nesting habitat quality is the proximity of the colony to food sources and disturbance within surrounding areas. Foraging is a constant need for nesting shorebirds, and they cannot use habitats if they will require high energy expenditures to reach foraging grounds.

Colonial Shorebird Species

Black Skimmer

The black skimmer is not federally threatened or endangered, but it is federally protected under the MBTA. In North Carolina, the black skimmer is listed as a special concern species. They occur at the Seashore primarily during nesting season when they breed and raise young (Cornell University 2017b). To feed, skimmers use the lower mandible of their bills to skim the surface of the water for small fish and invertebrates.

The NPS includes skimmers in the shorebird monitoring program. The number of black skimmer nests and chicks fledged within the Seashore from 2014 through 2018 is provided in table 12. Black skimmer nesting activity within the Seashore increased from 95 nests and 59 fledged chicks in 2014 to 368 nests and 116 fledged chicks in 2018 (NPS 2017d, 2017e, 2017c, 2018c, 2019c). Black skimmers share many of the same threats as other shorebirds including habitat loss and nest predation (NPS 2017e). Skimmers are also a disturbance sensitive species, and anthropogenic noise can lead to nest abandonment (Burger et al. 2010).

Common Tern

The common tern is not federally listed under the ESA, but it is federally protected under the MBTA. It is also listed as a special concern species in North Carolina due to continued disturbance of nesting sites along the coast. Common terns are the most widespread tern species of North America. However, breeding populations along the coast have severely decreased within the last 40 years (LeGrand 2020d). Common terns typically forage by hovering over the water and diving for prey species below the surface.

Breeding areas for common terns include beaches along the Atlantic coast from Canada to North Carolina, including the Seashore. At the Seashore, these terns typically occur from April through October, and the Seashore is a traditional nesting site. Common tern nesting is included in the shorebird monitoring program conducted by NPS. Common tern nests and chicks fledged within the Seashore from 2014 through 2018 is provided in table 12. Numbers of common tern nests have increased from 38 and 16 in 2014 and 2015, respectively, to between 72 and 91 in 2016, 2017, and 2018. Common tern fledged chick numbers have generally followed the same trend, increasing from 2 in 2014 to 12 in 2018. In 2016, NPS staff documented a total of 42 fledged chicks, but this appears to be an outlier year (NPS 2017d, 2017e, 2017c, 2018c, 2019c).

Gull-billed Tern

The gull-billed tern is not federally threatened or endangered, but it is listed as threatened in North Carolina. It is also federally protected under the MBTA. Gull-billed terns breed during the summer months along the Gulf coast from Mexico to Florida and from Florida to New Jersey along the Atlantic Coast, including the Seashore. Nesting habitat requirements are non-specific, and they nest on materials ranging from deposited wrack material to open sand to silty-clay soils (Molina et al. 2010). These habitats can occur on open sandy beaches, dredge-spoil islands, overwash fans, shell ridges, and marsh islands. At the Seashore, nesting gull-billed terns occurred only on the south point of Ocracoke Island during the 2014 to 2018 nesting seasons.

Gull-billed terns have a broad diet that is not dependent on fish. Unlike most terns, it feeds on insects, small crabs, and other small invertebrates, found in the wet beach environment, on mudflats, in tidal marshes, or in upland areas (Cornell University 2017a). These feeding habits may make it less susceptible to beach nourishment as long as both benthic and terrestrial macroinvertebrates are not affected simultaneously by the placement of sediment.

Gull-billed terns are common at the Seashore from mid-May through July when they breed, build nests, and fledge their young. By November, the terns have departed from the North Carolina coast, and they begin to return each year in March. The numbers of gull-billed tern nests and chicks fledged within the Seashore from 2014 through 2018 is provided in table 12, and they have, in general, increased from 2014 (1 nest and 0 fledged chicks) to 2018 (50 nests and 10 fledged chicks) (NPS 2017d, 2017e, 2017c, 2018c, 2019c).

Least Tern

The least tern is not federally threatened or endangered, but it is federally protected under the MBTA. It is listed as special concern species in North Carolina due to continued disturbance of nesting sites along the coast. The least tern feeds primarily on small freshwater and saltwater fish in open ocean habitats where it can locate prey visually and capture it by diving into the water. Least terns also forage on small crustaceans and insects found in the wet beach or mud flat environments. They build their nests on sandy or gravelly beaches or along wide, sandy riverbanks and lake shores, and they may even use flat gravel rooftops as nesting sites in developed areas (Cowgill 1989).

At the Seashore, least terns begin to arrive in early April and are abundant from May through August. By the end of September, very few remain until the following breeding season. The numbers of least tern nests and chicks fledged within the Seashore from 2014 through 2018 is provided in table 12. Least tern nest numbers have varied dramatically, ranging from 469 (2014) to 189 (2017) to 475 (2018). The number of least tern fledged chicks has dropped significantly since 2014 when 134 individuals fledged. Fledged chick numbers decreased to 26, 30, 17, and 15 in 2015, 2016, 2017, and 2018, respectively (NPS 2017d, 2017e, 2017c, 2018c, 2019c).

Potential Threats to Colonial Shorebirds

Predation

Many species predate shorebird nests because eggs and chicks are easy prey for numerous predator species on the Seashore (Cuthbert et al. 2003). Ghost crabs, foxes, raccoons, gulls, crows, coyote, possum, feral cats, and minks have all been observed predating shorebird nests (NPS 2017c, 2017d, 2017e, 2018c, 2019c). Currently, NPS manages predators under the *Southeast Region Coastal Species of Concern Predation Management Plan* (NPS 2017c, 2017d, 2017e).

Coastal Land Development

Habitat loss due to development is a threat to common tern (Cuthbert et al.2003) and least tern (Cowgill 1989), as well as most other shorebird species. Coastal land development affects nesting and foraging species throughout their range by reducing habitat availability and habitat quality. Some shorebirds have adapted to nest in alternative areas within developed habitats. Least terns, common terns, and black skimmers will nest on flat gravel rooftops in portions of North Carolina (Cameron 2008), but habitat still needs to be close enough to the coast to allow foraging.

Climate Change/Severe Weather

Increased frequency of severe weather events is a result of climate change that may affect the nesting success of colonial shorebirds. From 2014 to 2018, seven named storm events impacted the Seashore. Of those events, only Hurricane Arthur was definitively linked to adverse effects on shorebirds, and nests located close to the water during the hurricane were prone to disruption and loss (NPS 2017d). The dynamic and unpredictable nature of storm events impacts shorebirds in various ways. Hurricane Arthur flooded and destroyed active shorebird nests, while other hurricanes, such as Hurricane Isabel in 2003, increased the available nesting habitat for shorebirds and may have led to greater nest success in subsequent years (NPS 2010a). Relative sea-level rise can change the rate of sediment transport along coastal beaches. It is unclear how relative sea-level rise impacts colonial shorebirds, but small islands and other key habitats could disappear as waters rise, especially in areas where development alters natural sediment transport and prevents migration of shorebird habitat along the coast.

Beach Sand Placement

Beach sand placement has been shown to alter some physical characteristics of beaches that are important for certain shorebird species such as the piping plover. However, given that colonial shorebirds use a variety of habitats for nesting, it is likely that the effects of beach sand placement would be diffuse so long as active nests were not buried during the process.

STRUCTURES AND INFRASTRUCTURE

The Seashore encompasses more than 67 miles of coastline spanning two counties: Dare County to the north and Hyde County to the south. The Seashore property encompasses a mix of land uses with villages, residences, commercial uses, tourist attractions, and nationally important resources existing within and adjacent to NPS managed areas (see figure 2 in appendix A). The NPS owns the beach area in front of villages within the Seashore; the Seashore boundaries include the ocean side beaches to the mean low water line and Oregon Inlet, and they extend 150 ft into Pamlico Sound from the mean low water line on the west side of the islands. Structures and infrastructure within the Seashore are essential elements of public health and safety, visitor use, resident access and experience, and socioeconomics. These topics are discussed in more detail below.

Public Health and Safety

NC 12 is a two-lane road spanning the study area for approximately 77 miles as part of the Outer Banks Scenic Byway. NC 12 is critical for the health and safety of communities up and down the Seashore because it is the primary access route for supplies, service personnel, visitors, and government business along the Seashore. This highway provides access to food, water, transportation, and shelter for local communities and visitors. NC 12 provides emergency access to hospitals in Nags Head and Manteo, as well as access for local fire and police and other first responders. Driving from the southern end of Hatteras Island to the nearest hospitals takes about 1.25 hours in normal traffic conditions, and NC 12 is the only roadway available for approximately 60 miles of that drive, making it a critical route. At the north end of Hatteras Island, along this route, NC 12 travels across Oregon Inlet over the Basnight Bridge. From Ocracoke Island, residents or visitors seeking emergency medical services would need to take the Ocracoke Ferry to Hatteras, adding approximately an hour to the trip. A 2.5-hour ferry to Cedar Island or 3-hour ferry to Swan Quarter, NC are also available; access to medical facilities requires additional travel time after the ferry lands.

Visitor Use and Resident Access and Experience

In 2019, there were 2,606,632 visitors to the Seashore, according to 2019 visitation statistics (NPS 2020a). There has been an upward trend in visitation since 2014, when 2,153,350 people visited the Seashore, followed by 2,274,635 visitors in 2015; 2,411,711 visitors in 2016; 2,433,703 visitors in 2017; and 2,591,056 visitors in 2018 (NPS 2019a). Visitors and residents access approximately 67 miles of ocean beaches between Bodie Island and Ocracoke, including long sections of Seashore beaches which front the communities on Hatteras Island. Residents rely on NC 12 to access the Seashore and their communities within it; smaller roadways off of NC 12 provide local access to residences and businesses. Occasionally, NC 12 is flooded or damaged and must be closed entirely or is impassible in certain locations. Between 2013-2020, this occurred 74 times at the Seashore, and 159 times at or near the Seashore (NCDOT, Williams, pers. comm., 2020).

The area of likely sediment management activities contains many points of visitor and resident access to Seashore attractions such as beaches, day-use areas, and the Bodie Island Lighthouse. In addition to five day-use areas which provide facilities such as restrooms, showers, and parking, there are also 23 public parking lots where visitors can park and access the beaches via access ramps (NPS 2018b). At these day-use areas, beach visitors enjoy a range of day activities, including sunbathing, beach combing, surfing, surf fishing, wildlife viewing, and photography. Some of the more popular visitor access areas are the

Haulover Day Use Parking Area and the lighthouse parking areas, including the Cape Hatteras Lighthouse and Bodie Island Lighthouse Visitor Centers. Coquina Day Use, Frisco Day Use and Ocracoke Day Use areas are also very popular all summer long. There are also four campgrounds, at Oregon Inlet, Cape Hatteras, Frisco, and Ocracoke, with 585 total sites and some hook-up access. Visitor use in the areas of likely sediment management activities also includes areas where ORV access is permitted. Permits are available for ORV use along 29 miles of designated routes in the Seashore, illustrated on figure 24 in appendix A. Visitor activities in the Pamlico Sound portion of the study area include family activities such as crabbing, as well as more active pursuits such as canoeing/kayaking and kiteboarding. Access points for these activities include Pea Island Launch, Salvo Day Use Area, Haulover Day Use Area, and access at the end of NC 12 in Ocracoke Village.

Socioeconomics

Dare County, the more populous of the two counties that encompass the Seashore, is a leading tourism destination on North Carolina's coast, and tourism is Dare County's main industry (NC State University 2016). Hatteras Island is a large contributor to the county's revenues. According to North Carolina Department of Commerce tourism data, visitor spending in Dare County amounted to $1.19 billion in 2018, resulting in $56.34 million and $53.60 million in state and local tax revenues, respectively (Visit North Carolina 2019). The communities and businesses on Hatteras Island account for roughly 20% of the Dare County total revenues.

The total population of Dare County was 35,412 in 2017, a 4.4% increase over the 2010 population of 33,920. The tax base in Dare County also grew by 1.36% in 2019. Projected revenue from property taxes for 2020 is $63.52 million (County of Dare North Carolina 2019). Dare County collects a 6% Occupancy Tax on gross receipts derived from room rentals, lodging, and campsite rentals. It also collects a 1% tax on food and beverages served. Revenue from the Occupancy and Food and Beverage Tax is used toward emergency services; tourist-related services including tourism promotion and refuse and solid waste disposal; and beach nourishment. These tax revenues can be impacted by extreme weather events and other emergencies in the area. Communities in Dare County include Rodanthe, Waves, Salvo, Avon, Buxton, Frisco, and Hatteras. In 2017, the total population of these communities was approximately 3,780. There are approximately 5,399 housing units within these communities, with median home values ranging from $263,300 in Avon to $393,800 in Hatteras.

Hyde County, located to the south of Dare County, encompasses the portion of the Seashore from Hatteras Inlet to Ocracoke Inlet. Though less populated than Dare County (with a total population of 5,507 in 2017), Hyde County also relies heavily on economic activity generated through tourism, including home rentals, hotel visitation, food and beverage services, and recreational activities such as ORV use, surfing, fishing, surf fishing, and boating. There were $39.26 million in visitor expenditures in Hyde County in 2018, resulting in $1.84 and $2.16 million in state and local tax revenues, respectively. In 2017, Ocracoke had a permanent population of 404, and 886 housing units, many of which are only occupied seasonally (Visit North Carolina 2019).

Hyde County revenues include revenues from a 5% Occupancy Tax for Ocracoke (a separate Occupancy Tax is applied to the mainland area of the county). Ocracoke Occupancy Tax revenue is estimated at $550,000 for the 2020 fiscal year, or 3.3% of total revenues for the county. This tax is derived from hotel, room, lodging, and campsite rentals. Unlike Dare County, property tax revenues have decreased in Hyde County in recent years, putting a strain on current service provision.

Ocracoke Island has a water plant located at 159 Water Plant Road. The Ocracoke Island Airport is a public airport within the Seashore located on the eastern side of Ocracoke Island and owned by the NPS and operated by NCDOT. Ocracoke can also be reached by ferry.

An NPS study on visitor spending effects reported that the nearly 2.6 million visitors to the Seashore in 2019 spent more than $168 million in communities in and around the Seashore. This spending supported approximately 2,422 jobs in the local area and had a cumulative benefit to the local economy of approximately $211 million (NPS 2020a). Total visitor spending in Dare and Hyde counties combined supported close to 14,000 jobs, which represent an estimated payroll of $271 million, contributing to total state and local taxes generated (Visit North Carolina 2019).

Smaller roadways off of NC 12 provide local access to residences and businesses. NCDOT's current State Transportation Improvement Program (STIP), last updated in September 2019, outlines the agency's ten-year capital improvement plan from 2020 to 2029. According to the STIP, major infrastructure improvements along NC 12 would include demolition of the Herbert C. Bonner Bridge over Oregon Inlet, which was replaced by the Basnight Bridge, and other NC 12 improvements in Dare County, as well as certain wayfinding and dock improvements to support ferry service from Hatteras ferry dock to Ocracoke ferry dock (NCDOT 2019d). Costs associated with NC 12 and other roadway repairs and improvements are also incurred after major storm events and emergencies, including most recently following Hurricane Dorian in 2019.

CHAPTER 4: ENVIRONMENTAL CONSEQUENCES

INTRODUCTION

This chapter analyzes the beneficial and adverse impacts that would likely result from implementing any of the alternatives considered in this DEIS. The resource topics presented in this chapter correspond to the descriptions of existing conditions in chapter 3. As required by the CEQ regulations implementing NEPA, this chapter provides a comparison of the environmental consequences for each alternative.

GENERAL ANALYSIS APPROACH

The following analysis evaluates direct, indirect, and cumulative impacts on the natural and human environment (i.e., physical, natural, cultural, and socioeconomic resources) from the implementation of the alternatives. A factual description of the direct and indirect impacts provides the reader with an understanding of how the current condition of a resource (as described in chapter 3) would likely change as a result of implementing the alternatives. The approach includes the following elements:

- Focusing the analysis to the greatest extent possible on management changes and associated issues that could have measurable impacts on the resources or values being evaluated.
- Using general analysis methods and assumptions that follow CEQ and US DOI regulations, policy, and guidance on NEPA implementation.

The potential for significant impacts from management activities are assessed and described in each issue topic as applicable. The impacts analysis reflects the highest potential possible impact, which is unlikely to occur due to permitting and budgeting constraints. As noted in chapter 2, emergency work by NCDOT may be permitted while this EIS is under development. The following guiding assumptions were used for this analysis:

Analysis Period. The framework considers actions over a 20-year timeframe, as a reasonable planning horizon.

Analysis Area. The analysis generally applies to the entire Seashore, as well as some areas outside of the Seashore, as specific project locations are not known at this time. While the NPS and its cooperators have identified areas of likely sediment management (as shown on figures 3 and 4 in appendix A), projects may occur outside of these areas if conditions warrant, under emergency circumstances, or a special use permit is requested. Generally, the analysis focuses on the following areas:

- The ocean side beach consisting of the sand dunes at the inland side of the beach, the dry beach environment located above mean high water, the wet beach environment located between mean high water and mean low water, and nearshore subtidal habitats.
- The sound side habitat area including shallow estuarine waters, tidal marshes, mud flats, sand bars and sandy bottom areas, submerged aquatic vegetation (SAV), and some sand beaches.
- The habitats adjacent to inlet channels including sandy beaches, sand bars, and channels. The channels were initially created naturally, and regular dredging attempts to maintain their current depths.
- The offshore bottom habitats consisting of sandy shoals offshore of the Seashore on the ocean side from which sand would be dredged for use in sediment management activities. These areas could be located within state or federal waters and may be up to 60 ft in depth. Specific areas used for dredging would be subject to project-specific planning and permitting by USACE and/or BOEM.

This analysis may be applied along the length of the Atlantic shoreline of the Seashore and adjacent submerged habitat unless otherwise specified. Areas of likely sediment management along the Pamlico Sound are shown on the map (figures 3 and 4 in appendix A) and the impact analysis could only be applied elsewhere along the sound side after review by the NPS to ensure conditions are similar to those described in chapter 3. Examples of areas where habitat restoration may occur include the south end of Hatteras Island and Green Island in Oregon Inlet, as these are areas where erosion has caused considerable loss of wildlife foraging and nesting habitats.

Offshore, appropriate areas for dredging were considered widely based upon BOEM's MMIS (https://mmis.doi.gov/BOEMMMIS/), as well as the USACE South Atlantic Coastal Study Sand Availability and Needs Determination (USACE 2020a, 2020b). Each of these initiatives maintains a record of recognized sand resources off the coast between Oregon and Ocracoke Inlets. Specific areas to be used for dredging would be subject to project-specific selection as described for alternative B, and analysis of offshore impacts would be reserved until sites are identified for individual projects. Potential borrow areas as noted in the USACE South Atlantic Coastal Study Sand Availability and Needs Determination are shown on figures 11-13 in appendix A.

CUMULATIVE IMPACTS

Cumulative impacts are defined as "the impact on the environment which results from the incremental impact of the action when added to other past, present, or reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions" (§ 40 CFR 1508.7).

Cumulative impacts are determined for each impact topic by combining the impacts of the alternative being analyzed and other past, present, and reasonably foreseeable actions that also would result in beneficial or adverse impacts. Cumulative impacts are considered for all alternatives, including alternative A. Following CEQ guidance, past actions were included, "to the extent that they are relevant and useful in analyzing whether the reasonably foreseeable effects of the agency proposal for the actions and its alternatives may have a continuing, additive, and significant relationship to those effects" (CEQ 2005).

Cumulative Scenario

Past projects or plans with ongoing effects and reasonably foreseeable future projects and plans were identified by an interdisciplinary team to provide the cumulative impacts scenario. Similar to the analysis of impacts of the alternatives, the cumulative impacts analysis focuses on cumulative actions within the analysis area, but also includes actions within the surrounding region as they apply to specific impact topics.

Past Beach Nourishment Activities. During the past decade, four large-scale beach nourishment projects have been conducted at or near the Seashore:

- Nags Head in 2011 and 2019 (placing approximately 4.6 million cy of sand in 2011 and 4 million cy in 2019, over 10 miles of shoreline) (The Outer Banks Voice 2019);
- Rodanthe-Pea Island NWR in 2014 (approximately 2 miles of shoreline); and
- Buxton from summer 2017 to spring 2018 (approximately 3 miles of shoreline)

In total, these nourishment activities amount to approximately 15 miles of shoreline (CSE 2015; The Outer Banks Voice 2019). The borrow areas for these projects have varied. Following storm events, emergency repair and nourishment activities occur on an as needed basis.

Channel Dredging and Dredge Disposal. During the past decade, several dredge disposal projects at Oregon Inlet have been conducted, impacting areas adjacent to navigational channels within the inlet as well as approximately 2 miles of the Pea Island NWR portion of the Seashore south of Oregon Inlet. In December 2019, USACE issued a Standard Permit (with special conditions) to Dare County for year-round dredging of Oregon Inlet and its associated inlets (USACE 2020c). In June 2020, NPS signed the *Finding of No Significant Impact: Dredging of Oregon Inlet with Dare County Dredge* decision document to issue the county a SUP for this action (NPS 2020c). Dare County commissioners approved a dredge contract in the spring of 2019, which involves a private partner designing, constructing, and operating a dredge to clear and maintain Oregon and Hatteras Inlets for 340 days/year over the next 10 years in the same manner and location as USACE currently maintains the channel (Coastal Review Online 2019a).

The channel dredging and dredge disposal activities that have occurred on the Pea Island NWR portion of the Seashore took place with the use of an ocean-going pipeline dredge. Dredged material was pumped onto the refuge beach via a pipeline in a “node/internode” fashion creating a scalloped pattern of dredged material placement with areas of dredged material (node) adjacent to areas without dredged material (internode). This dredge disposal method resulted in the internode areas being free of dredge disposal material, which allowed these areas to serve as a source of benthic invertebrate life available to quickly recolonize the adjacent node areas where the dredge disposal material had been placed.

In August 2019, a project was completed to dredge an emergency ferry channel between Rodanthe and Stumpy Point, to provide an emergency evacuation route during severe weather (Coastal Review Online 2019b). Dredging this channel provides deeper waters for ferries to operate, in case of NC 12 road closures (Coastal Review Online 2019b).

In 2018, Rollinson Channel was maintained by pipeline dredge, with material placed on Cora June Island. This is a straight narrow channel pointing northwest from Hatteras village to a few miles into Pamlico Sound. Dredging projects are anticipated for the Sloop Channel (which runs along the western side of Hatteras Inlet) and the South Dock Ferry Basin (USACE, Hughes, personal communication, 2020d). The Sloop Channel is maintained by the NCDOT Ferry Division; currently, a permit request is on hold due to funding needs for archeological studies (USACE, Hughes, personal communication, 2020d).

Roadway Improvements. Roadway improvement projects include the Bonner Bridge replacement project (now “Basnight Bridge”), Phase 1 of which was completed in February 2019 by the NCDOT. This bridge crosses Oregon Inlet, connecting Bodie Island and Hatteras Island. It provides important access for residents and tourists alike, not only to the Seashore, but to emergency services and other important amenities on the North Carolina mainland (HDR, Inc. 2019). Furthermore, the bridge serves as a critical evacuation route during severe weather (HDR, Inc. 2019). Most of the former Bonner Bridge has been dismantled and moved offshore to create artificial reefs for marine life (HDR, Inc. 2019). The second phase of this project includes constructing the NC 12 Rodanthe Bridge from the southern end of the Pea Island NWR portion of the Seashore over Pamlico Sound into Rodanthe (NCDOT 2019c). The purpose of this project is to provide a long-term solution to frequent breaches caused by storms, which deteriorate NC 12 along nearby “S-curves” (NCDOT 2019c). This elevated 2.4-mile bridge design would help protect the ocean shoreline and Rodanthe community while maintaining access for residents and visitors (NCDOT 2018). This bridge project will also allow natural processes, such as ocean over wash and subsequent sedimentation, to occur along with the formation of suitable bird nesting habitat. The project is expected to be completed in late 2020/early 2021 and, once completed, portions of NC 12 are anticipated to be maintained, while the road at the Pea Island NWR portion of the Seashore would be removed and the land returned to the refuge (NCDOT 2018). The section of NC 12 that is in between Pea Island and Rodanthe will also be removed from within Seashore boundaries and the land returned to NPS.

Use of Sand Bags on Private Property. Placement of sand bags on lands under jurisdiction of the Seashore requires NPS approval and is included in alternatives B and C, as described in chapter 2. However, small-scale use of sand bags on private property may take place without Seashore approval, and is therefore included in the cumulative scenario.

Predation Management for Coastal Species of Concern. In February 2019, NPS approved a *Coastal Species of Concern Predation Management Plan* for coastal park units in the NPS South Atlantic Gulf Region, including the Seashore (NPS 2019b). Under this plan, predators that have been observed depredating or have the potential to depredate coastal species of concern may be targeted for removal. After identifying target predators, park staff will use the most effective and humane tools and methods available to deter or remove predators. The plan allows for both lethal and nonlethal methods of control (NPS 2019b).

Off-Road Vehicle Management. In 2012, the NPS published a final rule for managing ORV use and access at the Seashore (note that ORV use is prohibited within the Pea Island NWR portion of the Seashore) and in 2015, prepared an environmental assessment and Finding of No Significant Impact to modify wildlife buffers under the context of this plan. The National Defense Authorization Act is a special regulation that governs ORV use at the Seashore. This act required the consideration of three modifications: (1) morning opening of beaches that are closed to ORV use at night, (2) extending the seasonal ORV routes for additional periods in the spring and fall, and (3) the size and location of vehicle-free areas. Under this rule, ORV routes were officially designated, including year-round routes, seasonal routes, and night-restricted routes. Seasonal and night-restricted routes are closed to ORVs during periods of high pedestrian use and/or during breeding/nesting season of sensitive bird and turtle species. ORV permittees are required to pay a fee and are provided with educational materials about sensitive bird and turtle nesting activities. Year-round vehicle-free areas were also designated (NPS 2010a and 2016b).

LITTORAL PROCESSES AND BARRIER ISLAND MORPHOLOGY

Methodology for Analyzing Impacts

The analysis of potential impacts on littoral processes and barrier island morphology as a result of proposed sediment management activities is focused on potential direct, indirect, and cumulative impacts of manipulating large quantities (i.e., millions of cubic yards) of sediment in order to mitigate impacts from erosion as well as relative sea-level rise. Impacts are not characterized as beneficial or adverse because there is a debate among scientists as to which is preferable for the Seashore, its resources, infrastructure, and communities. Whether sediment management activities are beneficial or adverse for littoral processes and barrier island morphology depends on whether there is a preference for a system more influenced by barrier island processes, or a system engineered to provide temporary shoreline stabilization while other alternatives are evaluated. This analysis is based on a review of existing data for the Outer Banks and shorelines in similar morphological settings, previous project experience along the Outer Banks, and relevant scientific literature. Qualitative descriptions of phenomena and potential impacts are based on professional judgment, while quantitative parameters are offered when available. Prior to any individual sediment management project, site-specific design may be subject to project-specific permitting by the USACE.

Impact Analysis

Alternative A (No-Action Alternative)

Under alternative A, NPS would not permit beach nourishment or other sediment management activities by other entities and would not conduct its own sediment management actions within Seashore boundaries. However, other entities might still engage in beach nourishment and other sediment management actions outside Seashore boundaries, as acknowledged under the “Cumulative Impacts” section below. Because of the interconnected nature of barrier island chains like those within the Seashore, these activities would almost certainly have some effect on the littoral processes and barrier island morphology of the Seashore itself. Because the scope and location of such activities is unknown, the analysis of alternative A instead focuses on the incremental effects of erosion, overwashes and breaches generally, as well as relative sea-level rise.

Relative sea-level rise rates along the Seashore are approximately 0.2 in per year, as measured at the Oregon Inlet observation station (NOAA 2020b). Rising sea levels increase the potential for inundation along the sound side shorelines and enhance the potential for dune erosion and overwash during storm events (Sallenger 2000).

Erosion rates are expected to continue as observed over the past century or so. Losses up to or exceeding 10 ft per year would be anticipated along portions of the ocean-facing Seashore (CSE 2015), resulting in the loss of millions of cubic yards of beach sand over the course of the framework (approximately 67 miles of beach, losing approximately 5 to 10 ft per year over 20 years is equivalent to 35 to 70 million cy). Although this is below the total amount of sediment possibly placed under alternative B, it is common for erosion mitigation projects (and particularly beach nourishment) to include an “overfill” volume to account for any unexpected changes in conditions over the lifetime of the project. Under alternative A, this could cause continued narrowing of the island, particularly in areas already facing ocean side shoreline recession like Rodanthe, Avon, Ocracoke, and Buxton. Narrowing of the beach itself would lead to more frequent wave attack on the foredune and more frequent island breaches.

The Outer Banks are also susceptible to sound side erosion, so a lack of sediment management along the that shoreline would also likely result in continued erosion and potential breaching. Historical studies of shoreline change along Hatteras Island have shown while the beach along the ocean side has receded hundreds of feet over the past approximately 200 years, the sound side shoreline has remained in roughly the same position generally shifted at a far slower rate (Riggs et al. 2009; Mallinson et al. 2008; Riggs et al. 1995). This distinction is because ocean facing beaches are subject to high-energy waves and wind and can be ‘reworked’ into a more landward position with a decrease in sediment supply or increase in sea levels. Sound side shorelines, however, do not have the same capacity to regenerate as rapidly because of the lower rates of sediment transport.

Under alternative A, breach fills would not occur. There have been several notable breaches on the Outer Banks in the past two decades including Hurricane Isabel (2003), Hurricane Dorian (2019), and a number of powerful nor'easter storms. There have been approximately 30 inlets opened and closed along the Outer Banks in the last approximately 400 years (NPS 2015c). Whether or not these breaches close naturally and how long that may take depends upon the tidal prism moving through the connection with the ocean. Under alternative A, these breaches may remain vulnerable to repeat breaching for years (Houser and Hamilton 2009; Mallinson et al. 2005).

Simple barrier islands such as those along most of the Outer Banks, are dependent upon storm overwash to build island elevation and width, a critical process for the health and evolution of the islands (Smith et al. 2008). Relative minor surge produces small-scale overwash fans on the ocean side and middle portions of the barrier island (Riggs et al. 2009). Large storm events with feet of water overtopping the island dunes result in large, arc-shaped overwash deposits that bury the back-barrier marshes and can occasionally build shallow shoals extending into the sound. As mentioned above, storm surge and waves can also create inlets through the barrier island that allow the interchange of brackish water and ocean water. These inlets construct extensive flood-tide deltas on the sound side of the barrier islands and ebb-tide deltas on the ocean side. The flood-tide delta shoals are essential for building back-barrier island width. With time, under alternative A, the overwash process may deposit sediment that assists in closing the inlet, builds elevation and becomes vegetated. Also, with time, the flood-tide inlet shoals may become vegetated, developing a back-barrier platform marsh (Riggs et al. 2009). Overwash fan deposits from recent storm surges can be observed along the elevated portion of NC 12 between Rodanthe and the Pea Island NWR portion of the Seashore.

Any eroding shoreline draws sediment off adjacent shorelines (Dean 2002; Kamphuis 2010; Davidson-Arnott 2010). As a result, portions of the Seashore experiencing shoreline recession in excess of 10 ft per year would likely spread over time without the addition of nourishment sand into the beach system. Increases in the rate of relative sea-level rise projected through the 21st century may cause more frequent overwash, increasing the possibility of rapid erosion (Leatherman et al. 2000; Cooper et al. 2019; NOAA 2019b; Cooper et al. 2016). This would likely trigger a likewise decrease in the land area of some portions of the Seashore (NPS 2015c; Moore et al. 2010; Gutierrez et al. 2009; Culver et al. 2008; Mallinson et al. 2008; Moore et al. 2007).

Cumulative Impacts

Portions of the Seashore have been modified repeatedly by sand scraping, dune construction, breach closures, shoreline stabilization via hardened structures, and emergency armoring via sand bags (Riggs et al. 2009; Riggs et al. 2011; NPS 2015c). Past large-scale beach nourishment projects at the Seashore have added millions of cubic yards of sediment to the barrier islands. Nourishment projects along the Seashore since 2010 have occurred at Rodanthe (2014, 1.6 million cy) and Buxton (2017, 2.6 million cy). Elsewhere along the Outer Banks near the Seashore, Nags Head has sponsored nourishment twice since 2010 (2011, 4.6 million cy; 2019, 4.0 million cy). Combined, these projects have collectively added up to 12.8 million cy of beachfront area in and around their project areas. This additional area offsets erosion losses of a similar magnitude, over the same period.

Many of these actions, including emergency measures following storm events, could impact natural littoral processes because they often produce abrupt changes to existing morphology (scraping and bulldozing) or introduce surfaces that reflect wave energy that were not otherwise present (sand bag revetments). For instance, property owners near the Seashore may continue to use sand bags around threatened structures. The ad hoc nature of these emergency actions, combined with increased pressures from rising sea levels, would likely result in more adverse short- and long-term impacts to the Seashore.

In addition to the long history of sediment placement along the Seashore, near-regular dredging is utilized in efforts to maintain navigation channels in Oregon Inlet, and periodic dredging occurs at Hatteras Inlet. These practices generally disrupt the sediment bypass system between islands and the exchange of sediment between the flood-tide and ebb-tide delta shoals (Riggs et al. 2009). In addition, removal of ebb-tide delta and/or flood-tide delta sediment changes the geometry and dynamics of an inlet and modifies the natural sediment budget. If enough sand is removed, it will affect the amount of channel migration and related shoreline erosion on the adjacent barrier islands. Because Oregon and Hatteras Inlets are regularly dredged, they are more positionally stable than under a scenario where dredging is not used to maintain navigational channels. This would continue as part of alternative A.

Alternative A would result in little to no sediment placement along the Seashore and would allow natural processes to continue. The Seashore and its surrounding areas have an extensive history of alteration and manipulation by non-natural means (e.g., inlet dredging, dune building and stabilization, beach nourishment, hardened shoreline structures) causing impacts to natural processes. Because natural processes continue to be interrupted with ongoing effects, over the lifetime of this framework (i.e., 20 years), alternative A may lead to dune and marsh recession, possible barrier island breach(es), and emergency measures such as beach scraping (to push sand into a protective berm) and sand bag installation to protect property as well as NC 12. When the incremental impacts of alternative A are combined with the impacts of past, present, and reasonably foreseeable actions, the overall cumulative impacts on littoral processes and barrier island morphology would likely cause broad changes in the way natural processes play out, with the added impacts of alternative A contributing most of these impacts. Natural processes have been historically altered, and a discontinuation of sediment management activities may impact the sediment budget of the area, causing new erosion and accretion patterns, loss of Seashore land, and loss of potential habitat for foraging, resting, migrating, and nesting wildlife.

Conclusion

The Seashore and other Dare and Hyde County beaches are part of a continuous barrier-island system extending along the 326-mile-long North Carolina coast. Barrier islands exist through the buildup of sand by waves. Over recent geologic time scales, barrier islands would tend to migrate landward or disintegrate under rising sea levels (Swift 1975). If the rate of sediment supply exceeds the rate of sediment losses (erosion), and sea level fluctuates at low rates, barrier islands would be preserved and even build seaward in some areas (Hayes and Michel 2008). If no new sediment is gained along the barrier islands and sea levels rise, the volume of sediment on the visible portion of the barrier island would diminish.

Under alternative A, it is likely that future storm events coupled with relative sea-level rise would continue erosional littoral processes and alter the footprint of the Seashore’s barrier islands. This, in turn, would likely bring cascading effects on processes including inlet formation and stability, overwash frequency, and dune growth. Compared to the current condition, if sediment management did not occur, changes to littoral processes and barrier island morphology would be affected by relative sea-level rise rates as measured across the region.

In conclusion, littoral processes and barrier island morphology would continue to evolve naturally, from a previously modified and engineered system to a dynamic barrier island system with increased erosion, island narrowing, and increased overwash events. There is a debate among scientists as to which is preferable for the Seashore, its resources, infrastructure, and those communities within the Seashore. Whether this is beneficial or adverse for littoral processes and barrier island morphology depends on whether there is a preference for a system more influenced by barrier island processes, or a system engineered to provide temporary shoreline stabilization while other alternatives are evaluated.

Alternative B (Proposed Action / Preferred Alternative)

Under alternative B, NPS would permit sediment management activities such as oceanfront beach nourishment, as well as sound habitat restoration, dune nourishment, and emergency actions such as breach fill following storm events.

Beach Nourishment
One of the primary impacts of beach nourishment on littoral processes and barrier island morphology is the rapid (relative to natural processes) introduction of large amounts (millions of cubic yards) of sand to a beach system that, oftentimes, is experiencing chronic erosion. Under alternative B, the frequency of beach nourishment events would likely increase within the Seashore; up to 6 miles of Seashore would be nourished with up to 1.32 million cy of sediment per mile every 3 years. Additionally, NPS would retain an option to nourish 6 additional miles of Seashore every 5 years in the event of a declared emergency. In order to quantify and compare impacts from these activities, 13 miles (approximately 20%) of the Seashore would be set aside as reference zones and not considered for sediment management activities (in all cases except for emergencies); these zones would also be used for monitoring short- and long-term impacts.

There are cascading effects from this injection of sand on various processes and landforms. These impacts are proportional to the size of nourishment volume for an individual project (e.g., larger volumes generate more intense, widespread impacts [Dean 2002]). In some locations with nearshore reefs or hardbottom habitats, burial with nourishment sand can create different patterns of sediment transport and deposition than were in place pre-project (Greene 2002; Riggs et al. 1995; Van Dolah et al. 1994). Pre-project mapping of hard bottom habitats would help identify sensitive habitats so that dredge and fill operations could avoid those areas. In the event of burial due to a dredging operation, these effects generally decrease over time. Post-project monitoring of sediment quality and physical conditions may help future projects minimize such impacts.

The sudden injection of thousands to millions of cubic yards of beach sand through nourishment can also change the slope of the beach as compared to pre-project conditions (Dean 2002). Over time, the nourished beach would gradually adjust back to its pre-project slope, so long as wave conditions and sediment grain characteristics remain similar to pre-project conditions (de Schipper et al. 2012). This process is known as “equilibration” of the beach profile and can occur in as little as a few weeks or as long as multiple years. The ability of a nourished beach to equilibrate back to a state resembling pre-project conditions is dependent on the wave climate and sediment characteristics of the nourishment sand (Brutsche et al. 2015; de Schipper et al. 2012; Larson et al. 1999). Due to the variable nature of wave conditions at many coastal sites, some studies have suggested the time required for equilibration is dependent on storm energy during this period (Browder and Dean 2000; Dean and Campbell 1999). For instance, it is not uncommon to see relatively rapid adjustment of a beach profile through an active fall- and winter-storm season on the US Atlantic coast.

Upon project completion, storm waves and winds would quickly shift some nourishment sand toward the dune, as well as into deeper water. The resulting "equilibrated" profile would exhibit a narrower berm (i.e., dry beach) on the backshore, as illustrated in figure 26 in appendix A. The berm width would vary between approximately 150 ft and 350 ft according to the specific sand deficit and erosion rate at a particular segment of beach. The area of beach face is expected to remain constant but be displaced seaward after initial equilibration of the nourishment sand (see figure 26 in appendix A) (NC Coastal Resources Law, Planning and Policy Center and NCDCM 2009).

Nourishment sand must also reasonably match the characteristics of the native beach sand in order to allow for continued transport of the material into the adjacent dunes (Stauble 2005; Davidson-Arnott and Law 1990). Nourishment sand that consists of finer material than the native beach would be transported inland more easily, and coarser material would remain on the beach longer, under the same wind conditions (see Bagnold 1941 for foundational discussions on wind-blown sand transport). This may affect sediment delivery to the dunes and result in different types of dune morphologies along nourished portions of the Seashore compared to pre-project conditions (Davidson-Arnott and Law 1996; Houser and Mathew 2011; Pye 1983). If nourishment sand contains a significant portion of large shell fragments, this can result in a coarse pavement of shells on the beach (known as a 'lag deposit') rather than sand.

The increase in beach volume following nourishment results in an increased delivery of sand to the foredune system, provided wind energy is sufficient to move the grains placed on a nourished beach. In the Outer Banks, this generally happens quicker than in more sheltered locations like Georgia (at the head of the South Atlantic Bight). The ability of onshore winds to transport nourishment sand inland along the Outer Banks was on display following the 2011 Nags Head nourishment, when engineered sand dunes migrated freely into private residences and pools (CSE 2013b). The increase in dune volume can lead to vertical accretion of the foredune ridge, which can cause narrowing of the beach over time (see discussion in chapter 3 on past management efforts at dune building along the Seashore [Short and Hesp 1982]).

With increased dune accretion along nourished portions of the Seashore, natural patterns of overwash and sound side deposition of beach sands during overwash events may be altered. Overwash and overwash deposits are one of the ways barrier islands like the Outer Banks are affected by sea-level rise (Mallinson et al. 2008; Culver et al. 2008; Riggs et al. 1995), and overwash typically occurs in locations with lower dune elevations (Houser and Hamilton 2009; Sallenger 2000). So, it is likely that repeated nourishment would lead to vertical dune growth and decrease the frequency of overwash at these locations.

Overwash deposits create a platform on the sound side of a barrier island, which can help mitigate land losses due to relative sea-level rise (USGS 2007; Riggs et al. 1995. Sound side sediment placement would increase the ability of sound side shorelines to adjust to future changes in water levels by incrementally raising the back-barrier elevation similar to what nourishment does on the beach side.

Sound side sediment management activities would result in burial of any habitats already in place. At the same time, an increased sound side shoreline elevation would likely improve the barrier island's ability to withstand storm impacts by reducing the threat of sound side flooding and breaching. Because some breaches are caused by flooding from the sound side, increasing shoreline resiliency through protective efforts like sediment management and placement would also help reduce the collective impacts of island breaches over time. Sound side sediment placement would also allow for the creation of habitats similar to overwash deposits, which have traditionally assisted the Outer Banks' land loss with rising sea levels

(USGS 2007; Riggs et al. 1995). This could help mitigate some of the decreased overwash resulting from higher dune ridges due to repeat nourishment projects.

Collectively, sediment management activities along the beach and sound side shorelines would allow for the placement of tens of millions of cubic yards of compatible sediment within the Seashore. This volume represents a larger injection of new sediment than has traditionally been placed along the Seashore but would be used to offset erosional losses of a similar magnitude predicted over the proposed framework's lifetime.

Habitat Restoration
Habitat restoration activities along the Seashore would involve moving dredged sediment from navigational channels within Pamlico Sound to sensitive shorebird areas within the Seashore. The dredging of navigational channels does have an impact on inlet stability and estuarine hydraulics in both the short- and long-term; a deepened channel can affect wave transformation patterns in a similar manner to an offshore borrow area. The resultant wave patterns could induce some additional erosion along sound side shorelines, although these impacts are likely to be relatively minor due to the generally low wave energy environment within Pamlico Sound.

The placement of dredged material along portions of the Seashore for the purposes of habitat restoration is likely to have a greater impact than the dredging itself. Site-specific conditions would need to be assessed before placing sediment, in order to ensure there are not adverse short- or long-term impacts on sediment quality or transport within the Seashore. As is the case with beach nourishment, a successful habitat restoration project will rely on a compatible sand source with similar grain size and sorting characteristics. A reasonable match between sediments is necessary to avoid impacts on local sediment transport patterns; finer grains will be more easily removed from a restoration site, while coarser grains will remain in place longer.

Dune Nourishment and Sand Relocation
Dune nourishment consists of relocating sand (e.g. shipping from an off-site borrow pit or scraping from the adjacent beach) into a berm along the upper dry beach. A higher dune ridge generally reduces the frequency of overwash (see Morton 2002; Sallenger 2000; Thieler and Young 1991). While sand relocation can expedite creation of a new dune ridge, other less-invasive methods are possible as well. These include planting native dune vegetation or installing sand fences to encourage deposition of wind-blown sand.

Sand scraping can impact littoral processes by removing sand from the shallow breaker zone and placing it within the dune system or dry beach. Cut depths are typically less than 2 ft but can disrupt nearshore sediment transport patterns. This can also result in a thinner dry beach, which provides less sand to the foredune system. Repeated dune nourishment and sand relocation projects may reduce dry beach width as well as increase foredune height and continuity alongshore; this may lead to more frequent overwash (Smith et al. 2008; Magliocca et al. 2011).

Placing sand from an off-site borrow pit involves less disturbance on the inter-tidal beach adjacent to a study area but can bury native vegetation. However, dune nourishment generally occurs in eroded areas where vegetation has been removed and can no longer grow 'naturally' to help establish a protective dune ridge. In these cases, sand fencing and vegetation would help establish a 'new' dune. Impacts from fencing and vegetation include increased potential for debris along the beach following high-water events, because sand fencing and/or newly planted vegetation may be eroded and removed from the project site.

Emergency Breach Fill

Under alternative B, relative sea-level rise and increased storm activity due to climate change could lead to increased frequency of overwash and breach events (Emanuel 1987; Broccoli and Manabe 1990; Michener et al. 1997). Breach fill and repair projects consist of placing fill in the area of a breach through a barrier island (USACE 2005). The volume of an emergency breach fill can vary from approximately 100,000 cy to over 1,000,000 cy and depends on the size of a particular breach.

Breaches are typically created by large-scale weather systems like hurricanes, tropical storms, cold fronts, or nor'easters. Breach repairs typically occur immediately and tend to be dominated by dredge-based projects designed to 'fill the gap' cut through the island. Within the Seashore, breach fill serves to maintain the connectivity along NC 12 between populated areas.

As with ocean side beach nourishment, emergency breach fills alter littoral processes and barrier island morphology by placing sand in areas where it was previously removed. In the short term (e.g., weeks to months), breaches disrupt habitat connectivity and sediment transport alongshore. However, they allow for a cross-shore (e.g., ocean-to-sound and vice versa) sediment transport. In a longer-term sense (years to decades), this is a beneficial feature of barrier islands like the Outer Banks because it allows for landward migration of the island. However, unmitigated breaching would likely lead to a gradual reduction in the land area of the Seashore itself (see Gutierrez et al. 2009; Mallinson et al. 2008; Moore et al. 2007).

Cumulative Impacts

The impacts from past, present, and reasonably foreseeable actions would be the same as those described for alternative A. Alternative B would permit the placement of sediment along the Seashore in order to increase the volume of sediment along Hatteras and Ocracoke Islands. These actions would temporarily mitigate erosion due to relative sea-level rise and storms. Oceanfront beach nourishment would likely result in larger volumes of sediment along the surf zone and within the dunes but may also prevent overwash. Sound side sediment placement would help mitigate the reduction in overwash frequency by building habitats within submerged portions of the barrier islands in Pamlico Sound, imitating natural overwash processes. There is a potentially beneficial role of overwash in allowing barrier systems to respond to relative sea-level rise, although it is somewhat unlikely that alternative B would effectively stop this process at a geological scale.

When the incremental impacts of alternative B are combined with the impacts of past, present, and reasonably foreseeable actions, the overall cumulative impacts on littoral processes and barrier island morphology would result in some localized changes to the existing conditions where sediment management activities are carried out. The Seashore has been modified and engineered in the past; the increase in the number of localized sediment management actions would likely provide more shoreline sediments available for erosion, resulting in potential accretion in locations not specifically targeted for sediment management activities. The incremental impacts of alternative B contribute most of the impacts to this resource.

The strongest trends observed in historical shoreline studies is the erosion of the beach and limited landward advancement of the sound side shoreline (Hapke and Henderson 2015; NPS 2015c; Mallinson et al. 2008). However, some research along the Outer Banks has suggested reducing barrier breaching reduces the island's ability to mitigate increased relative sea-level rise (Riggs et al. 1995; Riggs et al. 2009). A framework for ocean- and sound side sediment management along the Seashore would allow NPS to permit projects that temporarily address these issues and mitigate the effects of relative sea-level rise by promoting habitat expansion within the Seashore. The monitoring component of Alternative B also allows for critical analyses of the impacts of sediment placement along portions of the Seashore, so NPS can re-evaluate methods as techniques and information evolve. This gives NPS flexibility in determining the best path forward to mitigate the effects of relative sea-level rise at the Seashore.

Conclusion

Alternative B may impact some elements of natural littoral processes and barrier island morphology by continuing to engineer and manipulate the shoreline over the next 20 years. While some features of littoral processes and barrier island morphology may be altered under alternative B, the fundamental role of natural processes would continue. Adding new sand to the barrier system at a greater rate than previously done may help maintain the continuity of the island at a management scale (months to years) by increasing or maintaining the volume of sediments available for erosion along some sections of the beach, dune, and sound side shorelines. At geologic time scales, many barrier islands are currently migrating landward or struggling to reconstitute through rising sea levels (Cooper et al. 2016; Riggs et al. 1995; Swift 1975). Alternative B would likely create an immediate increase in the sand supply along the Seashore and provide a framework for NPS and its permittees to pursue a range of actions to combat relative sea-level rise in the future. At shorter time scales, impacts from sediment management would likely remain localized to the areas immediately surrounding a project site. These impacts would likely be indeterminate after just a few months, depending on wind and wave conditions.

Under alternative B, the change from current conditions would likely be moderate since sediment management activities would occur at a higher frequency than presently occurs along the Seashore. However, the impacts are likely to offset erosional losses anticipated over the lifetime of the proposed framework. Alternative B would blend the development, utilization, and maintenance of the economic infrastructure with the natural dynamics of climate change, including sea-level rise, increased storm frequency, shoreline recession, and habitat evolution and migration. Using a combination of methods as described under alternative B, sediment management activities along the Seashore would likely be able to mitigate some of the erosional side effects of relative sea-level rise beyond what is currently possible.

Alternative C

Under alternative C, NPS would permit sediment management activities on up to 6 miles of beach every 5 years, rather than every year under alternative B. Under alternative C, sediment management activities would inject up to approximately 24 million cy of sediment into the Seashore over the next 20 years. Finally, reference zones set aside under alternative B would not be established under alternative C. This would lead to a similar suite of impacts as described under alternative B, but at a lesser extent due to the reduction in volume and frequency of sediment placement activities.

Potential impacts of sediment management activities such as beach nourishment, habitat restoration, dune nourishment, and breach repairs on littoral processes and barrier island morphology include burial of nearshore habitats, potential changes to shoreface slope, and increased delivery of sediment to the foredune.

Discrete impacts to littoral processes and barrier island morphology would be most obvious near project sites. Because of the decreased frequency of actions under alternative C as compared to alternative B, the degree of impacts would likely be proportional to the increased time between projects. While alternative B would likely represent an increase in the amount of sediment management activities along the Seashore, as compared to the past few decades, the frequency and magnitude of projects possible under alternative C would probably resemble the present status quo along much of the Seashore. As a result of the increased time between permitted actions, the collective degree of impacts under alternative C would be less than that of alternative B.

Cumulative Impacts

The impacts from past, present, and reasonably foreseeable actions would be the same as those described for alternative B and alternative A. Alternative C would seek to permit the management of sediment along the Seashore consistent with past permitting frequency in order to increase the volume of sediment in place along various shorelines (e.g., sound side, ocean-side) of the Seashore. These actions would temporarily mitigate erosion due to relative sea-level rise and storms. However, it is unlikely that sediment management activities would effectively stop erosional and barrier migration process at a geological scale.

When the incremental impacts of alternative C are combined with the impacts of past, present, and reasonably foreseeable actions, the overall cumulative impacts on littoral processes and barrier island morphology would result in little localized changes to the existing conditions on specific beaches where sediment management activities are already carried out. Because alternative C was developed to reflect the current status quo of project magnitude and frequency, the net change from current conditions would likely be relatively minor in both a short- and long-term sense.

Conclusion

Alternative C may impact some elements of natural littoral processes and barrier island morphology by continuing to engineer and manipulate the shoreline over the next 20 years, albeit less frequently than as described under alternative B. While some features of littoral processes and barrier island morphology may be altered under alternative C, the fundamental role of natural processes would continue. Alternative C would result in a slightly more resilient Seashore with some additional sand volume added to the barrier islands over 20 years. Adding new sand to the barrier system may help maintain the continuity of the island at a management scale (months to years) by increasing or maintaining the volume of sediments available for erosion along some sections of the beach, dune, and sound side shorelines. Under alternative C, the change from current condition would be small, as this alternative was developed based on past permitting frequency.

Comparative Conclusion of Alternatives

Under alternative A, relative sea-level rise, climate change, wind and waves would continue to impact littoral processes and barrier island morphology. Littoral processes and barrier island morphology would continue to evolve, from the previously modified and moderately engineered system to a dynamic barrier island system with increased erosion, island narrowing, and increased overwash events. Under alternative A, the volume of sediment on the visible (sub-aerial) portion of the barrier island would likely continue to diminish over time.

In comparison, alternative B may help maintain the continuity of the barrier island system at a management scale (months to years) by increasing or maintaining the volume of sediments available for erosion along some sections of the beach, dune, and sound side shorelines. This may reduce the frequency of overwash and breach events, which may be potentially beneficial in allowing barrier systems to respond to relative sea-level rise. Habitat restoration, dune nourishment, and sound side sediment placement would likely create additional sources of erodible sediments to help the Seashore mitigate land loss over the lifetime of the proposed framework. It is likely that sediment management activities would slow the effects of chronic erosion along the Seashore at a management scale (i.e., months to years). Under alternative B, up to 158 million cy of sediment placement would be permitted along the Seashore over the 20-year lifetime of this framework. This volume would be used to mitigate erosion of beaches, dunes, and uplands across the Seashore over the lifetime of alternative B.

Alternative C would result in a smaller departure from current conditions than alternative B, because the frequency of projects would be designed to reflect the current status quo along the Seashore. This alternative would permit up to approximately 24 million cy of sediment placement along the Seashore over the next two decades. As is the case under alternative B, alternative C would involve the burial of nearshore and shoreline habitats, but many of these would be eroded naturally under the condition described in alternative A.

While sediment management activities under alternatives B and C would likely cause some temporary impacts (lasting weeks to months) to littoral processes and barrier island morphology, alternative B would likely help maintain continuity of the processes and habitats that have been in place along the Seashore in recent years.

BENTHIC ORGANISMS AND ESSENTIAL FISH HABITAT

Methodology for Analyzing Impacts

This analysis includes benthic organisms and EFH, including HAPCs, located on the ocean side, sound side, at the inlets, and at the potential borrow sites that may be affected by the alternatives. Benthic organisms play an important role in the ecosystem as they form the link between primary production and predator species including fish and birds (Baptist et al. 2009). Twelve EFHs and seven HAPCs are present within the area of analysis, as broadly defined as the general vicinity of the Seashore (see the “General Analysis Approach” section). Six of the EFHs are estuarine, located on the sound side of the Seashore: emergent tidal wetlands, soft bottom, hard bottom, intertidal flats, estuarine water column, and submerged aquatic vegetation (SAV), mainly seagrass. Seagrass is often considered separately from other SAV, such as hydrilla (*Hydrilla verticillata*) and wild celery (*Vallisneria americana*), when discussing EFH or HAPC because seagrass is present in high salinity environments while other SAV occurs in low salinity to freshwater; therefore, fish species use the habitats differently based on their preferences for high salinity or low salinity environments. At the Seashore, the vast majority of SAV are seagrasses, so for the purposes of this analysis, all SAV is considered together. Six marine EFHs, located on the ocean side of the Seashore, are also present: soft (mud and sand) bottom, (nearshore) hard bottom (including artificial reefs), Sargassum, pelagic waters (water column), shallow coastal, and Cape Hatteras sandy shoals. Of the HAPC, three are located on the ocean side of the Seashore (nearshore hard bottom, Sargassum habitat, Cape Hatteras sandy shoals), two are located on the sound side (tidal marsh and SAV), one is located at the inlets (coastal inlets), and one is species-specific (sandbar shark nursery and pupping grounds, which are located primarily on the sound side of the Seashore but also include the coastal inlets).

Qualitative descriptions of impacts are based on professional judgment, information provided by NPS staff, relevant references, and technical literature. Where possible, a range of quantitative measures is given, such as volume of sand, length of beach, and area of dredging. Prior to any individual beach nourishment project, site-specific design may be subject to project-specific permitting by the USACE and/or BOEM.

Impact Analysis

Alternative A (No-Action Alternative)

Onshore and Nearshore Impacts

Under alternative A, the Seashore would not permit sediment management activities and, overall, shoreline recession rates would likely continue as observed over the past several decades (NOAA 2019b). Shoreline recession could be exacerbated by relative sea-level rise due to climate change.

The progressive rise in sea level over the 20-year life of the management framework would shift the intertidal, wet beach zone inland in small, but consistent, increments forcing benthic species adapted to this environment to move inland with the changing intertidal zone (Galbraith et al. 2002). Intertidal benthic species are mobile enough to move in accord with relative sea-level rise (Maurer et al. 1978; Essink 1999; Speybroeck et al. 2006); however, in developed areas at the villages, beaches are not able to migrate inland and intertidal benthic species would lose habitat (Birchenough et al. 2015). In general, modeling studies have predicted that intertidal benthic organisms would lose habitat and populations would decline as a result of climate change-induced sea-level rise (Beukema 2002; Galbraith et al. 2002; Fujii 2012; Birchenough et al. 2015). It is important to note that these studies did not model conditions present at the Seashore, and a modeling study of the habitats at the Seashore may yield different results. The impacts of relative sea-level rise on intertidal, wet beach zone benthic organisms is complicated by various associated environmental changes including steepening of the intertidal slope, sediment coarsening, increased wave exposure, and other localized effects (Speybroeck et al. 2006). Steeper slope and a narrower wet beach zone are known to reduce diversity and abundance of benthic organisms (McLachlan 1996). Although these effects would lead to the decline in intertidal benthic abundance according to modeling studies, the local impacts on the benthic community at the Seashore would likely be variable and difficult to predict (Yamanaka et al. 2013). Relative sea-level rise would open new habitat for shallow-water subtidal benthic species at the Seashore beaches because the intertidal zone would shift inland as sea levels increase (Galbraith et al. 2002). This could provide expanded habitat for subtidal benthic organisms allowing for an increase in the population as they colonize new subtidal areas. However, depending upon the local bathymetry, seaward habitat for shallow-water subtidal species could be lost as organisms adapted to deeper water and the hydraulic processes that occur at greater depths encroach into the area and outcompete the existing community (Birchenough et al. 2015). The amount of habitat for shallow water organisms could increase, decrease, or remain the same depending upon a number of variables, and it is difficult to predict what will occur. The same is true of deep water habitats.

Relative sea-level rise at the projected rates may provide minor benefits to some types of ocean side EFH (soft bottom, hard bottom, artificial man-made reefs, Sargassum, marine water column, and shallow coastal) or HAPCs (nearshore hard bottom, Sargassum habitat, Cape Hatteras sandy shoals) by increasing the depth of the water column and therefore increasing the size of the habitat. In general, increased depth of the water column is associated with increases in productivity and nutrient uptake of phytoplankton and algae (Reise and van Beusekom 2008; Saunders et al. 2013). It is likely that relative sea-level rise over the life of the framework would not impact nearshore EFH at Seashore beaches.

On the sound side and in the inlets of the Seashore, the effects of relative sea-level rise are dependent upon the type of habitat. Organisms located in sandy wet beach habitats on the sound side and at the inlets would migrate inland, if possible, similar to the wet beach on the ocean side. Unvegetated, subtidal bottom and pelagic EFH, estuarine water column, oyster shell/banks, soft bottom, and hard bottom, may benefit from increased depth of the water column and associated increases in phytoplankton and algae productivity (Reise and van Beusekom 2008; Saunders et al. 2013). This could increase the availability of food to forage from the water column or the bottom habitats. In general, relative sea-level rise would not adversely affect these EFHs. Coastal inlets are important EFH and HAPC for penaeid shrimp, sandbar shark, and the snapper-grouper complex of fish. An increase in available food sources would increase the value of these habitats as EFH and HAPC. Benthic organisms present in subtidal, unvegetated habitats could receive similar benefits from increased depth of the water column (Reise and van Beusekom 2008; Saunders et al. 2013). However, modeling studies have indicated that relative sea-level rise would reduce intertidal mud flats and the benthic communities within these habitats would decline (Beukema 2002; Galbraith et al. 2002; Fujii 2012; Birchenough et al. 2015). Oyster reefs, on the other hand, are capable of accreting at a rate that would match predicted sea-level rise, and therefore may not be adversely impacted by rising sea levels (Rodriguez et al. 2014).

Vegetated EFH/HAPC, such as tidal marsh and SAV, may be considered wetlands by the NPS and would likely be negatively impacted by rising sea levels. Tidal marsh habitat in areas with lower substrate elevation would be drowned by increased water depths (Moorhead and Brinson 1995; Morris et al. 2002; Voss et al. 2013). Tidal marshes may naturally migrate shoreward to compensate for relative sea-level rise; however, this migration would depend on site-specific conditions on the inland side of the marsh. Marsh vegetation would incrementally recruit into tidally appropriate inland areas by seed or vegetative growth if inland slopes are gentle enough to accommodate marsh expansion. In areas with steep slopes created by development or shoreline hardening, it is unlikely that appropriate tidal conditions for marsh expansion would develop (Craft et al. 2009; Saunders et al. 2013; Torio and Chmura 2013; Voss et al. 2013). In these situations, marsh habitat at lower elevations, and the benefits it provides to fish and benthic organisms including forage, refuge, and nursery functions, would be lost (SAFMC 2009b). Tidal marshes also naturally accrete organic material which traps sediment and raises the elevation of marsh, although marsh accretion generally occurs more slowly than the current rate of relative sea-level rise (Morris et al. 2002; Voss et al. 2013).

SAV beds would also be negatively impacted by relative sea-level rise (Saunders et al. 2013; Valle et al. 2014). SAV habitats are composed of plants that require sunlight to survive, and as such their distribution is dependent on sunlight availability more than other variables (Duarte et al. 2007). In the Pamlico Sound, sunlight penetration within the water column ranges between 4 meters (13.1 ft) and 10 meters (32.8 ft) in depth, depending on physical factors such as turbidity, tide, freshwater influx, temperature, etc. (Paerl and Peierls 2008). SAV is limited to shallower areas of this range due to factors such as light attenuation by plankton, epiphytes on SAV, and the water itself (Brush and Nixon 2002; Ralph et al. 2007). SAV distribution modeling studies indicated that as water depths increase with sea-level rise, SAV in deeper areas would be lost due to a lack of sufficient sunlight for survival (Davis et al. 2016; Saunders et al.

2013), and this habitat area would likely be lost to fish and benthic invertebrates that use SAV. At the same time, SAV communities could expand into more shallow areas that have become subtidal due to relative sea-level rise, leading to a shoreward shift in SAV beds and the potential for their continued growth at the Seashore (Bjork et al. 2008; Saunders et al. 2013; Davis et al. 2016). Studies have indicated both loss and gain of SAV habitat from increased water depths due to relative sea-level rise depending on site-specific factors such as bathymetry, sediment accretion, water quality, turbidity, and substrate, with the majority indicating an overall loss of SAV (Shaugnessy et al. 2012; Saunders et al. 2013). Migration of SAV shoreward would also be limited by the presence of shoreline stabilization structures and unsuitable sediments including marsh peat left by retreating tidal marshes (Wicks 2005).

Under alternative A, relative sea-level rise and increased storm activity due to climate change could lead to increased frequency of overwash and breach events (Emanuel 1987; Broccoli and Manabe 1990; Michener et al. 1997). NCDOT may continue to manage NC 12 repairs within the existing NC 12 easement as necessary following overwash events and inlet breaches. In overwash events, NCDOT most often bulldozes overwash sand from the highway and shapes the sand into dunes within the ROW along the east edge of NC 12 in areas of existing easement—an activity which would have no effect on benthic communities or EFH /HAPC within the vicinity of the Seashore because it would not impact tidal or aquatic habitats.

An island breach would result in a larger impact/change, depending on the scale and dynamics of the breach. NCDOT would likely fill or bridge the breach under an emergency action. These activities would be limited to the NC 12 ROW under alternative A. The benthic community within the ocean side wet beach habitat at the breach location would be temporarily disturbed or removed during breach formation, but additional tidal or aquatic habitat would be created in the breach itself for benthic organisms adapted to the high energy beach environment (Dernie et al. 2003), an environment that includes continuous wave action, undertow, and rip currents. Also, the new habitat within the breach may become stabilized and populated by a complete community of benthic fauna before service of NC 12 is restored through emergency measures depending on the timeline of construction activities (Dernie et al. 2003).

Depending on its dynamics, a breach would impact EFH/HAPC and benthic communities on the sound side of the Seashore by removing benthic organisms at the breach location and converting the habitat. Tidal marsh and SAV beds could be eroded by water overflowing the island and the area converted to tidal flats or estuarine water column (Wamsley and Hathaway 2004; Cabaço et al. 2010; Friess et al. 2014). Additionally, tidal marsh and SAV HAPCs near the shoreline of the sound would likely be impacted by deposition of material eroded from the Seashore during the breach (Hayes and FitzGerald 2013). This material may include large amounts of sand that could bury benthic organisms and vegetation, and studies have documented declines in SAV beds near recently opened inlets (Cabaço et al. 2010). However, impacted areas could be recolonized. In some cases, the sediment from the overwash fan could increase accretion in marsh and seagrass areas to match rates of relative sea-level rise and maintain sustainability of the habitats (Michener et al. 1997).

The sound side areas exposed to a breach may also be subject to cooler water temperatures than what is typical in the shallow sound environment. The influx of cooler water reduces overall temperature in the vicinity of the breach, although the exact area influenced depends on circulation patterns. Similarly, the influx of ocean water from a breach can improve circulation patterns and increase flushing.

Increased water column turbidity would occur in all areas near a breach, but the sediments would consist primarily of sand and would settle from the water column in a short time, as intermittent suspensions under the wave-breaking process settle quickly, on the scale of a few minutes (Roman-Sierra et al. 2011) to a few hours (Van Dolah et al. 1992). Depending on wind speed and wave energy, suspended sediments may take longer to settle or may become resuspended by wave energy (Manning et al. 2013). These communities are already adapted to relatively high turbidity due to the wave and tidal energy, therefore the increased turbidity would not noticeably affect benthic organisms or EFH/HAPC (Baptist et al. 2009). However, benthic organisms could be affected by settling suspended sediments, the magnitude of which would depend on the amount of material. Sediment layers less than 1 centimeter in thickness have been shown to reduce abundance of many types of small organisms although larger bivalves were not affected (Lohrer et al. 2004). Additionally, mobile organisms would likely leave the area and avoid adverse impacts from elevated turbidity levels.

A breach would also expose nearby organisms and habitats to water with higher than normal salinity for the estuarine environment. Organisms within an estuarine environment are naturally adapted to wide ranges of environmental variables, a characteristic that makes them suitable for living within an estuary (Wolff 1971). However, in general, productivity and species diversity increase as salinity increases from freshwater to seawater (Wolff 1971; Fujii 2012). Also, increases in salinity due to a breach would likely not adversely impact SAV species present in Pamlico Sound at the Seashore because they are tolerant of hypersaline conditions (van Katwijk et al. 1999; Koch et al. 2007).

Under alternative A, NPS would not restore or repair damaged sand dunes, but would allow NCDOT to restore dunes within their easement if NC 12 was compromised. Throughout the Seashore, beach dune systems have historically been degraded by storms, floods, and other continuous erosive processes (Sciaudone et al. 2016). Without active restoration, the dune systems would continue to degrade as they have in the past. This process would not affect benthic communities or EFH.

Should a ferry service be implemented by NCDOT, it could result in some general impacts on EFH and benthic communities. Increased boat wakes on calmer sound side environments could cause more erosive actions on the sound side shorelines, some of which are EFH.

Offshore Impacts

Alternative A would not impact benthic communities in the offshore borrow areas.

Cumulative Impacts

Past, present, or reasonably foreseeable actions that affect benthic organisms and EFH include beach nourishment, channel dredging and dredge disposal, use of sand bags on private property, and predation management for coastal species of concern. Beach nourishment projects include Nags Head (10 miles in 2011 and 2019), Rodanthe-Pea Island NWR (2 miles in 2014), Buxton (3 miles in 2017 and 2018), and a combined project for Duck (1.6 miles), Kitty Hawk (3.8 miles), and Kill Devil Hills (2.6 miles). These projects have impacted intertidal and nearshore subtidal benthic organisms by burying during sand placement (Greene 2002; Wilber and Clark 2007; Manning et al. 2013; Rosov et al. 2016; Wooldridge et al. 2016). Dredging activities at borrow locations to supply sand for nourishment also directly removed benthic organisms and caused temporary increases in turbidity which impacted benthics and reduced EFH quality (BOEM 2013). Typically, benthic communities both at the beach and in the borrow areas recover their abundance and diversity over a period lasting from six months to several years (Wilber and Clark 2007;

Roman-Sierra et al. 2011; BOEM 2013; CZR Incorporated and CSE 2014; Rosov et al. 2016). Beach nourishment projects also lessened the slope of the intertidal benthic habitat, which increased the areal extent of the intertidal zone and reduced wave impact by dissipating energy along a longer, gentler slope (Baptist et al. 2009). The result of a more gradual slope is an increase in abundance and diversity of benthic organisms (McLachlan 1996). Beach nourishment also impacts EFH by removing the benthic food sources, increasing turbidity plumes, and potentially burying nearshore hardbottom habitat (NMFS 2003; NCDEQ 2016).

Channel dredging and dredge disposal would impact benthic communities and EFH/HAPC by direct removal of organisms during dredging, increase in turbidity at the dredge and disposal locations, increase in noise during dredging activities, and burying of fauna and habitats at the disposal location (similar to beach nourishment). Dredge and disposal events completed at Oregon Island included placement of sand on approximately 2 miles of beach within the Pea Island NWR portion of the Seashore. In 2019, Dare County approved a contract to dredge Oregon Inlet for 340 days per year over the next 10 years. It is likely that dredging would remove benthic organisms and deplete benthic communities within the inlet over the entire length of the project and subsequent recovery period. Dredging noise would elicit avoidance responses in benthic organisms and fish (NMFS 2003). The turbidity created by the dredge would reduce visibility (NMFS 2003), although it could act as a barrier to normal movement and behavior (GARFO 2020).

NCDOT projects conducted at the Seashore include the construction of Basnight Bridge crossing Oregon Inlet, connecting Bodie Island with Hatteras Island. NCDOT also conducts dune restoration along NC 12 involving the removal of overwash sediment from the road to create dunes within the NC 12 ROW and protect the road from future flooding. Construction of Basnight Bridge required the driving of support piles in the inlet potentially crushing benthic organisms, and the support piles may influence hydraulics that determine invertebrate and fish larvae transport and settlement (NMFS 2003). Phase 2 would be located between the southern end of the Pea Island NWR portion of the Seashore and Rodanthe, and it is anticipated that Phase 2 would have similar impacts to benthic organisms and EFH as Phase 1. Dune restoration would have little to no effect on benthic communities or EFH/HAPC, because this work would not occur in or near EFH or benthic habitats.

Sand bags may continue to be placed on private property and within the NCDOT ROW. Relative sea-level rise and erosion resulting in a more narrow dry sand beach could increase sand bag usage in the future. Sand bags function the same as other types of coastal armoring (FWS 2017) and reduce the area of inner surf zone substrate for benthic organisms, and continued erosion tends to concentrate coarser sediments in the beach zone where sand bags are present (Kraus and McDougal 1996; Rice 2009). This has the potential to modify the marine subtidal soft bottom EFH through sedimentation and change the substrate conditions, which would alter the existing benthic population assemblages (Greene 2002; Wilber and Clark 2007; Rosov 2016; Wooldridge et al. 2016). However, the projects envisioned under this cumulative action would be relatively small-scale (to protect individual private structures) and would rarely take place in the beach zone where benthic organisms potentially affected by this framework exist. Therefore, any adverse impacts on benthic species and habitat would be highly localized, allowing for rapid recovery and recolonization following sand bag removal.

In addition to those actions, the Seashore may remove as many as 5,600 ghost crabs annually as analyzed in the *Coastal Species of Concern Predation Management Plan* and programmatic environmental assessment (NPS 2018h). Removal of ghost crabs would alleviate some predation pressure on smaller benthic species located within the intertidal zone (Peterson et al. 2000).

For these reasons, past beach nourishment activities, channel dredging, roadway improvements, use of sand bags on private property, and predation management have generally adversely impacted benthic communities and EFH/HAPC. Benthic communities are relatively resilient, and recovery of abundance and community diversity to support predator species would take from six months to several years. Future dredging activities at Oregon Inlet would occur so frequently over a 10-year time period that the benthic community would not have time to recover between events, and the inlet would have no value as HAPC while the dredging continues.

When combined with the impacts of past, present, and reasonably foreseeable actions, alternative A would result in the alteration of benthic and EFH resources, with some lost or degraded and others improved and expanded, in the face of future relative sea-level rise, severe weather events, and natural erosion processes. This result would conform with the NPS approach to protect these resources by allowing natural processes such as overwash or inlet breaches to alter, bury, or bisect some of these benthic communities and back-barrier EFH (NPS 2006).

Conclusion

Alternative A would not permit beach nourishment, habitat restoration, and other sediment management activities within the boundaries of the Seashore. Benthic communities and EFH/HAPC could be impacted through erosion, loss of shoreline, steepening of the beach slope, and the resulting degradation of intertidal and nearshore benthic communities (McLachlan 1996; Greene 2002; Baptist et al. 2009), as described above. Although it is difficult to predict the specific consequences of relative sea-level rise and the human activities conducted by others at the Seashore (i.e., not NPS) in response to relative sea-level rise (Yamanaka et al. 2013), modeling studies have predicted a reduction in intertidal habitat (Birchenough et al. 2015) and a decline in intertidal benthic populations (Beukema 2002; Galbraith et al. 2002; Fujii 2012; Birchenough et al. 2015). Modeling studies have also indicated that relative sea-level rise would reduce certain types of EFH including intertidal mud flats (Beukema 2002; Galbraith et al. 2002; Fujii 2012; Birchenough et al. 2015), SAV (Davis et al. 2016; Saunders et al. 2013), and tidal marsh (Moorhead and Brinson 1995; Morris et al. 2002; Voss et al. 2013), and would lead to a decline in the abundance and diversity of the benthic communities within these habitats. However, unvegetated subtidal bottom and pelagic EFH, estuarine water column, soft bottom, and hard bottom, could benefit from increased depth of the water column and associated increases in productivity and nutrient uptake by algae and phytoplankton (Reise and van Beusekom 2008; Saunders et al. 2013). Under alternative A, island breaches and washovers would be likely to increase (Emanuel 1987; Broccoli and Manabe 1990; Michener et al. 1997). Breaches and washovers have both positive and negative impacts on benthic communities and EFH (Wolff 1971; Michener et al. 1997; Fujii 2012; Hayes and FitzGerald 2013). Many of the negative impacts are temporary and benthic resources and EFH would likely recover after being impacted (Van Dolah et al. 1992; Lohrer et al. 2004; Baptist et al. 2009; Roman-Sierra et al. 2011; Manning et al. 2013). However, impacts to some EFH such as tidal marsh, SAV, and hard bottom could be permanent (Wamsley and Hathaway 2004; Cabaço et al. 2010; Friess et al. 2014).

Alternative B (Proposed Action / Preferred Alternative)

Onshore and Nearshore Impacts

Sediment management activities would impact ocean side, sound side, and inlet benthic communities by burying and smothering benthic organisms with sediment place over their habitats (Greene 2002; Speybroeck et al. 2006; Baptist et al. 2009; Wilber et al. 2009; Rosov et al. 2016; Wooldridge et al. 2016). The magnitude of the effect of burial on benthic communities is dependent upon several variables including thickness of sediment overburden (Essink 1999; Speybroeck et al. 2006), species resistance or resilience (Essink 1999; Peterson and Manning 2001), characteristics of the deposited sediment (McLachlan 1996; Rakocinski et al. 1996; Peterson and Manning 2001; Manning et al. 2014; Wooldridge et al. 2016), and seasonal timing of sediment placement (Peterson et al. 2000; Manning et al. 2014; Wooldridge et al. 2016).

The thickness of the layer of sediment deposited in the wet beach and subtidal environments is important because benthic invertebrates may migrate through thin layers of sediment to the surface, rather than being smothered. Migration could reduce the overall loss in the benthic communities impacted by sand placement (Essink 1999, Speybroeck et al. 2006). Several species of intertidal mollusks and polychaetes have demonstrated the ability to migrate through 60 to 90 centimeters of sand or 20 to 60 centimeters of mud to reach the surface (Essink 1999). Generally, the ability of a species to migrate through sediment is determined by its resistance to being covered, its migratory ability, and the composition of the sediment (Essink 1999; Speybroeck 2006). Although some habitat restoration projects may involve the placement of thinner layers of sediment, through which buried benthic organisms may migrate to the surface, the thickness of the overburden layer during beach nourishment is typically greater than 1 meter, which would result in a total loss of benthic species within the project footprint (Greene 2002; Speybroeck et al. 2006; Baptist et al. 2009).

Under alternative B, sediment placement at the Seashore by hydraulic pipeline would increase turbidity in the intertidal and subtidal zones of the beach up to 400 meters from the outfall (Wilber et al. 2006). Turbidity levels would be the greatest within the swash zone where waves break, and levels would generally measure between 100 and 150 NTUs (USACE 2001a; Manning et al. 2013). Total suspended solids would range between 34 and 64 milligrams per liter (mg/L) (Wilber et al. 2006). This concentration of suspended sediment would be less than typically observed during a tropical storm or nor'easter event (Van Dolah et al. 1992; USACE 2001a; Wilber et al. 2006) and less than the level shown to impact benthic species (approximately 390.0 mg/L) (EPA 1986). Suspended sediments would be dispersed by wave action within a period of several minutes (Roman-Sierra et al. 2011) to several hours (Van Dolah et al. 1992) after sand placement ceased. However, depending on wind speed and wave energy, suspended sediments may take longer to settle or may become resuspended by wave energy (Manning et al. 2013). Organisms living in the intertidal and subtidal beach environments are adapted to turbulent conditions (Van Dolah et al. 1992; Greene 2002; Baptist et al. 2009; Manning et al. 2013; Wilber et al. 2009; Rosov et al. 2016); however, elevated turbidity levels during sand placement would persist continuously for days or weeks and may overwhelm organisms living within these habitats (Reilly and Bellis 1983; Jaramillo et al. 1996; Moffett et al. 1998). Wave energy (more turbid during storms), quality of sand (more turbid if clay, silts, or organics), and mode of placement (more turbid with barge rainbow spray than hydraulic pipeline) would determine actual turbidity levels caused by sediment management activities (Greene 2002). In particular, organics, silts, and clays would cause persistent turbidity that waves could resuspend for years after nourishment (Greene 2002; Speybroeck et al. 2006; Baptist et al. 2009). Under alternative B, sediment management project proponents would closely match the grain size and sediment type of the placement material to the native beach or shore conditions. At the Seashore, beach sand is typically coarse sand with few finer sediments like silt and clay, so it is unlikely that sediment would be suspended for years after nourishment due to wave action.

An increase in turbidity can also decrease primary production by reducing light levels for photosynthetic plankton. This would impact benthic organisms that subsist on phytoplankton. For filter feeders, suspended sediments can clog food uptake systems and decrease food quality by increasing the ratio of inorganic to organic particles (Baptist et al. 2009). Both of these effects could increase the energy required to feed, resulting in a decrease in growth rate (Peterson and Manning 2001) or mortality of filter feeders (Baptist et al. 2009; Reilly and Bellis 1983). Suspended sediments may also clog the gills of more sessile species, which could result in death due to anoxia (NRC 1995; Greene 2002). Benthic organisms could be adversely affected by the settlement of suspended sediments, depending on the amount of material in the water column. Sediment layers less than 1 centimeter in thickness have been shown to reduce abundance of many types of small organisms, but larger bivalves were not affected (Lohrer et al. 2004). Additionally, mobile organisms would likely leave the area and avoid impacts from elevated turbidity levels.

Because most sediment management activities under alternative B would completely bury, and therefore remove, the existing benthic community within the footprint of each individual project, recovery of the impacted community would occur through recruitment due to the settlement of larval life stages or migration from adjacent areas (Greene 2002; Speybroeck et al. 2006; Wilber and Clark 2007; Baptist et al. 2009; Wilber et al. 2009; Rosov et al. 2016; Wooldridge et al. 2016). Numerous studies have indicated that recovery is dependent upon several factors including the season of application (Peterson et al. 2000; Manning et al. 2014), sediment characteristics of the placed material (McLachlan 1996; Rakocinski et al. 1996; Peterson and Manning 2001; Wooldridge et al. 2016), timing between sediment placement episodes (Manning et al. 2014), and species specific resilience and recruitment (Peterson and Manning 2001; Miller et al. 2002; Leewis et al. 2012; Manning et al. 2014). Biological populations are inherently variable and may exhibit large, natural differences in diversity and abundance from site to site under the same seasonal conditions, so it may be difficult to discern whether variations between communities in different locations are caused by natural variation or sand placement (Peterson et al. 2000; Rosov et al. 2016).

Several studies have indicated that sand placement occurring in the winter (i.e., during the season when most intertidal invertebrates have moved offshore) would have a smaller impact on the benthic community (Peterson et al. 2000; Manning et al. 2014; Wooldridge et al. 2016). However, as discussed in chapter 2, the offshore conditions in the Outer Banks are typically rough in the fall and winter and may be unsafe for dredging activities. Therefore, under alternative B, sand dredging and placement activities could occur during the spring and summer. During sand placement, the active work zone typically would extend approximately 600 to 800 ft alongshore, and the active pumping zone would extend approximately 300 ft alongshore. On a given day, between 200 and 300 ft of nourished beach would be completed, and benthic invertebrates could immediately begin to recruit into the completed area. For example, Peterson and Manning (2001) observed recruitment of the polychaete *Scolelepis squamata* into a nourished beach within one day.

Sediment size and type, and similarity to native sediments existing on the receiving beach, have a determining effect on the recovery time of benthic communities (McLachlan 1996; Rakocinski et al. 1996; Peterson and Manning 2001; Wooldridge et al. 2016). Studies of the results of benthic community monitoring subsequent to beach nourishment indicate that, when nourishment sand of similar size and texture to the target beach is used, community recovery times are generally anticipated to be between six months to several years for benthic fauna common to the wet beach environment, including amphipods, mole crabs, bean clams, and polychaetes (Peterson and Manning 2001;Greene 2002; Speybroeck et al. 2006; Wilber and Clark 2007; Baptist et al. 2009; Wilber et al. 2009; Leewis et al. 2012; Rosov et al. 2016). Perhaps most relevant for this sediment management framework for the Seashore is the benthic monitoring conducted for two years subsequent to the 2011 beach nourishment project at Nags Head, which indicated that within two years of the impact, the benthic community in the area of sand placement was statistically the same as the control site in terms of taxa richness and abundance, which received no sand placement (CZR Incorporated and CSE 2014).

However, several other studies have indicated recovery of the benthic community after sediment placement could take longer than two years in certain situations (Peterson and Manning 2001; Colosio et al. 2007; Manning et al. 2014; Wooldridge et al. 2016). Peterson and Manning (2001) observed decreased populations of amphipods, mole crabs, and bean clams on a beach in Bogue Banks where sediment placed on the shoreline exhibited a higher shell content than the native sediment. In addition, the body size of bean clams and mole crabs was smaller than on the beach pre-nourishment or on adjacent beaches, and after two years, the body sizes did not converge with control populations. Peterson and Manning (2001) concluded the higher shell content slowed burrowing rates and increased energy expenditure leading to smaller body sizes, which was also supported by McLachlan (1996). Colosio et al. (2007) determined that beaches nourished with non-matching sediments (i.e., a higher proportion of clay and silt than target beach sediments) exhibited no recovery after one year, while a beach nourished with matching sediments, did not differ from control beaches after construction. Additionally, sand compaction could result from beach fill projects, especially those that use sediment with smaller grain size than those native to the target beach. Compaction could inhibit oxygen transport through the sediment, which would reduce the health of benthic infauna (Viola et al. 2014).

Manning et al. (2014) studied the recovery of the intertidal benthic invertebrate community on a beach in Topsail Beach, North Carolina, where beach nourishment occurred during two consecutive years and found that abundance of some species recovered in the time between beach nourishment events, but full recovery of the community took longer than two years. This study indicates that repeated sand placement from beach nourishment activities would have a greater impact on benthic communities than a single event. It was also noted that the sand placed on the beach was of a finer grain size with more sorting than the sand on the target beach indicating the observed longer recovery time may be a cumulative effect of repeated sand placement and differing sediment characteristics (Manning et al. 2014; Rosov et al. 2016). Under alternative B, there may be a few locations where beach nourishment would occur every three years over the lifetime of the sediment management framework due to high erosion rates and proximity to shorefront development. Little is known about the effect of extended periods of repeated sand placement on benthic communities; but assuming benthic recovery could take several years, the benthic community in these areas would likely exhibit reduced abundance and diversity over the majority of the life of the sediment management framework.

Wooldridge et al. (2016) studied the intertidal invertebrate community for 15 months following a beach nourishment project at eight beaches, each with nourished and control sections, across San Diego County, California. The density of the polychaete community was reduced by beach nourishment and remained at approximately one-third of control levels after 15 months. Densities of the mole crab *Emerita analoga* at some nourished sites surpassed those found at control sites after four months, but the population subsequently declined until there was no difference between control and nourished sites through the remainder of the study. Populations of amphipods and bean clams recovered with one year. This study highlights the variability in recovery times for different species at different locations.

Sediment grain size would also determine beach profile which could affect the species composition of the benthic community within the study area. Subsequent to sand placement, wind, tides, and wave action would redistribute the sediment to a more stable profile (NRC 1995), and sand of larger particle size than native sediments would form a beach with a steeper profile than present prior to sand placement (McLachlan 1996; Greene 2002). A steeper beach profile would lead to changes in hydrodynamics including an increase in wave energy on the beach face (Speybroeck et al. 2006). Steeper slope and a narrower wet beach zone would result in a reduction in diversity and abundance of the benthic community (McLachlan 1996). These effects could also impact benthic and demersal fish that forage within intertidal and nearshore subtidal habitats by increasing the energy expenditure required to feed, resulting in decreased growth rates, and reduce larval recruitment onto the nourished beach (McLachlan 1996).

The sand placed during sediment management activities assumes a profile that more closely matches natural conditions, a process known as equilibration which includes the natural reshaping of beach slope by waves and currents (NRC 1995), as described in the "Littoral Processes and Barrier Island Morphology" section. A nourished beach would typically reach equilibrium within six months after sand placement, so the impacts from offshore sediment transport would be relatively short term (NRC 1995). Following this process, the adverse impacts associated with a steeper slope and narrower wet beach zone may be reduced.

Impacts from proposed habitat restoration projects would be similar to those described above and as detailed for alternative B except that habitat restoration may involve the placement of thinner layers of sediment, through which buried benthic organisms could migrate to the surface. The thickness of the overburden layer during beach nourishment is typically greater than 1 meter, which would result in a total loss of benthic species within the project footprint (Greene 2002; Speybroeck et al. 2006; Baptist et al. 2009). Several species of benthic invertebrates have demonstrated the ability to migrate through 60 to 90 centimeters of sand or 20 to 60 centimeters of mud to reach the surface (Essink 1999); therefore, some species of benthics invertebrates could survive burial under thinner layers of sediment. The impacts on EFH/HAPC would be the same as described above including increases in turbidity and loss of prey base.

Breach fill impacts would be similar to other sediment management activities and would include burial of the entire benthic community. The primary difference is that the resulting habitat would be dry and therefore unavailable for recruitment of benthic invertebrates. It is anticipated that breach fill would return the area to the same conditions present prior to the formation of the breach, and therefore it is unlikely that there would be an overall loss of benthic habitat. Breaches would not be EFH/HAPC and the impacts from breach fill would be the same as described above including turbidity and loss of prey base.

Alternative B would preserve approximately 13 noncontiguous miles (approximately 20% of the Seashore) as reference areas and remove them from consideration for sediment management activities in all cases except for emergencies. The Seashore would complete ecological studies in these areas that could be used for comparison to areas impacted by sediment management activities. In addition, alternative B would require biological monitoring before and after any significant sediment management project for the purposes of learning and improving conditions associated with future projects. This monitoring could include studies of intertidal invertebrates, wildlife use, and other metrics that could be used to inform current knowledge of ecological recovery rates in areas where sediment management activities occur. Information gained from monitoring could further improve conditions associated with future projects including modification of the frequency and timing of sediment management activities and other project parameters. Project proponents would develop monitoring protocols in association with individual sediment management projects.

As stated in chapter 2, sand placed on the beach would be clean sand that closely matches sand present at the placement site in size and texture, as recommended by the "National Park Service Beach Nourishment Guidance" (NPS 2012) and the North Carolina Administrative Code (NCAC), 15A NCAC 07H.0312, "Technical Standards for Beach Fill Projects" (North Carolina OAH 2014). Therefore, alternative B would likely provide the environmental setting that would promote recovery of abundance and diversity anticipated within six months to several years (Baptist et al. 2009; Rosov et al. 2016; Wilber and Clark 2007). Therefore, impacts from benthic community smothering/removal by sand placement during sediment management activities and increases in turbidity at the placement site would likely be temporary in nature, lasting from a few days for turbidity to return to normal, to several years for benthic community recovery. Locations where beach nourishment would occur repeatedly are likely to remain depleted as long as repeated nourishment continues.

Sand placement would impact ocean side EFH, sound side EFH, and coastal inlet EFH/HAPC. Sand placed on the beach would smother benthic communities, and the loss of benthic prey resources due to sand placement would reduce the value of the affected EFH to fish species that feed on benthic organisms. It would reduce local food availability and likely cause fish to use other areas for foraging (Peterson and Manning 2001; Greene 2002; Speybroeck et al. 2006; Baptist et al. 2009; Wilber et al. 2009). This reduction of habitat value is anticipated to last between six months and several years until the benthic community recovers, as described above, at which time benthic foraging fish species would return to the area (Wilber et al. 2009).

Sediment management activities at the Seashore would also introduce more turbidity into the water column, impacting EFH and HAPCs. As described above, turbidity levels would be the greatest within the swash zone where waves break, and levels would generally measure between 100 and 150 NTUs (USACE 2001a; Manning et al. 2013). Total suspended solids would range between 34 and 64 milligrams per liter (mg/L) (Wilber et al. 2006). Suspended sediment concentration would be below the level that would impact fish (580.0 mg/L for the most sensitive species, with 1,000.0 mg/L more typical) (Wilber and Clark 2001). Increases in suspended sediments could reduce visibility, leading to a decrease in foraging and predator avoidance capabilities (Peterson and Manning 2001; Greene 2002; NMFS 2003). Reduced feeding ability could result in decreased growth rates and limited resistance to disease if high levels of suspended sediments persist (Greene 2002; NMFS 2003). Higher turbidity may also help surf zone fish by temporarily protecting smaller individuals from predators (Beyst et al. 2002). In general, it is anticipated most species would avoid the area during sediment management activities; however, some species such as Spanish mackerel have exhibited an attraction to areas where sand placement by hydraulic pipeline was occurring (Wilber et al. 2003).

Sediment management activities may occur within HAPCs on the ocean side (nearshore hard bottom, Sargassum habitat, and Cape Hatteras sandy shoals) or on the sound side (tidal marsh and SAV). These habitats could experience an increase in water column turbidity during sand placement. Increased turbidity would reduce water clarity, which would limit light availability for SAV (SAFMC 2009b; Gregg 2013). Seagrass in particular requires sufficient light to subsist, a minimum of 15 to 25% of the light available at the surface (Gregg 2013). Turbidity levels that lower light below this threshold would impact seagrass beds (a particular type of SAV which is particularly sensitive to changes in light caused by turbidity). The settlement of suspended sediments may cover SAV and tidal marsh plants for a short time, reducing photosynthetic production, but it is likely the sediment would settle to the substrate where it would contribute to the accretion that typically occurs in SAV and tidal marsh habitats (Michener et al. 1997; SAFMC 2009b).

Through the process of equilibration, as previously defined, a nourished beach would typically reach equilibrium within six months after sand placement, so the impacts from offshore sediment transport would be relatively short term (NRC 1995). During the equilibration process, where the nourished beach profile is naturally reshaped, some material is transported from the beach into offshore waters, and some drifts downcoast (downstream of the prevailing nearshore current flow, in this case south) to other habitats (NRC 1995). This sand can cover habitat and may impact benthic communities that serve as food sources located within these habitats due to smothering (Lohrer et al. 2004). For example, hard bottom habitat near Wrightsville Beach, south of the Seashore along North Carolina's coast, was buried under 2 to 6 in of sand through erosion from nourished beaches (NCDEQ 2016). Nearshore hard bottom habitat in Broward County, Florida, was also buried by sediment from a nearby beach nourishment project (Wilber et al. 2009). These impacts are permanent and the fisheries formerly present in these areas have not recovered (NCDEQ 2016; Wilber et al. 2009). Similar impacts could occur at the Seashore depending on the proximity of hard bottom resources nourished beaches, and in general, they would also likely be permanent.

On the sound side of the Seashore, many sandy bottom areas where sediment management activities are likely to occur are immediately adjacent to tidal marsh and SAV HAPCs. Because the currents and tides are less energetic on the sound side than the ocean side and because vegetation in these habitats would trap suspended solids, the sediment eroded during equilibration would be transported a shorter distance and deposited over a smaller area in adjacent tidal marsh and SAV habitats. The deposited sediment could bury and smother vegetation and immobile benthic organisms within these habitats (NMFS 2003; SAFMC 2009b). It is likely that vegetation would recruit into the impacted areas by seed dispersal or vegetative spreading during the next growing season, generally defined as the spring and summer seasons, and the habitat would recover (Schile et al. 2014). However, some habitat may be lost if the sediment raises the substrate to a tidal elevation that is not sustainable for the impacted habitat. For example, SAV beds may be elevated to intertidal levels that could not support SAV adapted to subtidal environments. However, this deposited sediment could also enhance the natural accretion processes that occur in tidal marsh and seagrass beds helping to keep pace with relative sea-level rise (Michener et al. 1997; Schile et al. 2014). The specific impacts from sediment management activities would be determined by the strength and direction of local sediment transport processes and would need to be assessed on a case by case basis to determine the extent and intensity of effects on adjacent HAPC habitats. Due to the small size and limited occurrence of sandy bottom habitats on the sound side, it is unlikely that sediment management activities would impact enough area of these habitats to reduce the HAPC value throughout the Seashore.

Under alternative B, dune restoration would also occur, including activities that would promote natural dune-building processes, such as beach grass planting and installation of sand fencing. It is unlikely that dune restoration activities would impact benthic communities or EFH/HAPC within or near the Seashore.

Offshore Impacts

Dredging for sediment management actions could directly impact offshore marine water column, soft bottom, sandy shoal, *Sargassum* EFH, *Sargassum* habitat HAPC, and sandbar shark HAPC. The marine water column EFH in the offshore area would be deeper over the shoal following removal of the sediment (dredge cut depth would be likely to reach or exceed approximately 6 ft, or shallow enough to not have a measurable effect on wave climate), and only a relatively small portion of the offshore shoal would be disturbed if hopper dredges are used (CSE 2015). However, the dredge operator may elect to use some combination of hopper dredge and cutterhead dredge. The latter would dredge up to a maximum of 8 ft (maximum allowed under North Carolina law) over an incrementally smaller footprint, leaving more of the shoal area undisturbed. Hardbottom EFH and HAPC, including artificial reefs, would be avoided to the maximum extent practicable, see mitigation measures under alternative B in chapter 2.

Dredging of any kind would result in the direct removal of benthic fauna including the infaunal (living within the substrate) and epifaunal (living on the substrate) organisms in that habitat. BOEM's MMIS indicates that approximately 29,000 acres of sand resources are available off the coast of the Seashore, of which only approximately 1% would be used in a given year, ensuring similar substrate would remain in the borrow area subsequent to dredging (BOEM 2019a). Many benthic fauna are highly opportunistic (Posey and Alphin 2002), which promotes rapid recovery of former dominant species and abundances (Van Dolah et al. 1984). Therefore, recruitment of a similar suite of benthic organisms is expected within the potential borrow areas (Van Dolah et al. 1984; Posey and Alphin 2002; BOEM 2013; CZR Incorporated and CSE 2014). Results from similar projects along with the corresponding sediment characteristics between native beach sands, borrow sands, and underlying sands in the borrow area, support the expectation that recolonization would be rapid, from as little as one month (Sánchez-Moyano et al. 2004) to two years (Van Dolah et al. 1984; Johnson and Nelson 1985; Posey and Alphin 2002; Roman-Sierra et al. 2011; BOEM 2013; CZR Incorporated and CSE 2014). However, benthic recovery time is highly variable and could take longer depending on site conditions (Greene 2002; Speybroeck et al. 2006; Baptist et al. 2009; BOEM 2013).

Borrow area dredging could lead to changes in the sediment composition and biological community at the dredge site (Crowe et al. 2016; Wilbur et al. 2009). The rate and composition of sediment refilling of dredge pit depends on the mobility of adjacent sediments and wave and current energy (Van Dolah et al. 1998). In many locations, dredge pits fill with adjacent sandy sediments, but in others, dredge pits may fill with finer, more mobile sediments such as clay, silt, or fine sands (Van Dolah et al. 1992; Van Dolah et al. 1994; Van Dolah et al. 1998; Crowe et al. 2016). Studies conducted in South Carolina have indicated that the location of borrow areas strongly influences the type of sediment that refills the borrow area. Borrow areas near the north end of a barrier island tend to accumulate finer sediments, while areas at the south end of the island refill with sand from adjacent areas (Van Dolah et al. 1998; Crowe et al. 2016). This is likely due to the placement of borrow areas relative to inlets where ebb tides carry finer sediments from estuaries seaward through navigation channels. In South Carolina, coastal currents then carry the sediment southwest towards the borrow areas where the pits slow current speed allowing the sediment to settle (Blanton et al. 1997). Prevailing coastal currents at the Seashore also move from north to south, and sediment transport could be similar; however, studies to determine if sediment transport at the Seashore follows a similar pattern have not been conducted.

Borrow area dredging could lead to hypoxic or anoxic conditions when it involves the digging of steep banked, deep holes that prevent normal flow and exchange of water. Although common in past decades, current standard dredging practices avoid the creation of these deep pits (NMFS 2020b). Also, dredging could resuspend toxins if sediments at the borrow site are contaminated. Under alternative B, sediments within potential borrow areas would be tested for contamination prior to selection of the project borrow site(s) in order to avoid resuspension of toxins at the dredge site and introduction of toxins at the placement site.

Based on multiple studies of similar borrow areas and benthic population recovery (BOEM 2013) and the specific results of the Nags Head benthic monitoring program (CZR Incorporated and CSE 2014), the effect of dredging sand from offshore borrow areas on the benthic community and sandy shoal EFH at the Seashore would be minimal for the following reasons:

1) Areas of offshore sandy substrates like the potential borrow areas typically recover more quickly than intertidal or shallow water benthic communities (Van Dolah et al. 1984; Johnson and Nelson 1985; Posey and Alphin 2002; Sánchez-Moyano et al. 2004; Roman-Sierra et al. 2011);
2) Areas of the potential shoal would be left undisturbed to serve as refugia and recolonization resources; and
3) Standard dredging practices would avoid the creation of pits which could infill with finer sediments than normal for the area and promote rapid colonization by undesirable, early successional benthic species.

Dredging would also increase turbidity within the water column. Near-bottom sediment plumes caused by hopper dredges would extend from 2,300 to 2,400 ft down-current from the dredge (USACE 2015). Total suspended solids (TSS) concentrations may be as high as several hundred mg/L near the discharge port and as high as several tens of mg/L near the draghead. Concentrations would typically range from 80.0-475.0 mg/L near hopper dredge operation (GARFO 2020). Depending on local hydraulics and sediment composition, the majority of suspended sediments would resettle close to the dredge within one hour, although very fine particles may settle only to be re-suspended by subsequent ebb or flood currents (GARFO 2020). The TSS levels expected for hopper dredging (maximum of 475.0 mg/L) would be below those shown to have adverse effect on fish (Wilber and Clarke 2001), as stated above. However, TSS levels, if they reach the maximum, could be high enough to impact sessile benthic invertebrates by clogging gills or feeding systems (Reilly and Bellis 1983; NRC 1995; Greene 2002).

TSS levels associated with cutterhead dredging would not be as high as those generated by hopper dredging. Modeling indicated that elevated TSS levels caused by cutterhead dredging would be detectable within the bottom 6 ft of the water column and would extend approximately 1,000 ft from the dredge (USACE 2015), and studies indicate elevated TSS levels would be present within a 900 to 1,500 ft radius of the dredge (Wilber and Clarke 2001). TSS levels from cutterhead dredges would typically range from 11.5 to 282.0 mg/L (USACE 2015). Overall, TSS levels from cutterhead dredge operation would be below the level that would be expected to impact fish or benthic invertebrates.

Suspended sediments would be expected to settle from the water column within a relatively short time (minutes to an hour) subsequent to the ending of dredging operations. Settling velocities of sand-sized particles (approximately 0.1 to 2.0-mm diameter) would roughly be in the range of 1 to 20 centimeters per second in quiet water (Komar 1998). Thus, settling would occur in seconds to minutes for sand-sized particles in the range of depths typical of the seashore, including the potential borrow areas (CSE 2015).

The following list of considerations to minimize impacts to EFH and benthic habitats was developed in coordination with the NCDMF and NMFS during early project planning for the 2014 emergency project at Rodanthe. The following measures have been used in previous projects and would reduce physical and biological impacts to benthic communities and EFH and assure that any adverse impacts are short-term and localized:

- Promote quick benthic recovery through shallow borrow area excavation, as described in chapter 2.
- Use topographic highs and/or areas of high sediment mobility within the borrow area.
- Encourage dredge operations that leave behind unimpacted ridges to allow for recovery.
- Avoid hard bottom resources (within the nearshore toe of fill and offshore borrow area).

Additional actions under alternative B would include dune nourishment, sand relocation, and habitat restoration. These activities would have little to no effect on offshore benthic communities and EFH.

Under alternative B, sediment management activities would occur on up to 6 miles of beach annually at the Seashore. Approximately every 5 years, up to 12 miles of beach could receive nourishment due to emergency actions. The volume of dredging to supply material for these sediment management activities would impact a small percentage (less than 1%) of the total offshore sand resources available at the Seashore (BOEM 2019a). As stated above, benthic community recovery is anticipated to take between six months to several years of dredging impacts. Increased turbidity from active dredging would cover a larger areal extent at any given time; however, as discussed above, sediments in the water column would settle out quickly once the dredging ceased or the dredge moved to another location (Komar 1998; Wilber and Clark 2001; USACE 2015). Therefore, completing a maximum of 6 miles of beach nourishment in an average year and up to 12 miles every 5 years would result in a temporarily depleted benthic community over a small area of offshore substrate but would not impact the overall condition of the EFH or the benthic community offshore of the Seashore as a whole.

Cumulative Impacts

Past, present, or reasonably foreseeable actions that would affect benthic communities and EFH under alternative B would be the same as described above under alternative A, and based on the results of various benthic community monitoring studies, some benthic communities in areas impacted by past activities would have recovered but other areas could have been permanently impacted (Greene 2002; Speybroeck et al. 2006; Baptist et al. 2009; Wilber and Clark 2007; Wilber et al. 2009; CZR Incorporated and CSE 2014; Rosov et al. 2016; Wooldridge et al. 2016). As described for alternative A, roadway improvement projects, particularly the Bonner Bridge replacement project (now "Basnight Bridge"), Phase 1, have permanently impacted benthic communities and EFH with the installation of support pilings which changed local hydraulics. Future roadway improvement projects, Phase 2 of the Bonner Bridge replacement project in particular, would have similar impacts. Dredging activities at Oregon Inlet would severely impact the benthic community within the inlet because dredging would occur so frequently over the 10-year project timeline that the community would not have time to recover between events. The repeated dredging would also reduce or eliminate the value of the inlet as HAPC. In addition, the *Coastal Species of Concern Predation Management Plan* would benefit the benthic community by reducing predation pressure on benthic organisms present in the wet beach environment by removal of ghost crabs (Posey et al. 2002). Predator management is unlikely to affect EFH/HAPC at the Seashore.

Alternative B would periodically impact benthic communities, in the wet beach and subtidal environments, and EFH with sediment management activities, primarily beach nourishment or dredging. Impacts would include removal or burial, followed by at least three years between projects at the same site, which provides the benthic community more than the two years required for complete recovery. Sand placement would also enhance the wet beach, intertidal habitat, and nearshore subtidal habitat by reducing the slope of the beach profile, resulting in reduced wave energy and greater community abundance and diversity. Although little information is available concerning benthic impacts from repeated nourishment events, regular sand placement in these habitats would likely lead to a depleted benthic community being present most of the time. Alternative B would impact EFH and HAPCs by burial of some near shore benthic habitat, leading to a reduction of prey base, and increases in turbidity during sediment management activities. It would also impact tidal marsh and SAV habitats by providing sediment to increase accretion rates to keep pace with relative sea-level rise. Ongoing use of sand bags on private property would adversely affect benthic organisms and associated habitat on a temporary and highly localized basis. Furthermore, use of sand bags on non-NPS lands may decrease under the scenario where alternative B is implemented (as compared to alternative A).

The literature and past experience suggest the benthic community and EFH/HAPCs have recovered from past activities within and near the Seashore, including beach nourishment and inlet channel dredging. Roadway improvements have permanently impacted benthic communities and EFH and would likely continue to do so as road construction projects continue. Predation management would remove predation pressure on benthic invertebrates without impacting EFH/HAPCs. Future dredging activities are likely to impact the benthic community and EFH/HAPC within Oregon Inlet by continuously removing benthics and degrading the habitat with elevated levels of turbidity. When combined with the impacts of past, present, and reasonably foreseeable actions, alternative B would result in adverse impacts to benthic communities and EFH/HAPC, with the incremental impacts of alternative B contributing most of the impacts.

Conclusion

Compared to alternative A, beach nourishment under alternative B would likely provide a wider dry-sand beach and restore a less steep beach profile. This would increase the areal extent of wet beach habitat for benthic organisms compared to existing conditions. Furthermore, the beach would develop a less steep profile, which would reduce the wave energy in the intertidal and subtidal habitats (Speybroeck et al. 2006). A less steeply sloped wet beach zone would increase the diversity and abundance of benthic communities (McLachlan 1996). These effects could also improve the nearshore EFH for benthic and demersal fish that forage within intertidal and nearshore subtidal habitats by providing more habitat for benthic invertebrates and an increase in foraging resources (Peterson and Manning 2001). Under alternative B, however, benthic organisms could also be adversely affected by the settlement of suspended sediments. In addition, if TSS levels are high enough, they could impact sessile benthic invertebrates by clogging gills or feed systems (Reilly and Bellis 1983; NRC 1995; Greene 2002). However, measures used in previous sediment management projects could help reduce these physical and biological impacts to benthic communities and EFH to assure that any adverse impacts are short-term and localized. These impacts would occur over a total of 6 miles of beach per year in typical years. Approximately every 5 years, up to 12 miles of beach could receive nourishment due to emergency actions. The volume of dredging to supply material for these sediment management activities would impact a small percentage (less than 1%) of the total offshore sand resources available at the Seashore (BOEM 2019a). As stated above, benthic community recovery is anticipated to take between 6 months to several years of dredging impacts. Increased turbidity from active dredging would cover a larger areal extent at any given time;

however, as discussed above, sediments in the water column would settle out quickly once the dredging ceased or the dredge moved to another location (Komar 1998; Wilber and Clark 2001; USACE 2015). Therefore, completing a maximum of 6 miles of beach nourishment in an average year and up to 12 miles every 5 years would result in a temporarily depleted benthic community over a small area of offshore substrate but would not impact the overall condition of the EFH or the benthic community offshore of the Seashore as a whole. Alternative B would also preserve approximately 13 noncontiguous miles (approximately 20% of the Seashore) as reference areas and remove them from consideration for sediment management activities in all cases except for emergencies. The Seashore would complete ecological studies in these areas that could be used for comparison to areas impacted by sediment management activities. In addition, alternative B would require biological monitoring before and after any significant sediment management project for the purposes of learning and improving conditions associated with future projects.

Over the life of the proposed framework (20 years), it is anticipated the completion of sediment management activities would benefit the intertidal and subtidal benthic communities and the quality of EFH and HAPC throughout the Seashore, as it would reduce impacts from relative sea-level rise, storms, and climate change such as washovers, inlet breaches, and shoreline erosion, as described under alternative A. The impacts that would occur as a result of sediment management activities are considered temporary and limited in spatial extent.

Over the life of the proposed framework, it is anticipated that the completion of sediment management activities would not impact the sustainability of the offshore subtidal benthic community or reduce the quality of the offshore EFH throughout the Seashore. Benthic monitoring has demonstrated that the subtidal benthic community within offshore borrow sites could reestablish itself in a recently dredged area within two years (BOEM 2013; CZR and CSE 2014), although it could take longer depending on site conditions. Therefore, the currently proposed size and rate of projects would not result in a substantial loss of benthic fauna in the offshore area adjacent to the Seashore. Given the temporary nature of the impacts to EFH for any individual project, including an increase of sediment load in the water column and reduction of prey species, it is unlikely the overall quality of EFH offshore of the Seashore would be reduced by the proposed sediment management actions.

Alternative C

Under alternative C, sediment management activities would be expected to occur on up to 6 miles of beach every 5 years, rather than every year as could be permitted under alternative B. This would cause similar impacts as described in detail under alternative B but to a lesser extent. In addition, alternative C would not establish reference areas, so no area at the Seashore would be removed from consideration for beach nourishment and no reference monitoring would occur.

Onshore and Nearshore Impacts

Impacts to EFH and HAPC from sediment management activities under alternative C would be similar to those described for alternative B. Sand placement on beaches and within intertidal zones would bury benthic communities and reduce local prey availability within the project footprint (Peterson and Manning 2001, Greene 2002, Speybroeck et al. 2006, Baptist et al. 2009, Wilbur et al. 2009, Rosov et al. 2016). It is anticipated benthic communities would recover within six months to several years, as described under alternative B, assuming that sediment placed in the intertidal zone at the beach would match the existing native sediment (Greene 2002, Speybroeck et al. 2006, Baptist et al. 2009, Wilber et al. 2009, CZR Incorporated and CSE 2014, Rosov et al. 2016). EFH would also experience increases in turbidity during sand placement. This would reduce visibility in the water and decrease foraging and prey avoidance abilities in fish (Peterson and Manning 2001, Greene 2002, NMFS 2003). Reduced light due to turbidity would also impact phytoplankton and primary productivity of SAV, particularly seagrass (SAFMC 2009b, Gregg 2013). The settling of suspended sediments could also increase accretion in tidal marsh and SAV HAPCs to keep pace with relative sea-level rise. After completion of sand placement, beach equilibration would increase turbidity in offshore habitats (NRC 1995), and sediment carried from the beach during equilibration could bury offshore EFH/HAPC (Lohrer et al. 2004, Wilber et al. 2009, NCDEQ 2016).

Under alternative C, dune restoration would also occur, including activities that would promote natural dune-building processes, such as beach grass planting and installation of sand fencing. It is unlikely that dune restoration activities would impact benthic communities or EFH/HAPC within or near the Seashore.

Impacts from proposed habitat restoration projects would be similar to those described above and as detailed for alternative B except that habitat restoration may involve the placement of thinner layers of sediment, through which buried benthic organisms could migrate to the surface. The thickness of the overburden layer during beach nourishment is typically greater than 1 meter, which would result in a total loss of benthic species within the project footprint (Greene 2002; Speybroeck et al. 2006; Baptist et al. 2009). Several species of benthic invertebrates have demonstrated the ability to migrate through 60 to 90 centimeters of sand or 20 to 60 centimeters of mud to reach the surface (Essink 1999); therefore, some species of benthics invertebrates could survive burial under thinner layers of sediment. The impacts on EFH/HAPC would be the same as described above including increases in turbidity and loss of prey base.

Breach fill impacts would be similar to other sediment management activities and would include burial of the entire benthic community. The primary difference is that the resulting habitat would be dry and therefore unavailable for recruitment of benthic invertebrates. It is anticipated that breach fill would return the area to the same conditions present prior to the formation of the breach, and therefore it is unlikely that there would be an overall loss of benthic habitat. Breaches would not be EFH/HAPC and the impacts from breach fill would be the same as described above including turbidity and loss of prey base.

Although under alternative C the impacts of each project would be the same as under alternative B, there would be fewer sediment management actions over the next two decades, so the impacts would occur over a much smaller area, i.e., 6 miles every 5 years, than under alternative B which includes 6 miles per year with 1 year in 5 having 12 miles of sediment management activity. There would also be fewer areas that would experience repeated sand placement. This would provide more recovery time for impacted benthic communities, and it would lead to fewer areas that would remain depleted of benthic resources by repeated treatments (Manning et al. 2014). Fewer sediment management actions would also reduce the frequency of impacts such as turbidity that are generally temporary in nature. Smaller amounts of sand placed on the beach over time would reduce the potential for impacts to EFH from sand transported offshore during beach equilibration, including burying of habitats such as hard bottom (Lohrer et al. 2004; Wilber et al. 2009; NCDEQ 2016). In addition, alternative C would not preserve reference areas and would not conduct reference monitoring. This would leave the entire Seashore open to sediment management activities and the associated impacts. The lack of monitoring would not increase impacts, but it could hinder the abilities of project proponents and regulators to reduce impacts and increase sustainability of sediment management projects.

Offshore Impacts

As described in detail under alternative B, dredging would impact the benthic community in the potential borrow areas by directly removing organisms and sediments. Dredging could also result in changes to sediment composition at the dredge site which would alter the biological community (Crowe et al. 2006; Wilber et al. 2009). During dredge operation, sediment removal would increase turbidity at and around the dredge. Increased turbidity and the settlement of suspended solids could clog gills of benthic invertebrates and feeding structures of filter feeders (Reilly and Bellis 1983; NRC 1995; Peterson and Manning 2001; Greene 2002; Baptist et al. 2009; USACE 2015; GARFO 2020). Settlement of suspended solids onto benthic organisms could also reduce local abundance of the community (Lohrer et al. 2004).

Dredging would remove or alter EFH and HAPC including soft bottom, sandy shoal, *Sargassum*, and hard bottom resources. As described for alternative B, hardbottom EFH and HAPC would be avoided to the maximum extent practicable. Dredge activity would also increase turbidity in the potential borrow area. As described for alternative B, increased turbidity could reduce foraging and prey avoidance ability in fish (Peterson and Manning 2001; Greene 2002; NMFS 2003), but TSS levels would be below those that would impact fish (Wilber and Clarke 2001).

Under alternative C, fewer sediment management actions over the timeline of the plan would reduce the amount and frequency of sand removal from potential borrow areas. Fewer impacts to benthic communities and habitats in these areas would occur, and benthic communities would have more time to recover following dredging.

Cumulative Impacts

Past, present, or reasonably foreseeable actions that would affect benthic communities and EFH would be the same as described above under alternative B and alternative A. Alternative C would impact benthic communities and EFH by removing benthic communities by burial or dredging, increasing turbidity during dredging or sand placement, and potentially provide sediment for accretion in marshes and SAV to keep pace with relative sea-level rise. These impacts are similar to those described in detail for alternative B, but alternative C would cause a lower magnitude of these impacts over the next two decades. When combined with the impacts of past, present, and reasonably foreseeable actions, alternative C would likely result in adverse impacts to benthic communities and EFH/HAPC, with the incremental impacts of alternative C contributing most of the impacts.

Conclusion

Alternative C would result in similar project specific impacts to alternative B and would help reduce impacts from relative sea-level rise, storms, and climate change such as washovers, inlet breaches, and shoreline erosion as described under alternative A. Under alternative C, the beach would also develop a less steep profile, which would reduce the wave energy in the intertidal and subtidal habitats (Speybroeck et al. 2006). A less steeply sloped wet beach zone would increase the diversity and abundance of benthic communities (McLachlan 1996). These effects could also improve the nearshore EFH for benthic and demersal fish that forage within intertidal and nearshore subtidal habitats by providing more habitat for benthic invertebrates and an increase in foraging resources (Peterson and Manning 2001). However, projects would occur at a lesser frequency resulting in less disturbance to the benthic community and

EFH/HAPC. Over the course of 5 years, it is anticipated that impacts from sediment management activities would not exceed 9% of the Seashore.

Over the next 20 years, it is anticipated that the completion of sediment management activities under alternative C would not impact the sustainability of the offshore subtidal benthic community or reduce the quality of the offshore EFH throughout the Seashore. Therefore, the rate of projects under alternative C would not result in a substantial loss of benthic fauna in the offshore area adjacent to the Seashore. Given the nature of the impacts to EFH (anticipated to last between 6 months to several years) for any individual project, it is unlikely the overall quality of EFH offshore of the Seashore would be reduced by sediment management activities as they would be completed under alternative C.

Comparative Conclusion of Alternatives

Under alternative A, benthic communities and EFH/HAPC within the wet beach and nearshore environments on the Atlantic and Pamlico Sound sides of the Seashore and at the inlets may be impacted by continued erosion leading to potential habitat disappearance and degradation including steeper beach profile and recurrent inlet breaches. Although it is difficult to predict the specific consequences of relative sea-level rise and the human activities conducted at the Seashore, modeling studies of relative sea-level rise have predicted a reduction in intertidal habitat and a decline in intertidal benthic communities. Modeling studies have also indicated that relative sea-level rise would reduce certain types of EFH including intertidal mud flats, SAV, and tidal marsh, and would lead to a decline in abundance and diversity of the benthic communities within these habitats. However, unvegetated, subtidal bottom and pelagic EFH, estuarine water column, soft bottom, and hard bottom, could benefit from increased depth of the water column and associated increases in productivity and nutrient uptake of phytoplankton which would improve food resources available in benthic communities and EFH.

Compared to alternative A, alternative B would likely provide a wider dry-sand beach and restore a less steep beach profile through sediment management at specific sites. This may temporarily improve habitat for benthic communities and help to mitigate the effects of relative sea-level rise. Alternative B would result in the burial of benthic communities at the project site, with impacts anticipated to last between six months to several years. Unlike alternative A, alternative B would temporarily introduce more turbidity into the water column, impacting EFH and HAPCs. Completing a maximum of 6 miles of beach nourishment in a year would involve dredging impacts that would result in a temporarily depleted benthic community over a small area of offshore substrate in the potential borrow areas, but would not impact the overall condition of the EFH or the benthic community offshore of the Seashore as a whole. If an emergency is declared following a severe storm event, an additional 6 miles of sediment management may be permitted every five years. Impacts from this scenario would likely be the same as those mentioned above, but at a slightly larger magnitude. Alternative B would also preserve approximately 13 noncontiguous miles (approximately 20% of the Seashore) as reference areas and remove them from consideration for sediment management activities in all cases except for emergencies. These reference areas may be used to perform comparative studies with nourishment project study areas. Information gained from these studies could further improve conditions associated with future projects, including modification of the frequency and timing of sediment management activities and other project parameters.

Alternative C would also provide a wider dry-sand beach, but sediment management activities would occur at fewer locations, less often than under alternative B. The impacts of each individual project would be the same as those described for alternative B, but the collective impact of all sediment management activities would be much less. Under alternative C, sediment management activities would occur along 6 miles of beach over a period of 5 years, rather than 6 miles each year as assumed under alternative B. It can be assumed that trends discussed in chapter 3 would continue under this alternative since project frequency would be similar to historic frequencies. Alternative C would not preserve reference areas, incorporate beneficial monitoring, or establish a holistic framework.

Alternative C would result in project specific impacts similar to alternative B; however, projects would occur at a lesser frequency resulting in less disturbance to the benthic community and EFH/HAPC. Over the course of 5 years, it is anticipated that impacts from sediment management activities would not exceed 9% of the Seashore.

While impacts from sediment management activities under alternative B are anticipated to last from six months to several years for benthic communities and EFH, alternative B may help maintain the continuity of the barrier island system at a management scale (months to years) by increasing or maintaining the volume of sediments available for erosion along some sections of the beach, dune, and sound side shorelines, thus creating and maintaining habitat for benthic communities. Because alternative A would not permit sediment management activities beyond emergency actions within the NC 12 ROW and alternative C would continue sediment management activities at a rate similar to current management, it is anticipated they may not maintain the barrier island system as effectively as alternative B.

SEA TURTLES

Methodology for Analyzing Impacts

The ESA (16 USC 1531 et. seq.) mandates that federal agencies ensure that any action authorized, funded, or carried out by the agency is not likely to jeopardize the existence of any endangered or threatened species or destroy or adversely modify their critical habitat, by consulting with the FWS and NMFS. Prior to any individual sediment management projects, site-specific design could be subject to project-specific permitting by the USACE.

Impact Analysis

Alternative A (No-Action Alternative)

Onshore and Nearshore Impacts

As discussed in detail under the “Littoral Processes and Barrier Island Morphology” section, under alternative A, relative sea-level rise and increased frequency and severity of storm events would result in varying rates of beach erosion and bring the wetted portion of the beach inland closer to the foredune or development and roadways leading to loss of dry sandy beach (Fish et al. 2005; Baker et al. 2006). Climate change would also impact sea turtle nesting by increasing the frequency and severity of storms that can erode or inundate nests (Michener 1997; Leatherman 2000; Pike and Stiner 2007; Van Houtan and Bass 2007), increasing density dependent impacts to nesting success (Tiwari et al. 2006), and elevating nest temperatures to levels that alter sex ratios or hatching success (Hawkes et al. 2007; Fuentes et al. 2010).

Sea turtles require dry sand beaches from 1.5 ft to 3.0 ft in depth for nesting (Tomillo et al. 2017). Relative sea-level rise and erosion may narrow the area which is suitable for sea turtle nesting and in general reduce the areal extent of appropriate nesting habitat (Baker et al. 2006; Reece et al. 2013). Habitat loss could be exacerbated in developed areas where the beach cannot naturally migrate inland in response to relative sea-level rise (Mazaris et al. 2009). The reduction in nesting habitat could cause an increase in false crawls, cause female turtles to nest in unsuitable locations or expend energy to find other areas that are appropriate for nesting. In some locations, the beach may become too narrow to support nesting by sea turtles, or the water levels on the beach may rise to a level that would inundate turtle nests causing nest failure. Lower, narrower beaches are more susceptible to sea-level rise than higher, wider beaches (Fish et al. 2005). A decrease in suitable nesting habitat could cause more sea turtles to nest within the remaining appropriate habitats. This could generate high nest densities on some beaches, and it may lead to an increase in density dependent impacts to sea turtle nests (Baker et al. 2006; Tiwari et al. 2006; Mazaris et al. 2009; Leighton et al. 2010). Density dependent impacts to sea turtle nests could include the destruction of existing nests by turtles excavating new nests and an increase in nest and hatchling predation in areas where nest densities are higher (Tiwari et al. 2006).

An increase in frequency and intensity of storm events would increase the overwash/inundation of sea turtle nests and the loss of nests to erosion (Milton et al. 1994; Addison et al. 1998; Van Houtan and Bass 2007). Addison et al. (1998) compared nest loss at a beach in Collier County, Florida, during a particularly active hurricane season, 1995, with nest loss during the previous and subsequent years which were more typical for the Atlantic Region, 1994 and 1996. In 1995, during an active storm season, 83% of nests were inundated and 27% of nests were washed out by erosion. In 1994 and 1996, 23% and 11% of nests were inundated and 1% and 2% of nests were washed away, respectively. This indicates a considerable increase in nest loss due to hurricane events. In addition, Van Houtan and Bass (2007) determined that at Dry Tortugas National Park, nest flooding is higher when tropical storm intensities are greater, and hatchling success declines as tropical storm intensity increases. At the Seashore, more intense tropical storms have inflicted greater impacts on sea turtle nests than other high tide events which may cause nest inundation or erosion. From 2014 to 2018, documented sea turtle nest loss to erosion caused by named tropical storms totaled 61 nests, compared to 27 nests lost to erosion during other high tide events (NPS 2017c; NPS 2017j; NPS 2017k; NPS 2018d; NPS 2019d). In addition, overwash fans caused by storm flooding could bury nests, trapping hatchlings and reducing emergence success (Milton et al. 1994).

To mitigate the effects of storm events, sea turtles distribute their nests both spatially and temporally and deposit large numbers of eggs into each nest. This strategy ensures that the total annual hatchling production is never fully affected by storm-generated beach erosion and inundation, although local effects may be high. During erosion events at the Seashore, some nests could be uncovered or completely washed away. Nests that are not washed away could suffer reduced reproductive success as the result of frequent or prolonged tidal inundation (NPS 2017c, 2017j, 2017k, 2018d, 2019b). Egg saturation with seawater could lead to embryonic mortality (Milton et al. 1994). However, Ernest and Martin (1999) determined that although frequent or prolonged tidal inundation resulted in fewer emergent hatchlings, occasional overwash of nests appeared to have minimal effect on reproductive success. Accretion of sand above incubating nests could also result in egg and hatchling mortality (Ernest and Martin 1999).

Offshore Impacts

NPS implementation of alternative A would not impact offshore sea turtles.

Cumulative Impacts

Past, present, or reasonably foreseeable actions that affect sea turtles include beach nourishment activities, channel dredging and dredge disposal, use of sand bags on private property, predation management for coastal species of concern, and ORV management. Beach nourishment activities have been reported to alter dry beach nesting habitat, deter nesting, and reduce hatch or emergence success. Observed declines in nesting on nourished beaches have been attributed to modification of the natural beach profile, sediment compaction, and escarpment formation. Typically, nesting activities return to normal in the second or third nesting season after project completion (FWS 2017). Nesting and hatchling impacts from beach nourishment have not been documented at the Seashore, and nests laid during the 2018 nesting season within the footprint of the 2017 Beach Restoration to Protect NC Highway 12 at Buxton Project exhibited higher hatch and emergence success than exhibited on average by other nests laid on beaches that were not nourished during the same season (NPS 2019d). Positive nesting results at the Seashore were most likely due to mitigation measures conducted during and after beach nourishment projects. These measures include ensuring material placed on the beach was similar to the existing beach sediment in terms of grain size and composition, identification and removal of escarpments, and soil density testing and tilling to identify and alleviate sand compaction. Beach nourishment projects at Nags Head (2011 & 2019); Rodanthe-Pea Island NWR (2014); Buxton (2017-spring 2018); and Duck, Kitty Hawk, and Kill Devil Hills (2017) followed similar mitigation measures to minimize impacts to sea turtles. Sea turtle impacts and benefits of sand placement onto beaches are described in detail below under alternative B. Overall, beach nourishment projects completed at the Seashore have benefited nesting sea turtles by helping to offset beach recession due to relative sea-level rise and preserving areas for sea turtle nesting.

Dredging at borrow locations could also entrain sea turtles (NMFS and FWS 2008; NMFS 2020b), and this has been recorded, albeit rarely, in association with beach nourishment projects on the Outer Banks. Other impacts at borrow locations would include those from sea turtle relocation by trawlers that removes turtles from the path of active dredges. Sea turtle relocation in itself is considered a take by the ESA and potential impacts could include physiological stress effects from forced submergence (Lutcavage and Lutz 1997; NMFS 2020b). Forced submersion of female sea turtles could also cause them to release part or all of an egg clutch into the water (NMFS 2020b). The impacts from dredging at potential borrow locations is described in detail under the alternative B impacts discussion.

Channel dredging and dredge disposal may impact sea turtles by entrainment of turtles during dredging and modification of the beach at the location of disposal including changing the beach profile, sediment compaction, and escarpment formation (similar to beach nourishment). Although small numbers of sea turtle takes have occurred during dredging for beach nourishment projects on the Outer Banks, no sea turtle take has been reported for dredging operations at Oregon Inlet. Telemetry data indicate sea turtles have traveled through Oregon Inlet while dredging activities were underway (McClellan 2009), and it is likely that sea turtles swam through and were not adversely affected by temporary increases in turbidity (USACE 2018; GARFO 2020). No negative sea turtle nesting impacts have been reported for the sand placement. In 2019, Dare County approved a contract to dredge Oregon Inlet for 340 days per year over the next 10 years. It is expected that sea turtle impact by entrainment is unlikely and they would swim through the turbidity plume to avoid the area (GARFO 2020).

NCDOT projects conducted at the Seashore include the construction of Basnight Bridge crossing Oregon Inlet and connecting Bodie Island with Hatteras Island. NCDOT also conducts dune restoration along NC 12 involving the removal of overwash sediment from the road to create dunes within the NC 12 ROW and protect the road from future flooding. To date, no sea turtle impacts have been reported by the Basnight Bridge construction, and because the bridge construction will not impact nesting beaches, no impacts would occur from the completion of the project. Dune restoration could impact sea turtles by removing small areas of nesting habitat within the ROW of NC 12; however, dunes are likely to benefit sea turtles by creating a buffer between the nesting beach and the road and reducing artificial light that may misorient nesting females or emerging hatchlings (Witherington and Martin 2000).

Sand bags may continue to be placed on private property and within the NCDOT ROW, and use may increase in the future under this alternative due to relative sea-level rise and more storms. Increased sand bag use could result in fewer successful sea turtle nesting emergences on the beach in front of the sand bags (Mosier and Witherington 2000). Sand bags would also limit sea turtle access to the back beach and foredune, and nests on beaches with sand bags would occur at lower elevations where they would be more susceptible to repeated inundation and erosion (Fish et al. 2005). Sand bags can also cause wave reflection and scour, processes that accelerate beach erosion seaward of the structure and steepen the offshore sediment profile (Kraus and McDougal 1996), and they prevent the natural landward migration of the beach system that may lead to the eventual loss of beach nesting habitat at that location (Rice 2009). Sand bag structures may also deteriorate, scattering bags and debris on the beach. Hatchlings do not avoid obstacles on the beach, so this debris may impede hatchlings migrating from the nest to the water and may lead to an increase in hatchling mortality from predation or dehydration (NMFS and FWS 2008; Triessnig et al. 2012). However, the projects envisioned under this cumulative action would be relatively small-scale (to protect individual private structures not on the Seashore beaches and NC 12) and would rarely take place on areas of the beach potentially used by sea turtles. Therefore, any adverse impacts on sea turtles would be highly localized, allowing for rapid recovery and recolonization following sand bag removal.

The *Coastal Species of Concern Predation Management Plan* could reduce nest and hatchling predation (NPS 2019b) by reducing prey species in the vicinity of sea turtle nesting. ORV use would result in compaction of sand, creation of ruts, and potential erosion on the beaches. These changes in sand may result in diminished nesting habitat for sea turtles. Additionally, ORV use could contribute to false crawls and strikes if nesting events occur within the ORV area. However, survey, monitoring, seasonal and night restrictions, and buffers would be undertaken to minimize these impacts.

For these reasons, past beach nourishment activities, channel dredging and dredge disposal, roadway improvements, and predation management have generally benefited sea turtles with some adverse impacts that are spatially and temporally limited. Future dredging activities are likely to impact sea turtles by limiting access to important foraging areas in Pamlico Sound, and although unlikely, impacts from entrainment are possible. ORV use may result in some adverse impacts, but protections are in place to avoid or minimize these impacts. When combined with the impacts of past, present, and reasonably foreseeable actions, alternative A would contribute noticeable adverse impacts to sea turtles from continued erosion, loss of shoreline, and the resulting degradation of potential nesting habitat.

Conclusion

Sea turtles have experienced shifts in climate and sea level over their evolutionary histories, and they have responded by shifting their distributions to more suitable habitat (Reece et al. 2013). Tracking studies indicate loggerhead sea turtles alter their nesting distributions over small spatial scales in response to climate change (Schofield et al. 2010). Sea turtles at the Seashore would also be likely to find new nesting locations as nesting beach area is lost. Redistribution of nesting locations would be complicated by coastal development (Mazaris et al. 2009) and the speed of sea-level rise (Fuentes et al. 2010). Sea-level rise is occurring quickly when compared to the evolutionary time frame, and sea turtles may not be able to adapt to nesting beach changes and alter their nest distribution fast enough to mitigate the loss of nesting beaches. If not, the density dependent impacts observed at other nesting beaches, such as intra-specific nest destruction and increased predation (Baker et al. 2006; Tiwari et al. 2006; Mazaris et al. 2009; Leighton et al. 2010), could occur at the Seashore and reduce overall nest productivity. The nesting trends described in chapter 3, are likely to decrease as available habitat decreases.

Alternative B (Proposed Action / Preferred Alternative)

Alternative B would result in a temporary disturbance to sea turtles as a result of sediment management activities. Specifically, dredging at offshore borrow locations and placement of sand on the beach would have the greatest potential for impacts on sea turtles. As described in chapter 2, offshore conditions may be too rough during the fall and winter to safely accommodate offshore dredging operations. It is likely that some project activities would occur in the spring and summer when sea turtles are nesting at the Seashore and present in offshore waters adjacent to the Seashore.

Onshore and Nearshore Impacts

Under alternative B, sediment management activities would take place on up to 600–800 ft of beach on any given day, and 200–300 ft of a project would be completed per day under normal conditions. Sediment management activities could include beach nourishment, habitat restoration, or breach repair. Heavy machinery used to grade sand on beaches could have adverse effects on sea turtles. The physical changes to the beach and loss of plant cover caused by vehicles on the beach or dunes could lead to instability and dune migration (FWS 2017). Vehicles could temporarily displace sand downward as they move, potentially lowering substrate. It is also possible, that in some areas, vehicles could inhibit plant growth and open areas to wind erosion. In the past, vehicular traffic on the beach or through the dunes has resulted in compacted beach sand, potentially causing localized overwash and erosion. Accessing the construction site directly from the road and driving along the beachfront between the low and high tide water lines would minimize impacts from vehicles on the beach (FWS 2017).

Per recommendations of FWS and NCWRC, all sea turtle nests laid within a sediment management study area before or during construction would be relocated to areas outside of active sand placement. During sand placement, nests laid within the study area, whether under active construction or not, would be relocated to a location outside of the study area. Site selection for the relocated nest and methodology would follow the *Handbook for Sea Turtle Volunteers in North Carolina* (NCWRC 2006). Nest relocation has become a standard management strategy, although considered a last resort, for protecting sea turtle nests laid in areas likely to experience disturbance (e.g., sand placement), erosion, or inundation. Some studies have documented higher hatch and emergence success in relocated nests than nests left in situ (Wyneken et al. 1988; Dellert et al. 2014), while other studies have documented lower hatch success of relocated nests than in situ nests (Baskale and Kaska 2005). At the Seashore, nests relocated during the 2014 to 2018 nesting seasons generally exhibited higher hatch and emergence success than in situ nests, including the 15 nests relocated from the 2017 Beach Restoration to Protect NC Highway 12 at Buxton Project (NPS 2017c, 2017j, 2017k, 2019d).

Relocation of sea turtle nests has inherent risks. Egg relocation could cause early embryo death if it occurs during the critical period of embryonic membrane organization, between 48 hours and 2.5 weeks after being laid (Kaska and Downie 1999). To minimize egg impacts, relocation of nests laid within areas of sand placement would occur as soon as possible after egg deposition and would be completed no later than 9 a.m. of the morning after egg deposition (i.e., within 12 hours) (NCWRC 2006). Handling of sea turtle eggs could increase the risk of accidental puncture or other structural damage to the shell that could reduce viability of the egg. Nest relocations at the Seashore would be completed with care to avoid damage to eggs from handling. From 2014 to 2018, no egg loss during relocation activities was reported in annual sea turtle monitoring reports (NPS 2017c, 2017j, 2017k, 2018d, 2019d).

Because sea turtle nest incubation time and sex determination are temperature dependent, nest relocation alters incubation time and could affect the sex ratio of hatchlings by raising or lowering the temperature of the nest environment (Baskale and Kaska 2005). The pivotal temperature for sex determination in sea turtles is the temperature which gives a 1:1 sex ratio. Above the pivotal temperature, mostly females develop, and below the pivotal temperature, mostly males develop. The pivotal temperatures for sex determination of sea turtles nesting at the Seashore are approximately 29ºC (84ºF) for loggerheads (Mrosovsky and Yntema 1980), approximately 29.3ºC (84.7ºF) for greens (Godfrey and Mrosovsky 2006), and approximately 30ºC (86ºF) for Kemp's ridleys (LeBlanc et al. 2012). However, these temperatures may vary up to 1ºC in either direction between populations. The Seashore is a northern nesting beach for sea turtle species, and it produces higher abundances of male offspring for populations that are highly female biased (Hawkes et al. 2007; Hays et al. 2014). Therefore, changes in the sex ratio of hatchlings at the Seashore could affect the population dynamics of the loggerhead sea turtle Northern Recovery Unit (Reneker and Kamel 2016), as well as DPS and recovery units for other sea turtle species that nest at the Seashore.

The primary sea-finding mechanisms for nesting sea turtles and sea turtle hatchlings are visual cues created by ambient light on the sea and determined by several factors including light wavelength and orientation (Mann 1978; Dickerson and Nelson 1989; Witherington and Bjorndal 1991; Frazer 1992). Artificial lighting near the beach could misdirect nesting turtles and hatchlings as they migrate from sea to nest or nest to sea (Mann 1978; Nelson et al. 2000; NMFS and FWS 2008), and a decrease in nesting activity has been documented on beaches exposed to artificial lights (Witherington 1992; Witherington and Martin 2000). Due to the unnatural beach slope created by sand placement on the beach, sediment management activities could expose nesting sea turtles and their nests to lights that were less visible from nesting beaches prior to sand placement. Artificial light exposure could lead to a higher incidence of misorientation or disorientation, which would greatly increase mortality of hatchlings and could cause mortality of nesting females. A review of 10 years of beach nourishment projects indicated the number of misoriented nesting sea turtles and emergent hatchlings is greater on the post-construction beach compared to pre-nourishment reports (FWS 2017). This is dependent on whether a constructed dune feature is included as a component of the project. When dunes are included as a component of the sediment management project, they help to block lighting impacts.

Indirect impacts on sea turtle reproduction success could occur during and after completion of sediment management projects (FWS 2017). Studies that documented a decline in nesting success on nourished beaches have generally reported a return to normal nesting activity by the second or third season after project completion (Steinitz et al. 1998; Ernest and Martin 1999; Rumbold et al. 2001; Brock et al. 2009). In the case of a severely eroded beach, the restoration of a higher, wider dry beach may enhance the quality of sea turtle nesting habitat. Immediate increases in nesting success have followed nourishment projects on chronically eroded beaches (Davis et al. 1999). However, sand placement could 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 (USACE 1988b). These changes could result in impacts to sea turtle nest site selection, digging behavior, clutch viability, and hatchling emergence (Nelson and Dickerson 1987; USACE 1988a), although some investigators found compaction did not affect sea turtle nesting (Davis et al. 1999). The time required for sea turtles to excavate an egg chamber would be substantially higher on hard-packed sands following beach nourishment than on natural beaches. However, over time natural processes would reduce compaction levels on beaches where sediment management has occurred, and digging times would return to normal during the second post-completion year (Ernest and Martin 1999; FWS 2017). These changes in beach properties would result in a higher rate of sea turtles abandoning their nesting attempts during the first year after sediment management than on natural beaches (Ernest and Martin 1999; Rumbold et al. 2001). Under alternative B, placement sand would match native beach sand in texture, composition, and color. Testing and tilling of placement sand would be required to mitigate for compaction and associated impacts from moisture content and temperature in the nest environment. For these reasons, it is unlikely that projects completed at the Seashore would result in impacts to sea turtle nest site selection, digging behavior, clutch viability or hatchling emergence resulting from incompatible sand.

Compaction and the modification of substrate characteristics such as grain size, density, organic content, and color can alter the nest incubation environment leading to adverse effects on embryonic development and hatching success (USACE 1988b; Crain et al. 1995; Baskale and Kaska 2005). As a result, beaches where sand is placed would retain more water than natural beaches reducing gas exchange within the nest environment (Crain et al. 1995; Ackerman 1980). Warmer nest temperatures, attributable to the placement of sediments that are darker than native sands (Hays et al. 2001), may impede embryonic development or increase the incidence of late-stage embryonic mortality (Kaska and Downie 1999; Baskale and Kaska 2005; Fuentes et al. 2010; Dellert et al. 2014). Also, as described above, warmer nest temperatures may also alter hatchling sex ratios. Holloman and Godfrey (2008) studied the effects of multiple beach nourishment events on sea turtle nesting and hatching success on Bogue Banks. The five-year study, from 2002 to 2007, monitored nesting activity, hatch success, emergence success, substrate compaction, and nest temperature. Beach nourishment had no significant effects on nesting success (i.e., proportion of false crawls to nest depositions was not significantly different). In general, no indication that nourishment adversely affected egg development or hatching success was reported; however, one nest apparently failed due to poor gas exchange. Also, nourishment had no significant effect on sediment compaction. Temperatures in nests within nourished areas were an average of 1.9°C warmer than nests laid at comparable times on undisturbed beaches. Sex ratios were not determined, but it was concluded that the increase in nest temperature on nourished beaches was likely to have increased the number of females produced (USACE 2018). These impacts would be reduced by using sand matching the grain size, composition, and color of the existing sand and reducing sediment compaction by testing and tilling the placement sand (Nelson and Dickerson 1987; USACE 1988b; Ernest and Martin 1999; NMFS and FWS 2008; FWS 2017). Under alternative B, placement sand would match native beach sand in texture, composition, and color. Testing and tilling of placement sand would be required to mitigate for compaction and associated impacts from moisture content and temperature in the nest environment.

Steep escarpments may develop on beaches where sediment management activities have occurred at the water line as they adjust from an unnatural construction profile to a more natural beach profile (USACE 1984). Escarpments may hamper or prevent access to nesting sites. Researchers have shown that female sea turtles coming ashore to nest can be discouraged by the formation of an escarpment, and they may 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) (FWS 2017).

The SPBO provides conditions and conservation measures as examples to further mitigate the effect of sediment management activities on beaches. In the SPBO, FWS concluded similar beneficial effects would result from an increase in sea turtle nesting habitat; and that a nourished beach designed and constructed to mimic a natural beach system would benefit sea turtles more than an existing eroding beach (FWS 2017). Also, the NPS concluded from previous beach nourishment activities that, while beach nourishment could temporarily adversely affect sea turtles during the dredging and sand placement period and lasting two to three years, it is likely to have beneficial effects post-completion as potential turtle nesting habitat is likely to expand from a wider beach (CSE 2015). In June 2019, the NPS engaged in preliminary conversations with the FWS. FWS indicated that the SPBO would not apply to the action alternatives under development by the NPS. FWS suggested a Biological Assessment could be submitted that addresses all areas of likely sediment management actives identified and the season in which projects would be most likely to occur. The NPS is working with FWS to develop a Biological Opinion specific to this framework.

The potential restoration of habitat on Green Island and at the south end of Hatteras Island is unlikely to adversely impact sea turtles or sea turtle nesting. Currently, sea turtles do not nest in this area because it is inundated by daily tides (NPS 2017c, 2017j, 2017k, 2018d, 2019d). Restoration of these areas could provide a small amount of sea turtle nesting habitat, relative to the 67 miles of existing shoreline at the Seashore.

Under alternative B, impacts due to sea-level rise, storm activity, and erosion would continue to occur similar to what has been observed in the recent past, documented in chapter 3, and described for alternative A including increased occurrence and severity of storm events (Michener 1997; Leatherman 2000; Pike and Stiner 2007; Van Houtan and Bass 2007), inundation of nests (Milton et al. 1994; Addison et al. 1998; Van Houtan and Bass 2007), loss of nests to erosion (Milton et al. 1994; Addison et al. 1998; Van Houtan and Bass 2007), a narrower steeper beach (Baker et al. 2006; Reece et al. 2013) that could increase false crawls and density dependent impacts (Baker et al. 2006; Tiwari et al. 2006; Mazaris et al. 2009; Leighton et al. 2010), and elevating nest temperatures to levels that alter sex ratios or hatching success (Hawkes et al. 2007; Fuentes et al. 2010). It is anticipated that the impacts could be less under alternative B (i.e., overwashes and island breaches occur less frequently, wider dry beaches remain available for nesting sea turtles, and fewer nests are inundated or lost to erosion), because the proposed increase of sediment management activities would help mitigate for the loss of sand from the beaches.

Alternative B would also preserve approximately 13 noncontiguous miles (approximately 20% of the Seashore) as reference areas and remove them from consideration for sediment management activities in all cases except for emergencies. These areas would remain open to sea turtle use, and in general, sea turtle activities within these areas would be unimpeded. Because sediment management activities would not normally occur, these areas and the sea turtle nests that may occur there could be subject to impacts from sea-level rise and erosion as described under alternative A. These impacts are not anticipated to occur more often than in recent past years, as documented in the Seashore sea turtle monitoring reports, because most of these areas were chosen to be reference sites due to indications from recent shoreline studies that they experience low rates of erosion or significant beach width.

The Seashore would complete ecological studies in the preserved reference areas that could be used for comparison to areas impacted by sediment management activities. In addition, alternative B would require biological monitoring before and after any significant sediment management project for the purposes of learning and improving conditions associated with future projects. This monitoring could include studies of wildlife use, sediment characteristics such as grain size and density which may affect sea turtle nesting, and other metrics that affect sea turtle use of the beach for nesting. This monitoring in combination with the sea turtle nest monitoring and management activities normally conducted by the Seashore could be used to inform current knowledge turtle use of areas where sediment management activities have occurred and the impacts of sediment placement on the beach to sea turtle nesting behavior, nest conditions, eggs, and hatchlings. Information gained from monitoring could further improve conditions associated with future projects including modification of the frequency and timing of sediment management activities, sediment characteristics, and other project parameters. Project proponents would develop monitoring protocols in association with individual sediment management projects.

Offshore Impacts

Under alternative B, dredging could potentially impact sea turtles by entrainment in the draghead during dredge operation, and it could also present obstructions or increase vessel strikes to sea turtles in transit through offshore borrow areas (NMFS and FWS 2008). Dredging of sediment within borrow areas would also disturb Northwest Atlantic loggerhead DPS critical habitat, specifically migratory and sargassum habitat. Additionally, dredging operations can adversely affect offshore habitats by contributing noise, altering or damaging hardbottom and reef habitats, directly removing important benthic prey organisms, and increasing turbidity (BOEM 2017).

Sea turtles would be vulnerable to entrainment by hopper dredges, and hopper dredge lethal takes of sea turtles have occurred during beach nourishment related dredging for projects occurring on the Outer Banks. Observations during dredging projects in Texas and Florida suggest that sea turtles may be captured during pipeline or cutterhead operations; however, cutterhead-sea turtle interactions are considered rare due to the slow movement of the cutterhead. A recent Biological Opinion for the Bogue Banks Master Nourishment Plan indicated that cutterhead dredges proposed to mine sand at offshore borrow sites near Bogue Bank were extremely unlikely to affect sea turtles and the risk of injury to listed sea turtles was discountable (NMFS 2018). Clamshell dredges have not been implicated in mortality of sea turtles during dredging operations (NMFS and FWS 2008). Also, the risk of sea turtle entrainment in the draghead during dredging in offshore borrow sites, including both state waters and the OCS, would be relatively low when compared to navigational channel dredging. Offshore borrow sites are generally more expansive allowing more flexibility to implement current mitigation requirements to minimize sea turtle entrainment (BOEM 2017). It is more likely that hopper dredges would be used in the borrow areas, so potential impacts from cutterhead or clamshell dredges would be less relevant.

Relocation trawling would minimize the risk of lethal take by hopper dredges. The trawler would sweep the area around the hopper dredge with a modified shrimp trawl net to capture and relocate sea turtles and other ESA-listed species that could be in the dredging area. While the intent of relocation trawling would be to reduce the occurrence of lethal take from hopper dredging, the relocation of sea turtles or other ESA-listed species would be, in and of itself, a form of take under the ESA for the species caught by the trawler (NMFS 2020b). Relocation trawling would likely affect loggerhead, green, Kemp's ridley, and, leatherback sea turtles, with little to no effect to hawksbill sea turtles (NMFS 2020b). Impacts from relocation trawling of sea turtles would include physiological stress effects from forced submergence such as high oxygen consumption (NMFS 2020b) and altered blood acid-base balance from lactic acid (Lutcavage and Lutz 1997). Generally, these effects would be a result of struggling against the net underwater (Lutcavage and Lutz 1997), and they may take hours to stabilize (Lutz and Dunbar-Cooper 1987). The stress of forced submergence could also cause gravid females to release all or part of a clutch of eggs. The worst-case scenario would be that the turtle drowns (NMFS 2020b).

Dredge operational noise may disturb sea turtles at the borrow areas. Studies of underwater sound levels from dredging activity indicate the source level of the dredging activity ranges between 160 and 185 decibel (dB) re 1µPa, approximately (USACE 2001b; Jones and Marten 2016). (In underwater acoustics, sound is typically described in terms of sound pressure level (SPL), and the standard unit of acoustic pressure is the micro Pascal [µPa].) Therefore, the amplitude of acoustic pressure is referenced to 1 µPa [re 1 µPA], and the units for SPL are dB re 1µPa.). BOEM published a study in 2014 in which they recorded the sound levels of three hopper dredges at various distances between 50 meters and 2 kilometers. Sound levels for all three dredges during sediment removal were between 170 dB re 1µPa and 185 dB re 1µPa. In general, sound levels were approximately at ambient levels at distances between 1 and 1.5 km, although for one dredge the sound level increased at 2 km compared to 1 km (BOEM 2014). These sound levels are above the NMFS established behavioral threshold of 160 dB but below the injury threshold of 204 dB for sea turtles (NOAA Fisheries 2020). Little is known about the effects of noise on sea turtles, but behavioral effects may include avoidance responses such as diving or an increase in swimming speed. Considering the mobility and avoidance behavior of sea turtles, behavioral effects would be transient and localized as the sea turtle moves through the borrow area (USACE 2018).

The potential borrow areas would be located within Northwest Atlantic loggerhead DPS critical habitat. However, many of the potential impacts associated with dredging and/or disposal activities for sediment management activities are not expected to occur at a level that would affect or modify the physical and biological features of the critical habitat including constricted continental shelf area that concentrates migratory pathways and passage conditions to allow for migration to and from nesting, foraging, or breeding areas (NMFS 2013). Dredging operations for beach nourishment would involve one or two dredges and relocation trawlers operating at any one time. Also, dredging and related activities within critical migratory habitat would not reduce prey species (hard-shell benthic invertebrates and crustaceans for loggerheads) abundance to an unsustainably low level (CSE 2015). Dredging would avoid hard bottom habitats important to loggerheads and impacts would be localized to the footprint of the dredging, leaving similar foraging and migratory areas available nearby. Prey species abundance and biomass within the dredged area would be expected to recover within two years after dredging occurs (Wilber and Clarke 2007; BOEM 2013; CZR and CSE 2014).

As described under alternative A, sea-level rise and the increase in the intensity and frequency of storm activity cause by climate change would not impact offshore resources located within the borrow areas.

The SARBO was initially provided by NMFS in 1995 to address dredging impacts to sea turtles, particularly their entrainment in the draghead (or hopper head). In 2020, NMFS released an updated SARBO to include species that have been added to the ESA since 1995 and to update conditions and project design criteria (PDCs) (NMFS 2020b). It provides a detailed analysis of sea turtle impacts from dredging operations and capture with relocation trawlers. In the SARBO, NMFS established strict annual limits on sea turtle takes for USACE and/or BOEM permitted dredging projects, including borrow areas; and NMFS concluded that take levels established by the SARBO are “not likely to jeopardize the continued existence of these species” (loggerhead, green, Kemp’s ridley, leatherback, and hawksbill sea turtles) (NMFS 2020b). Under the SARBO, the USACE and/or BOEM must report sea turtle takes during dredging operations to NMFS (NMFS 2020b). For that purpose, the Operations and Dredging Endangered Species System (ODESS) was developed, and it provides publicly available sea turtle take reports. Since the publication of the initial SARBO (1995) through the end of 2019, no incidental take of sea turtles has been recorded for dredging operations associated with beach nourishment projects at the Seashore although a few takes have been recorded during dredging for beach nourishment sand intended for other locations in the Outer Banks (ODESS 2020). Dredging activities associated with beach nourishment projects permitted at the Seashore would follow the sea turtle take limits determined by the NMFS and USACE and incorporate the Conservation Recommendations provided in the SARBO operating procedures.

All PDCs required in the SARBO would be incorporated into the individual projects and would include but not be limited to: trawl ahead of operating hopper dredges with certified turtle trawlers that would relocate sea turtles if encountered; ensure proper installation and function of a rigid draghead deflector; reduce vessel speeds while traveling to, from, and between borrow locations; and employ a qualified NMFS-approved protected species observer on the dredge(s) at all times. Observers would be required to document and record all sea turtle takes. Adherence to these mitigation measures would minimize sea turtle mortality through entrainment in hopper dredges.

Cumulative Impacts

The impacts from past, present, and reasonably foreseeable actions would be the same as those described under alternative A. Alternative B has the potential to adversely impact sea turtles, lasting the duration of construction and returning to normal in the second or third year after the completion of a project, but it would also contribute noticeable benefits to sea turtle species across the Seashore from the addition or expansion of nesting habitat over the 20-year lifetime of the management framework. From 2014 to 2019, negative impacts to sea turtle nesting numbers, e.g., numbers of nests, nest success, hatch success, and emergence success, have not been documented for the recent beach nourishment projects at the Seashore (NPS 2017c, 2017j, 2017k, 2018d, 2019d), likely due to mitigation measures taken during and subsequent to nourishment activities. Dredging for beach nourishment in the Outer Banks including the Seashore resulted in a few lethal sea turtle takes and dozens of non-lethal relocation takes (ODESS 2020). It is also anticipated that landowners and localities would continue to use sand bags on properties outside of the Seashore. Impacts from the use of sand bags would be the same as described for alternative A; however, under alternative B, the proposed increase in permitted sediment management activities could potentially reduce the need for use of sand bags on non-NPS lands.

When the incremental impacts of alternative B are combined with the impacts of past, present, and reasonably foreseeable actions, the overall cumulative negative impact on sea turtles would be limited spatially and temporally, but these actions would also benefit sea turtles by preserving or restoring dry beach habitat for nesting. Most of these impacts and benefits would be contributed by alternative B.

Conclusion

The Seashore encompasses 67 miles of shoreline, with some areas more suitable for sea turtle nesting than others. Alternative B would impact up to 6 miles of shoreline in any year, with the potential for an additional 6 miles of sediment management activities no more frequently than every 5 years due to catastrophic damage. At least 61 miles of the Seashore (91%) would remain available at any point, and of those 61 miles, 13 miles (approximately 20% of the Seashore) would be set aside as reference zones and not considered for sediment management activities (in all cases except for emergencies). With impacts potentially lasting through the first nesting season after project completion, a maximum of 12 miles of beach would exhibit some changes as a result of beach nourishment, representing less than 18% of available beach habitat for nesting sea turtles.

The placement of sand on a beach with reduced dry foredune habitat may negatively impact nesting sea turtles through compaction and the modification of substrate characteristics such as grain size, density, organic content, and color. These impacts would be limited to the study area and would last through the first nesting season after project completion. Alternative B would also result in increased sea turtle nesting habitat. FWS concluded beneficial effects would result from an increase in sea turtle nesting habitat; and that a nourished beach designed and constructed to mimic a natural beach system would benefit sea turtles more than an existing eroding beach (FWS 2017). Dredging could impact sea turtles through disturbance, placement of obstacles in migratory corridors, stress effects during relocation trawling, and direct take by the hopper dredge draghead.

Future nourishment and habitat restoration projects would implement mitigation requirements to minimize impacts to sea turtle nesting. With the mitigation measures in place, habitat restoration and beach nourishment under alternative B would help maintain sea turtle nesting habitat, prevent density dependent nest impacts, and ensure sea turtles continue to use the Seashore for nesting. In addition, a nourished beach that is designed and constructed to mimic a natural beach system would benefit sea turtles more than the narrow, eroding beach it replaces.

Alternative C

Under alternative C, sediment management activities would occur on up to 6 miles of beach every five years, rather than every year as would be permitted under alternative B, and projects would be less frequent. This would cause the same impacts as described in detail under alternative B but to a lesser extent. Alternative C does not include the reference exclusion zones.

Onshore and Nearshore Impacts

Potential impacts of individual beach nourishment projects on sea turtles in the beach and nearshore habitats would include disturbance during sand deposition (FWS 2017), changes in artificial light exposure (Mann 1978; Nelson et al. 2000; NMFS and FWS 2008), and change to conditions on the nesting beach including compaction, composition, beach slope, sand grain size, and sand color (USACE 1988b; FWS 2017). Changes in beach conditions could impact nest site selection, digging behavior, clutch viability, and hatchling emergence (Nelson and Dickerson 1987; USACE 1988a; FWS 2017); increase false crawls and nest attempt abandonment (Ernest and Martin 1999; Rumbold et al. 2001; FWS 2017); and increase nest temperature which could change the sex ration of hatchlings (Nelson and Dickerson 1987; USACE 1988a; Ernest and Martin 1999; NMFS and FWS 2008; Holloman and Godfrey 2008; FWS 2017). As described for alternative B, these impacts would be temporary (lasting two to three years), and the impacts would be mitigated by using sand with matching grain size, composition, and color of the existing sand and reducing sediment compaction by testing and tilling the placement sand (Nelson and Dickerson 1987; USACE 1988b; Ernest and Martin 1999; NMFS and FWS 2008; FWS 2017).

Although under alternative C the impacts of each project would be the same as under alternative B, there would be fewer sediment management actions over the next two decades, so the impacts would occur over a smaller area and less often than under alternative B. There would also be fewer areas that would experience repeated sand placement, which would provide more time for the beach to equilibrate and develop more natural conditions (Steinitz et al. 1998; Ernest and Martin 1999; Rumbold et al. 2001; Brock et al. 2009). In addition, impacts due to sea-level rise, storm activity, and erosion would continue similar to what has been observed in the recent past and is documented in chapter 3. It is also anticipated that these impacts could worsen as sea-level rise accelerates and severe storms increase in frequency while sediment management activities remain at the same level. These impacts would be similar to those described for alternative A but less in severity because some sediment management activities would continue to occur to protect resources at the Seashore.

Offshore Impacts

As described in detail under alternative B, dredging could potentially impact sea turtles by entrainment in the draghead during dredge operation (NMFS 2020b; NMFS and FWS 2008; BOEM 2017; NMFS 2018), and it could also present obstructions or increase vessel strikes to sea turtles in transit through offshore borrow areas (NMFS and FWS 2008). Dredging of sediment within borrow areas would also disturb Northwest Atlantic loggerhead DPS critical habitat (NMFS 2013). Additionally, dredging operations can adversely affect offshore habitats by contributing noise (Pearson et al. 1992; USACE 2018), altering or damaging hardbottom and reef habitats (CSE 2015), directly removing important benthic prey organisms, and increasing turbidity (BOEM 2017). Mitigation measures that would reduce impacts would be included in permit conditions, including survey for hard bottom habitat and establish buffers to protect it, trawl ahead of operating hopper dredges with certified turtle trawlers, use a rigid draghead deflector, reduce vessel speeds, and employ a qualified NMFS-approved protected species observer on the dredge(s) at all times.

Under alternative C, fewer sediment management actions over the next two decades would reduce the amount and frequency of sand removal from potential borrow areas. Fewer impacts to sea turtles and sea turtle habitats would occur, and impacted habitats would have more time to recover subsequent to dredging. As described under alternative A, sea-level rise and the increase in the intensity and frequency of storm activity cause by climate change would not impact offshore sea turtle resources.

Cumulative Impacts

Past, present, or reasonably foreseeable actions that would affect sea turtles would be the same as described above under alternative B and alternative A. Alternative C would impact sea turtles by disturbance during construction or dredging, changing beach and sediment characteristics, increase in artificial lighting exposure, placement of obstacles in critical migratory habitat, and removal of prey organisms from the dredge site. These impacts are similar to those describe for alternative B, but alternative C would cause a lower magnitude of these impacts over the next two decades. When combined with the impacts of past, present, and reasonably foreseeable actions, alternative C would result in temporary adverse impacts to sea turtles, with the incremental impacts of alternative C contributing most of the impacts.

Conclusion

Sand placement on the beach would impact sea turtles as described for alternative B, although due to less frequent proposed sediment management activity, neither the adverse impacts nor the benefits would be as extensive as those anticipated under alternative B.

Over the life of the next two decades, it is anticipated the completion of sediment management activities under alternative C would impact nesting beach temporarily and would not permanently degrade or impact the sustainability of the sea turtle community, nesting habitat, or migratory critical habitat. The size and rate of projects under alternative C would most likely result in an increase in nesting habitat. Given the temporary (lasting two to three years) nature of the impacts to nesting habitat for any individual project, it is unlikely the overall quality of beach nesting habitat at the Seashore or the sea turtle populations that use the Seashore would be reduced by sediment management activities under alternative C.

Comparative Conclusion of Alternatives

With no future permitted sediment management activities at the Seashore under alternative A, nesting habitat loss could be exacerbated throughout the Seashore and particularly in developed areas where the beach cannot naturally migrate inland in response to relative sea-level rise. An increase in frequency and intensity of storm events may increase the overwash/inundation of sea turtle nests, the loss of nests to erosion, and a decrease of available beach for nesting.

Based on recent nourishment efforts and the mitigation provided, there could be adverse impacts under alternatives B and C, compared to alternative A, but these would likely be temporary. Alternative B would permit sediment management activities along up to 6 miles of beach annually and up to 12 miles every 5 years for emergency actions, potentially impacting sea turtle habitat selection, nesting, and hatchling emergence through construction related activity and sediment composition. While impacts could last until the second or third nesting season after project completion, it is anticipated that mitigation measures either already in place or required by permits and/or consultation documents would limit adverse impacts and allow most, if not all, sea turtles that desired to nest in the study area an alternate opportunity in nearby locations; thereby improving the chances for the continued use of the Seashore for nesting by sea turtles. Additionally, landowners and localities would continue to use sand bags to protect buildings and private property. However, under alternative B, sediment management activities would potentially reduce the need for sand bags in the villages of the Seashore. Over the course of 20 years, it is possible that alternative B may create or stabilize habitat for sea turtles. FWS also concluded similar beneficial effects could result from an increase in sea turtle nesting habitat; and that a nourished beach designed and constructed to mimic a natural beach system would benefit sea turtles more than an existing eroding beach.

Alternative C would also provide a wider dry-sand beach for turtle nesting, but sediment management would occur at fewer locations and less often (6 miles of beach every 5 years) than under alternative B. The impacts of each individual project would be the same as those described for alternative B, but the collective impact of all sediment management activities would be less.

LISTED SHOREBIRD SPECIES

Methodology for Analyzing Impacts

The ESA (16 USC 1531 et. Seq.) mandates that all federal agencies consider the potential impacts of federal actions on the species listed as threatened or endangered, including critical habitat. Furthermore, NPS *Management Policies 2006* (NPS 2006) states that potential impacts of actions on federal lands would also be considered on state or locally listed species. The following analysis focuses on piping plover, roseate tern, rufa red knot, American oystercatcher, black skimmer, common tern, gull-billed tern, least tern, and Wilson's plover. Prior to any individual sediment management project, site-specific design may be subject to project-specific permitting by the USACE. The NPS is developing a biological assessment for the impacts of this framework on piping plovers. Relevant mitigations that may be developed through ongoing consultation with FWS will be added to this framework, pending availability.

Impact Analysis

Alternative A (No-Action Alternative)

As discussed in detail under the "Littoral Processes and Barrier Island Morphology" section, ongoing erosion and relative sea-level rise under alternative A may submerge habitats and result in habitat loss along the over 67 miles of beach at the Seashore's Atlantic coastline. In some locations, the beach may become too narrow or too steep to support nesting by listed shorebirds. This natural, yet ongoing erosion would increase the likelihood of overwash or an inlet breach from a storm event. Overwash fans or a new inlet would create additional sandy beach habitat on the beach and the sound side of the island, and may create suitable habitat for listed shorebird species that nest on the beach or feed in the wet beach environment including piping plover, gull-billed tern, least tern, common tern, black skimmer, American oystercatcher, and Wilson's plover. Habitat creation by these events would be of unknown size and last for unknown durations, based upon whether or not the new conditions persisted, or the area was restored by NCDOT to maintain access to other parts of the island(s) via NC 12. Depending on the dynamics of the overwash or breach, it could also remove other types of habitat such as mud flat or tidal marsh on the sound side, which may be used for foraging by species, such as red knot, American oystercatcher, gull-billed tern, least tern, and Wilson's plover. Over the span of decades, it is likely that under alternative A, the rate of erosion, coupled with relative sea-level rise, would ultimately lead to a reduction of land area at the Seashore, which would further decrease habitat availability for listed shorebirds. With less available nesting and/or foraging habitat at the Seashore, listed shorebirds would likely find other locations for these activities.

The way these potential changes would affect the listed shorebirds depends on how each species uses the Seashore. Piping plovers, colonial shorebirds (gull-billed terns, least terns, common terns, and black skimmers), American oystercatchers, and Wilson's plovers use the Seashore for breeding. While these species could move from eroded or submerged areas to other appropriate locations, as available (e.g., moving from an narrow eroded breach to a newly formed overwash fan), the reduction of breeding habitat associated with loss of overall land mass at the Seashore over the span of decades could affect listed shorebird species. Loss of habitat would be especially meaningful since these shorebirds have been designated as species of concern due to the ongoing loss of regional habitat caused by human development, human disturbance, and predation. Wilson's plover nest in small numbers, if at all, at the Seashore (NPS 2019b), and a reduction in available dry sand beach habitat due to erosion and relative sea-level rise would not affect this species to as great a degree as species that use the Seashore more often. Common tern, gull-billed tern, and black skimmers nesting numbers have been increasing over the last five years (NPS 2018c, 2019c, 2017d, 2017c, 2017e); American oystercatcher nesting trends have remained steady over the last five years (NPS 2018c, 2019c, 2018g, 2017c, 2017g); and least tern nesting has varied over the same period (NPS 2018c, 2019c, 2017c, 2017d, 2017e). Nesting of these species at the Seashore could remain within current trends or could slowly decline with decreasing land mass as birds move to other appropriate habitats outside of the Seashore.

Piping plovers are especially vulnerable, given the existing downward trend in numbers of nests occurring at the Seashore (NPS 2018c, 2019c, 2017a, 2017b, 2017c) and their strong site fidelity (FWS 2017). The importance of the Seashore for this species recovery is highlighted by critical habitat for wintering piping plovers designated at the Seashore by FWS (FWS 2001). This habitat would be subject to the same physical changes described above. Critical habitat for wintering piping plover was defined as wintering areas that are critical to the recovery of the piping plover, and the loss of these areas would hinder recovery of the species (FWS 2001). Additionally, the Seashore provides an important habitat for the piping plover as one of the only areas in which the species can be found year-round (FWS 2017).

Piping plovers, colonial shorebirds (gull-billed terns, least terns, common terns, and black skimmers), American oystercatchers, and Wilson's plovers also use the Seashore for foraging. Intertidal foraging opportunities would vary with the changing processes described above, with reduction along steepening beaches, submergence by relative sea-level rise, and creation along overwash areas. Over a span of decades, a net loss of land area could result in less foraging habitat available. Roseate terns and rufa red knots also use the Seashore for foraging and resting during migration. The rufa red knot forages both on mudflats and in intertidal areas during its migratory stopovers at the Seashore, and the reduction in intertidal habitats and food availability would impact them. Additionally, for the red knot, changing climate conditions could affect the species' food supply, timing of its migration, and its breeding habitat in the Arctic. Shifts in migratory patterns could lead to mismatches between bird arrival and peak periods of food availability (FWS 2017). The loss of foraging habitat at the Seashore and along its migratory route could compound other factors that have caused population reduction (such as habitat loss in other areas, human interference, and reduced availability of prey) and threaten the continued survival of red knots. Roseate terns also use the Seashore during migration, for resting as well as for foraging in the offshore Atlantic waters of the Seashore. Aquatic foraging habitat would remain readily available regardless of shoreline changes. Therefore, even if the land mass of the Seashore was reduced over the coming decades, the remaining land would continue to provide resting habitat for any migrating roseate terns.

Cumulative Impacts

Past, present, or reasonably foreseeable actions that affect listed shorebird species include beach nourishment activities, channel dredging and dredge disposal, predation management for coastal species of concern, and ORV management. Beach nourishment and dredge disposal activities have helped offset shoreline recession due to relative sea-level rise by increasing the sand budget of the area, and therefore may have preserved critical areas for shorebird feeding, nesting, and resting. Beach nourishment activities have also resulted in effects on shorebird species from flushing due to disturbance from heavy equipment, depletion of benthic prey base which reduces habitat quality, and reduced nest success during and after construction. These impacts were directly associated with sand placement and shaping, but these effects are temporary. Habitat use typically recovered as intertidal and swash zone benthic food sources recruit into the impacted area and the beach equilibrates to a natural slope (Peterson and Manning 2001; FWS 2017; Convertino et al. 2018).

Separately, inlet channel dredging activities would cause temporary adverse impacts to shorebird species at specific dredge sites due to disruption from the use of heavy machinery, but these impacts would dissipate once the dredge operation was complete and listed shorebird species could re-inhabit the area. In 2019, Dare County approved a contract to dredge Oregon Inlet for 340 days/year over the next 10 years. It is likely that dredging would deplete benthic communities within the inlet repeatedly over the life of the project. This would limit bird foraging opportunities in Oregon Inlet for over 10 years, and dredging noise would disturb shorebirds and could cause them to avoid the inlet for the entire length of the project. The *Coastal Species of Concern Predation Management Plan* could reduce chick and egg mortality associated with predation (NPS 2019b) by reducing predator species populations in the vicinity of shorebird colonies, nests, or individuals. ORV use managed under the final rule could result in disturbance to non-breeding shorebirds due to noise and presence of vehicles along Seashore beaches. ORV use could also result in dispersal of invertebrates in the use areas, which could limit available forage for shorebirds that feed on invertebrates. However, the areas designated for ORV use are relatively small compared to the size of the entire Seashore or they avoid locations historically used by shorebirds for nesting. Additionally, seasonal ORV closures and standard measures to create closed areas around nesting activity, nests, and chicks would protect breeding and nesting shorebirds.

Overall, past, present, and reasonably foreseeable actions have maintained habitat for listed shorebirds through beach nourishment projects and have protected shorebirds from predation events, but these actions have also caused impacts such as flushing and disturbance from the presence of ORVs and dredge and nourishment related equipment. Alternative A could result in continued erosion and loss of shoreline due to relative sea-level rise and more intense storm events, leading to degradation of potential nesting, foraging, and resting habitat for resident and migratory shorebirds. It would also lead to an increase in overwash events and the creation overwash fans that would provide new habitat for shorebirds. When the incremental impacts of alternative A are combined with the impacts of past, present, and reasonably foreseeable actions, the overall cumulative impacts on listed shorebird species would remove habitat, reduce available shorebird habitat quality, with the incremental impacts of alternative A contributing most of the impacts.

Conclusion

Over the life of the sediment management framework (20 years), under alternative A, the loss of habitat at the Seashore for piping plover, red knot, and roseate tern would be inconsistent with the goals laid out in the recovery plans for these federally listed shorebird species and would impede recovery (FWS 1996a, 1998, 2019a). The loss of habitat from sea-level rise is listed as a severe threat for each of these species and is indicated as a factor that is driving the threatened status determinations for the piping plover and red knot (FWS 1996a, 2013a, 2019a). It is likely that the loss of habitat at the Seashore for listed shorebird species would cause them to find habitat elsewhere. This shift in distribution would reduce these species populations at the Seashore, but the effects to the population of each species as a whole would be unknown. It is likely trends discussed in chapter 3, would continue in the short term (one-five years), but over the course of the framework, trends for all species could decline due to loss of available habitat.

Alternative B (Proposed Action / Preferred Alternative)

Alternative B would result in disturbance of listed shorebirds and alteration of listed shorebird habitat at the Seashore as a result of sediment management activities. Specifically, the placement of sediment on the beach would have the greatest potential to affect listed shorebird species. Addition of sediment to the shorelines would have the potential to temporarily decrease habitat quality by altering sediment particle sizes, eliminating sparse vegetation, and burying benthic invertebrate prey species. Alternative B would have additional short-term effects (lasting during project activities) on listed shorebird species, including displacement of nesting, foraging, and wintering birds due to disturbance by equipment use (FWS 2017). Back beach planting and installation of sand fencing to promote dune development would also impact shorebirds nesting and foraging at the Seashore.

Listed shorebirds present at the Seashore during the summer could be breeding and nesting or involved in courtship activities. Listed shorebird species that use the beach during this time for breeding include piping plovers, colonial shorebirds (gull-billed terns, least terns, common terns, and black skimmers), American oystercatchers, and Wilson's plovers. Potential impacts of sediment management activities on nesting shorebirds may include burial of existing nests and chicks, destruction of chicks and eggs by vehicular traffic, and disturbance of adult birds by construction noise leading to nest abandonment (FWS 1996a, 2017; Carney and Sydeman 1999). If projects occur in spring, it could result in failure to establish territory and prevent nesting.

Alternative B would also preserve approximately 13 noncontiguous miles (approximately 20% of the Seashore) as reference areas and remove them from consideration for sediment management activities in all cases except for emergencies. These areas would remain open to shorebird use, and in general, shorebird activities within these areas would be unimpeded. Because sediment management activities would not normally occur in these areas, these areas could be subject to impacts from sea-level rise and erosion as described under alternative A. These impacts are not anticipated to occur more often than in recent past years, as documented in the Seashore shorebird monitoring reports, because most of these areas were chosen to be reference sites due to indications from recent shoreline studies that they experience low rates of erosion or undergo accretion.

The Seashore would complete ecological studies in the preserved reference areas that could be used for comparison to areas impacted by sediment management activities. In addition, alternative B would require biological monitoring before and after any significant sediment management project for the purposes of learning and improving conditions associated with future projects. This monitoring could include studies of intertidal benthic communities, wildlife use, sediment characteristics such as grain size and density, and other metrics that may affect shorebird use of the beach. This monitoring in combination with the shorebird monitoring and management activities normally conducted by the Seashore could be used to inform current knowledge shorebird use of areas where sediment management activities have occurred and the impacts of sediment placement on the beach to shorebird nesting, behavior, and foraging. Information gained from monitoring could further improve conditions associated with future projects including modification of the frequency and timing of sediment management activities, sediment characteristics, and other project parameters. Project proponents would develop monitoring protocols in association with individual sediment management projects.

Assuming that sediment management activities would occur during shorebird nesting season, deposition of sediment onto beaches and shaping of that sediment with heavy equipment would have the potential to affect shorebird species using the Seashore at this time. Potential impacts would include flushing of birds by the sound and sight of heavy machinery (FWS 1996a, 2017). This disturbance could lead to nest abandonment or increased predation of eggs or chicks while the attending adult is away (FWS 1996a, 2017; Carney and Sydeman 1999) and can lower the chance of colonial shorebird recolonization in the future. During the 2017 Beach Restoration to Protect NC Highway 12 at Buxton Project, however, loss of preferred nesting habitat did not appear to occur, and nesting activity was avoided during the project; areas of nesting activity were then nourished when nesting concluded. To prevent direct impacts to nesting shorebirds, NPS staff would regularly patrol and monitor potential shorebird nesting areas (including study areas), and they would establish exclusion zones around areas with observed nesting activity by listed shorebirds. These zones would remain in effect until all nestlings fledge and all nesting activities are complete. Exclusion zones would be closed to the public and no sediment management activities would occur within them. This monitoring program at the Seashore would mitigate impacts from sediment management activities on nesting shorebirds.

Construction activity could also disturb foraging or wintering birds, but it is not likely that flushing would result in shorebird mortality. Shorebirds would most likely be displaced to other nearby areas along the Seashore (FWS 2017). Approximately 600-800 ft of beach would be impacted at one time with active sand placement, which is approximately 0.2% of the overall Seashore length, a majority of which currently provides suitable shorebird habitat. Approximately 200–300 ft of nourishment would be completed per day and would become immediately available for use by birds in the area the following day depending on the species tolerance to disturbance and proximity to human activity. The listed shorebirds included in the analysis tend to be more sensitive to human activity and would delay return to these habitats to greater than 10 minutes, unlike gulls which would return immediately (Burger et al. 2010).

Beach nourishment and dune creation at the Seashore would alter the natural profile and sediment composition of existing beaches at the Seashore (NPS 2010a; FWS 2017). In turn, native plant assemblages and successional processes would be interrupted, resulting in unnatural habitat conditions that could affect shorebird activity (NPS 2010a; FWS 2017). If the area does not receive repeated nourishment, the plant succession and ecological development would restart immediately after sand placement. Repeated nourishment events would regularly interrupt and restart successional processes causing disruption as long as nourishment continues. Altered particle size, favoring fine-grained sandy beaches would be one potential cause of changes in shorebird use on altered beaches (Cohen et al. 2008; Convertino et al. 2018). However, under alternative B, grain size, density, organic content, and color of sand placed on the beach would match the native beach characteristics, minimizing impacts to shorebirds.

Beach nourishment and dune creation could prevent overwash and inlet breaches, which create new shorebird habitat on flood delta platforms and input sediment to build the backshore. Shorebird species are routinely observed using overwash, and sparsely vegetated sandy deltas adjacent to newly formed inlets for breeding and foraging, while backshore provides important roosting habitat for many species (FWS 1996a, 2001, 2017; Peterson et al. 2006). However, in areas with suitable nesting habitat susceptible to overwash, beach nourishment and dune creation would serve as protection from nest mortality caused by overwash during storm events. Monitoring indicates nest overwash has historically been a common cause of nest, egg, and chick loss for various shorebird species (NPS 2017a, 2017b, 2017c, 2017d, 2017e, 2017g, 2017h, 2017i, 2018c, 2018g, 2019c).

Listed shorebird species would also use the Seashore for foraging. Specifically, piping plover, rufa red knot, American oystercatcher, Wilson's plover, and occasionally the gull-billed tern and least tern, prey upon invertebrates in the intertidal area (Cornell University 2017d, 2019; National Audubon Society 2019; FWS 2010, 2013b). As discussed in the "Benthic Communities and Essential Fish Habitat" section, sand placement would bury and suppress communities of benthic fauna along up to 6 miles per year of shoreline where NPS would permit sediment management activities. These impacts would be confined to less than 9% of the total length of the Seashore every year (with active construction related impacts affecting a much smaller area). At least 61 miles of the Seashore (91%) would remain available at any point. As mentioned above, of those 61 miles, 13 miles (20% of the Seashore) would be set aside as reference zones and not considered for sediment management activities (in all cases except for emergencies). Furthermore, if an emergency is declared following a severe storm event, an additional 6 miles of sediment management may be permitted, for a total of up to 12 miles every 5 years. In years where this kind of large-scale activity (or activities) are warranted, up to 18% of the Seashore may be impacted. These activities would reduce the availability of prey to many shorebird species within these areas (Peterson and Manning 2001; Greene 2002; Peterson et al. 2006; Speybroeck et al. 2006; Baptist et al. 2009; Wilber et al. 2009; Rosov et al. 2016; Wooldridge et al. 2016). Reductions in the availability of invertebrate prey could negatively affect the energy budgets of shorebirds, potentially resulting in reduced breeding potential or relocation from the depleted area (Evans 1976). If enough prey are not readily available for migrating shorebirds, the shorebirds may be forced to cease migration, or risk running out of energy prior to reaching their breeding grounds (Weidensaul 2018). In either of these scenarios, prey shortage reduces the chances of an individual to breed and stunts the population until food supplies recover, and normal migration can resume.

Abundance and diversity of the impacted benthic community would take between six months to several years to recover, and foraging habitat quality for relevant shorebird species would return to pre-impact levels (Peterson and Manning 2001; Greene 2002; Speybroeck et al. 2006; Baptist et al. 2009; Wilber and Clark 2007; Wilber et al. 2009; Leewis et al. 2012; CZR Incorporated and CSE 2014; Rosov et al. 2016; Wooldridge et al. 2016). Due to the benthic recovery rate, recurring sediment management actions over many years would not be expected to noticeably reduce the availability of invertebrate prey species within the entirety of the Seashore. Because a large proportion of unimpacted beach would be available at the Seashore for shorebird foraging, and because shorebirds are highly mobile, it is unlikely that impacts to benthic communities from sediment management activities would significantly affect the prey base of shorebird populations that use the Seashore (FWS 2017).

The rufa red knot may be a relatively brief visitor to the Seashore during migration in the spring, but this migration stopover is critical for foraging and energy renewal. A reason for the decline of red knot in the late 20th century was overharvest of the horseshoe crab, the eggs of which are a preferred prey species for the rufa red knot (FWS 2013b). Therefore, this species may be especially sensitive to changes in availability of invertebrate prey species along its migratory route. However, park biologists indicate the Seashore has historically provided limited foraging habitat for this species (NPS 2019b). When compared with seven other US Atlantic Coast locations, the Outer Banks ranked last in regional importance for red knots, and it is noted that this species does not nest in North Carolina (Dinsmore et al. 1998). Therefore, it is unlikely that sediment management activities at the Seashore would meaningfully impact red knots.

Roseate terns are also known to use the Seashore occasionally for foraging during migration, but expert birdwatchers from North Carolina consider roseate terns a rarity in the state. They estimate that there is less than a 10% chance of seeing the bird even during optimal times of year in prime offshore, open ocean habitats near the Gulf Stream (LeGrand 2020b). Sightings are even less common in nearshore and beach habitats. Roseate terns prey on fish that would remain available in offshore waters of the Seashore during and after sediment management activities; however, on the rare occasions when it comes ashore, it would be subject to flushing by beach nourishment activities, as described above. Due to its rarity at the Seashore, it is unlikely that sediment management activities at the Seashore would meaningfully impact roseate terns.

Sediment management activities could occur within piping plover critical habitat for wintering piping plovers units NC-1, NC-2, NC-4, and NC-5, and any proposed activities would be coordinated with FWS due to the heightened importance of these areas to the recovery of the species (FWS 2001). Unit NC-3, which includes several islands in the Pamlico Sound known as Bird Islands, is outside the area of likely sediment management activities. Unit NC-5 is located within a proposed reference area that is unlikely to be impacted by sediment management activities but could be impacted during an emergency action. Portions of unit NC-2 have been indicated as areas of potential sediment management and activities could occur within this portion of the critical habitat unit. The remainder of the critical habitat unit would be a reference area and impacts from sediment management activities would be limited to emergency actions. Under alternative B, sediment management activities to restore wintering and nesting habitat would occur within piping plover CWH unit NC-1, on Green Island, and unit NC-4, at the south end of Hatteras Island. Over the last 15 years, Green Island has eroded and is now completely gone, most likely due to boat traffic in Oregon Inlet increasing wave (or wake) energy, climate change causing relative sea-level rise, and increased storm frequency and severity. Unit NC-4 on the south end of Hatteras Island has lost approximately one mile of sand beach and nearly all suitable piping plover habitat since 2001, when the designated CWH was last revised. Because little to no habitat remains within these CWH units, sand placement and shaping activities would benefit piping plover by restoring historic wintering and nesting habitat.

Under alternative B, impacts due to sea-level rise, storm activity, and erosion would continue to occur similar to what has been observed in the recent past, documented in chapter 3, and described for alternative A including habitat loss (beach narrowing and/or steepening), loss of nests to inundation and erosion (FWS 2017; NPS 2017a, 2017b, 2017c, 2017d, 2017e, 2017g, 2018c, 2018g, 2019c), and a reduction of benthic forage resources (Beukema 2002; Galbraith et al. 2002; Fujii 2012; Birchenough et al. 2015). In addition, beneficial impacts such as habitat creation from overwashes would also occur under alternative B. It is anticipated that the impacts could be less under alternative B than alternative A (i.e., overwashes and island breaches occur less frequently, wider dry beaches remain available for shorebirds, and fewer nests are inundated or lost to erosion), because the proposed increase of sediment management activities would help mitigate for the loss of sand from the beaches.

Mitigation for activities would be determined by a BO issued by FWS as a result of NPS consultation for this sediment management framework. Mitigation measures may include, but are not limited to, the following:

- Notifying the FWS of commencement of activities for the purposes of tracking incidental take;
- Educating all personnel involved in the sand placement process of the potential presence of piping plovers;
- Conducting a visual survey in the area of work before the start of each work morning to determine if piping plovers are present;

- Carefully moving equipment if piping plovers are present in the work area to allow the individuals to move out of the area; and
- Initiating coordination with the FWS if any activities would potentially adversely affect nesting piping plovers or if activities are ongoing and piping plovers are being territorial or exhibiting other nesting behaviors (FWS 2017).

Cumulative Impacts

The impacts from past, present, and reasonably foreseeable actions would be similar to those described for alternative A. Sediment management at the Seashore has the potential to impact shorebird species through flushing and disruption during construction activities and burial of benthic communities necessary for foraging. It also could eliminate sparse vegetation on beaches where nourishment has occurred, limiting cover for nesting communities. These effects would last for the duration of construction and could last from six months to several years after, when numbers of benthic organisms would recover. Vehicular traffic and sediment addition may also bury or destroy shorebird nests, although this is unlikely and not anticipated due to mitigation measures already in place and additional measures required by SUP conditions. Placement of sediment along the shoreline could also create habitat for shorebirds in future years, as natural processes transport the sediment to new locations and redeposit it naturally, creating the sparsely vegetated beach habitats in which many shorebirds typically would nest. In addition, proposed habitat restoration at Green Island (critical habitat unit NC-1) and the south spit of Hatteras Island (critical habitat unit NC-4) would increase critical habitat for wintering piping plover in these areas. When the incremental impacts of alternative B are combined with the impacts of past, present, and reasonably foreseeable actions, overall cumulative impacts would be beneficial with the incremental impacts of alternative B contributing most of the impacts. Overall listed shorebird species would experience displacement, nesting impacts, and foraging impacts during construction and lasting from six months to several years after construction, but they may also experience an increase in available habitat at the Seashore with an increase in dry sand beach after sediment management activities over the course of the framework.

Conclusion

The implementation of multiple beach nourishment projects each year over the span of 20 years may result in greater availability of dry beach (when compared to alternative A) for resting and nesting habitat. It may also increase the availability of a wider (lower-sloped) intertidal beach (when compared to the no-action) and increase foraging habitat for species that prey on the invertebrate community. It may also disrupt listed shorebirds, their habitat, and available prey during implementation and up to a year after. A study conducted near Cape Fear, North Carolina, south of the Seashore, following a beach nourishment project conducted by USACE concluded that there were no significant changes in total shorebird abundance after nourishment and that habitat use may have increased at this beach (Grippo et al. 2007). This study did note that feeding behavior declined after nourishment but there was no clear effect on shorebird behavior as a result of the project. The study noted that a decline in shorebird feeding behavior could be short in duration. It is likely nests lost to overwash would decline on beaches where sediment management has occurred. Between 2014-2018, two large beach nourishment projects occurred at the Seashore and it appears trends for most shorebird species were not impacted, positively or negatively. It is likely that over the course of the 20-year framework, Seashore-wide, shorebird sightings, nests, and fledglings would continue to fluctuate, with some temporary (lasting from 6 months to several years) impacts at construction sites and an increase in activity at sites where a dry sand beach has been created or stabilized as a result of beach nourishment. It is also likely that an increase in the sediment budget along the Seashore may result in accretion in some areas where nourishment is not proposed, potentially expanding habitat for shorebird species. The habitat restoration projects proposed under this alternative at Green Island and the south end of Hatteras Island would also create suitable habitat for foraging and nesting. Alternative B would preserve approximately 13 noncontiguous miles as reference areas, and it would remove these areas from consideration for sediment management activities in all cases except for emergencies. These areas would remain open to shorebird use, and in general, shorebird activities within these areas would be unimpeded.

Under alternative B, impacts due to sea-level rise, storm activity, and erosion would continue to occur, leading to degradation of potential nesting, foraging, and resting habitat for shorebirds. In addition, beneficial impacts such as habitat creation from overwashes would also occur. It is anticipated that the impacts could be less under alternative B when compared to alternative A (i.e., overwashes and island breaches occur less frequently, wider dry beaches remain available for shorebirds, and fewer nests are inundated or lost to erosion), because the proposed increase of sediment management activities would help mitigate for the loss of sand from the beaches.

Ensuring protection of shorebird habitats is critical to the recovery of listed species, as outlined in relevant recovery plans, and beach nourishment activities would increase the longevity of shorebird habitats. The extent of this benefit would depend upon the number and extent of projects proposed, especially due to ongoing net erosion along the Seashore and the threat of rising sea level. As described under the “Littoral Processes and Barrier Island Morphology” section, adding new sand to the beach system may help maintain the integrity of the barrier islands in the long term.

Alternative C

Under alternative C, sediment management activities would occur on up to 6 miles of beach every five years, rather than every year as would be permitted under alternative B. This means that all of the approximately 67 miles of the Seashore would remain available as habitat at any given time with the exception of every 5 years when 61 miles would be available if sediment management activities are occurring; exclusion areas for reference monitoring would not take place under this alternative. This would cause the same impacts as described in detail under alternative B but to a lesser extent.

Addition of sediment to the shorelines would have the potential to temporarily decrease habitat quality by altering sediment particle sizes, eliminating sparse vegetation, and burying benthic invertebrate prey species (Speybroeck et al. 2006; Cohen et al. 2008; FWS 2017). Beach sand placement would also limit overwash and the creation of sandy deltas (FWS 2017). Equipment use on the beach could disturb and displace nesting, foraging, and wintering listed shorebirds; result in burial or destruction of existing nests by workers or vehicles; and lead to potential nest abandonment (FWS 1996a, 2017). These impacts would be mitigated by using sand with matching grain size, composition, and color of the native sand on the existing beach (FWS 2017), and the benthic community would recover naturally between six months to several years(Greene 2002; Speybroeck et al. 2006; Baptist et al. 2009; Wilber et al. 2009; CZR Incorporated and CSE 2014; Rosov et al. 2016; Wooldridge et al. 2016).

Although under alternative C the impacts of each project would be the same as under alternative B, there would be fewer sediment management actions over the next two decades, so the impacts would occur over a smaller area than under alternative B. There would also be fewer areas that would experience repeated sand placement, which would provide more time for benthic and vegetation communities to recover (Manning et al. 2014; Rosov et al. 2016). In general, it is expected that current trends in shorebird use and nesting at the Seashore would continue as documented by the Seashore monitoring reports, because sediment management activities would not increase over the historic rate.

Cumulative Impacts

Past, present, or reasonably foreseeable actions that would affect shorebirds would be the same as described above under alternative B and alternative A. Alternative C would impact shorebirds by disturbance during construction that could lead to nest abandonment, potential nest or egg destruction by equipment or personnel, alteration of beach and sediment characteristics, and removal of benthic prey species and sparse vegetation. These impacts would be similar to those described in detail for alternative B, but alternative C would have a lower magnitude of these impacts over the life of the framework. When combined with the impacts of past, present, and reasonably foreseeable actions, alternative C would result in temporary adverse impacts to shorebirds and increases in nesting and foraging habitat, with the incremental impacts of alternative C contributing most of the impacts.

Conclusion

Sediment placement on the beach for purposes of sediment management or for the restoration of habitat would impact shorebirds as described for alternative B, although due to less frequent proposed sediment management activities, neither the adverse impacts nor the benefits would be as extensive as those anticipated under alternative B. Under alternative C, 91% of the Seashore's shorebird habitat would remain undisturbed by sediment management activities every 5 years; the remainder of the time, 100% of the Seashore would be undisturbed by sediment management activities. No designated reference areas that exclude sediment management activities would be established under this alternative. It is anticipated that current trends in shorebird nesting and use of the Seashore would continue as described in chapter 3. This would include the increases and decreases in Seashore use by listed shorebirds as reported in the Seashore monitoring reports.

Under alternative C, impacts due to sea-level rise, storm activity, and erosion would continue to occur, leading to degradation of potential nesting, foraging, and resting habitat for shorebirds. In addition, beneficial impacts such as habitat creation from overwashes would also occur. It is anticipated that the impacts could be lessened under alternative C when compared to alternative A (i.e., overwashes and island breaches occur less frequently, wider dry beaches remain available for shorebirds, and fewer nests are inundated or lost to erosion), due to sediment management activities which would help mitigate for the loss of sand from the beaches. However, impacts may not be reduced as much as they would under alternative B, given the less frequent sediment management activities permitted under alternative C.

Over the life of the proposed framework, it is anticipated the completion of sediment management activities under alternative C would temporarily impact nesting shorebirds and habitat but would not permanently degrade or impact the sustainability of the shorebird community, nesting habitat, or piping plover CWH. The size and rate of projects under alternative C would most likely result in an increase in nesting, foraging, and wintering habitat. Given the temporary (lasting from six months to several years) nature of the impacts to these habitats for any individual project, it is unlikely the overall habitat quality at the Seashore or the listed shorebird community that use the Seashore would be reduced by sediment management activities under alternative C.

Comparative Conclusion of Alternatives

Under alternative A, shorebirds would not be impacted by construction related activity associated with the NPS permitting of sediment management activities. It is likely erosion would continue along the Seashore and in areas where the island is prohibited from migrating landward due to development, there could be a loss of dry sand beach necessary for habitat. This loss could impact nesting, resting, foraging, migrating, and wintering shorebirds, and shorebirds would most likely be displaced elsewhere. Alternative A could increase the chance of overwash fans and inlet breaches in undeveloped areas which, although rare, could create new habitat on the sound side shoreline, which would benefit shorebirds. Alternative B would introduce impacts (lasting hours to several years) associated with construction noise and habitat disturbance, as well as disturbance to benthic communities vital for foraging shorebirds. These impacts would be confined to less than 9% of the total length of the Seashore every year (with construction related impacts affecting less area), as described earlier in this chapter. Alternative B may also create a wider dry sand beach necessary for nesting and foraging for shorebird species. Additionally, the potential restoration of habitat on Green Island or the south end of Hatteras Island and other areas of the Seashore may increase the total available habitat for shorebirds at the Seashore, generally improving conditions for these species. Under alternative C, 67 miles of the Seashore would remain available at any given time with the exception of every 5 years when 61 miles would be available if sediment management activities are occurring; exclusion areas for reference monitoring would not take place under this alternative. Alternative C would impact and benefit listed shorebirds similarly, but on a smaller scale than alternative B. Benefits from the monitoring component and holistic framework associated with alternative B would not be seen with alternative C.

STRUCTURES AND INFRASTRUCTURE

Methodology for Analyzing Impacts

The focus of this impact analysis is on changes to how residents, visitors, Seashore staff, and emergency personnel access the Seashore, as well as how that access affects the local economy and property values. NC 12 is the only access road into and out of the Seashore and is essential for access to villages and private property. Additionally, the economies of Dare and Hyde Counties are primarily tourism-based, and partially rely on the beauty of and opportunity to enjoy the Seashore, as well as a functioning NC 12 which provides access for those visitors to the Seashore. Past planning documents, park statistics, and input from park staff provide background on visitor use and experience at the Seashore and were used to estimate the effects of the alternatives on resident and visitor experience. Major storm and extreme high tide events, road closures, flooding, and relative sea-level rise result in substantial economic impacts; loss of access to hospitals, fire, and police protection; loss of accommodations tax revenue; and related devaluations of businesses and property. Anticipated impacts on socioeconomics and private property were analyzed using information from public records, previous studies, and similar project experience.

Impact Analysis

Alternative A (No-Action Alternative)

Under alternative A, the current risk factors affecting the Seashore and surrounding communities, including erosion and damage during severe weather events, would continue or worsen. NC 12 would remain vulnerable to continued erosion and overwash and would be at a higher risk for future roadway damage. With relative sea-level rise rates along the Seashore at approximately 0.2 in per year (NOAA 2020b), it is likely that storm and extreme high tide events may produce more severe overwash and erosion in the future. It is expected that under alternative A emergency closures of NC 12 would continue to occur and possibly increase after storm and extreme high tide events.

Given current conditions and anticipated future relative sea-level rise, there is an increased risk for NC 12 to be closed due to storm damage and remain closed until repairs to the roadway and utilities are completed. Because this is the only road into and out of the Seashore, as well as the major artery through the local communities, closures of NC 12 would cut off residents and visitors from important services and supplies such as hospitals and grocery stores, depending on where the closures occur. Between 2013-2020, NC 12 closed entirely, or was impassible, 74 times at the Seashore (NCDOT, Williams, pers. comm., 2020). Within this time span, the highest number of total road closures or impassible events (22) occurred in 2019 (NCDOT, Williams, pers. comm., 2020). If either Ocracoke Island or Hatteras Island were breached during a future storm event, NCDOT would run limited ferry routes depending on the location of the breach and would not create new emergency ferry basins or docks; this may further limit access to or evacuation from the islands for residents and visitors.

The following serves as an example of a recent storm event that resulted in closure of portions of NC 12 and limited access to the Seashore. In September 2019, Hurricane Dorian resulted in NC 12 becoming impassable due to overwash and severe damage, cutting off access to Hatteras Island and Ocracoke Island for an extended time (Dare County News 2019). During the recovery process, access to ferry service to Ocracoke Island was limited for the first few days to emergency responders, crews bringing supplies, and law enforcement (NCDOT 2019a). Emergency ferry services were implemented between Hatteras and Ocracoke Islands, bypassing the closed section of NC 12, to bring hurricane relief supplies and personnel to Ocracoke Island as well as to evacuate stranded residents. The ferry service took two-and-a-half hours for a one-way trip; the normal ferry trip when NC 12 is open is one hour (NCDOT 2019b). Future closures similar to this are expected to continue under alternative A, and emergency ferry services or other means of providing access would likely be required after severe storm and extreme high tide events.

Public Health and Safety

Limited access due to NC 12 damage may continue to result in adverse impacts on public health and safety if residents and visitors cannot access hospitals, grocery stores, or other needed supplies. For example, as discussed above, Hurricane Dorian resulted in closure of portions of the Seashore to residents and visitors while emergency crews cleared NC 12 of sand, water, and debris. In the hardest hit areas on Ocracoke Island, emergency ferry services were implemented to bypass the closed section of NC 12. Though the emergency ferry services provided needed access into and out of those areas, it increased the travel time from Hatteras to Ocracoke Island and then to final destinations such as a hospital or grocery store from a one-hour ferry ride to a two-and-a-half-hour ferry ride plus travel time to a nearby community (Hallac 2019). Although this is an example of a major storm event, similar, if less intense, closures of NC 12 occur under more typical seasonal storm and flooding events.

Visitor and Resident Access and Experience

Under alternative A, the current risk factors affecting visitor and resident access and experience would continue or worsen. If NC 12 continues to see overwash and damage during future storm and extreme high tide events, residents and visitors would have limited access to the Seashore until the road is cleared and/or repaired. Lack of access to areas of the Seashore would limit recreational and tourism opportunities during the closures, and potentially drive people to leave or stop coming to the Seashore. Visitation at the Seashore in 2019 was 2.6 million, the highest in 15 years, suggesting visitation would continue to increase and, therefore the number of visitors impacted by storm and extreme high tide events and alternative A would increase (NPS 2019f and 2020a). During future storm and extreme high tide events, local businesses may be inundated with storm surge, preventing viable tourism opportunities and negatively impacting visitor and resident experience through the closure of many amenities.

Erosion rates of Seashore beaches would continue or worsen. Over time, this would result in a loss of beach areas and recreation access, limiting areas for recreation such as sunbathing, walking, beachcombing, picnicking, surf fishing, ORV use, and surfing. This loss would diminish the resident and visitor experience as people may lose access to preferred beach areas and the remaining areas would become more crowded due to the lack of other opportunities. It is likely that existing public parking lots would see damage and overwash during future storm and extreme high tide events, which would diminish the visitor experience due to lack of parking and closures. If damages to infrastructure during storm and extreme high tide events occur, NPS visitor facilities may close for repairs. These closures would adversely affect the visitor and resident experience if they are otherwise able to access some areas of the Seashore, but not all NPS facilities.

Socioeconomics and Private Property

In 2019, 2.6 million visitors spent more than $168 million in communities within and near the Seashore. This spending supported 2,422 jobs in the local area and had a cumulative benefit to the local economy of $211 million (NPS 2020a). Under alternative A, the expected continuation of damage due to continued erosion, relative sea-level rise, and future storm and extreme high tide events would have long-term implications for the future health of the local economy. Property owners, including state and local agencies, would be subject to economic losses resulting from future maintenance needs, costs of repairs and temporary emergency measures, and losses in local tourism revenues.

NC 12 closures would have adverse effects on the local economy, as communities at the Seashore would be isolated from the mainland until access is restored. As mentioned in chapter 3, the closures are becoming more common. Most recently, this occurred after Hurricane Dorian when Ocracoke and Hatteras Islands were inaccessible due to severe damage and closure of NC 12. Figure 20 in appendix A shows an example of flooding experienced along NC 12, inundating utility poles. Both Hyde and Dare Counties rely heavily on tourism activities. Such closures have interrupted and would continue to interrupt visitation to the Seashore, and by extension, would disrupt house and lodging rentals and business operations. If transportation routes are closed due to storm damage or chronic erosion, communities at the Seashore, as in the past, would have to seek alternative ways of transporting materials, goods, and services, likely by ferry or small plane. However, the existing ferry system has limited capacity to transport visitors and materials to the Seashore. Based on an estimated cumulative benefit to the local economy of approximately $211 million per year from visitation, each day of road closure on Hatteras and Ocracoke Islands has a potential to severely impact business and tax revenues (NPS 2020a).

In addition to NC 12 closures, erosion and rising sea levels would continue to put private properties at risk of flooding and damage, reducing the attraction to the area and decreasing the ability to recruit local work force. Property damage and other access disruptions would also negatively affect revenues from the Occupancy Tax and Food and Beverage Tax, generally used towards local services and maintenance. Losses in revenues from the Occupancy Tax and/or Food and Beverages Tax could result in increases in property taxes while property values decrease or decreases in services to offset these losses, meaning both local residents and the future health of the tourism industries would be affected. Figure 25 in appendix A shows how beachfront erosion has affected private property at the Seashore.

Under alternative A, as erosion progresses and sufficient room to maintain protective dunes no longer exists, the state, county and individual property owners are likely to implement more short-term emergency measures during storm events, such as placing sand bags and pushing sand that came from the Seashore onto private property back onto the dunes. Costs associated with future roadway, infrastructure, and property repairs as well as the necessary emergency measures would be dependent on timing, frequency, and severity of future storm events. Consequently, there is the potential for very high costs associated with these needed repairs and emergency measures. Erosion and rising sea levels coupled with severe weather events would also cause damage to developed property at the Seashore. Economic losses would result not only from the cost of continuous property repairs, but also from depressed property values, lack of recruitment to the labor force, and loss of tourism-based revenue.

Cumulative Impacts

Past, present, and reasonably foreseeable actions that would affect structures and infrastructure include past beach nourishment activities, channel dredging, roadway improvements, and ORV management. Past beach nourishment activities have added sediment to the system. This sediment has temporarily reduced erosion and damage on NC 12 and beach front properties through the creation of a wider beach. These beaches will remain vulnerable to erosion over time. Past beach nourishment activities may have affected the volume and occurrence of overwash onto NC 12. Past, present, and future dredging of Oregon Inlet has caused and may continue to cause erosion to the south end of Bodie Island, referred to as the Bodie Island Spit. This erosion may result in reduced recreational opportunities for visitors in this specific site. Past and future ferry channel dredging has resulted in and may continue to result in beneficial impacts to Seashore access by improving the reliability of ferry services to and from areas of the Seashore. Roadway improvements may continue to result in improved access to and from the Seashore for residents and visitors. These improvements may also allow for more efficient evacuations prior to storm and extreme high tide events and more efficient emergency response after such events.

ORV management actions would provide expanded access for ORV use in the Seashore, which would be both beneficial and adverse to visitors and residents. Visitors and residents using ORVs may find the designated routes beneficial because they would be able to experience more of the Seashore via ORV. Other visitors may find the presence of any ORV on the beach a disruption to their experience. There would likely be no impacts on socioeconomics or private property due to ORV management. Overall, these past, present, and reasonably foreseeable actions have and would continue to have temporary and localized beneficial cumulative impacts on structures and infrastructure, impacting visitor experience, with some adverse impacts occurring at certain sites such as the Bodie Island Spit.

Under alternative A, NC 12 would remain vulnerable to erosion and damage. Limited access due to this may continue to result in adverse impacts on public health and safety if residents and visitors cannot access hospitals, grocery stores, or other needed supplies. Over time, erosion would result in a loss of beach areas and recreation access, which would diminish the resident and visitor experience. In addition to NC 12 closures, continued erosion and rising sea levels may continue to put private properties at risk of flooding and damage and decrease the ability to recruit local work force.

When the incremental impacts of alternative A are combined with the impacts of past, present, and reasonably foreseeable actions, the overall cumulative impacts to Seashore access would be adverse, with the incremental impacts of alternative A contributing most of the impacts.

Conclusion

Over the life of the sediment management framework (20 years), under alternative A, the Seashore's vulnerability to severe weather events would continue. As relative sea-level rise continues and the intensity of storm systems increase, it is increasingly likely that NC 12 would be inaccessible during and after storm events due to overwash and damage. Public health and safety would continue to be at risk during these closures because NC 12 is the only road into and out of the Seashore. Closures of NC 12 could cut off residents and visitors from important services and supplies such as hospitals and grocery stores, depending on where the closures occur. Closures of NC 12 and limited access to the Seashore would be detrimental to the local economy because it relies heavily on tourism. If tourists are unable to visit areas the Seashore due to lack of access via NC 12 or due to loss of beach areas due to erosion, local business owners would see losses in tourism revenue. Additionally, property owners and responsible entities at the state and local level would be subject to economic losses resulting from future maintenance needs, costs of repairs and temporary emergency measures, depressed property values, and lack of visitors. The magnitude of these impacts would depend on the severity and intensity of future storms, and impacts may be localized. However, it is likely that the Seashore, residents, and local economy would be increasingly more vulnerable to major storm events under alternative A.

Alternative B (Proposed Action / Preferred Alternative)

Sediment management activities authorized by the NPS may temporarily reduce the current risk factors affecting the Seashore (including erosion) due to the temporary widening of beaches and the stabilization of dunes. This sediment placement may mitigate damage to NC 12 from erosion during future storm events, which may reduce the frequency of closures. Specific beach nourishment actions permitted under alternative B would be designed to consider relative sea-level rise and may allow the Seashore to be more resilient during and after intense storm events. Although closures of and damage to NC 12 as a result of storm events would not be eliminated, reduced frequency of closures and a reduction in the severity of damage would improve the overall resiliency of the Seashore after storm events and may help restore access for residents and visitors.

Public Health and Safety

Alternative B may reduce the frequency of road closures by protecting NC 12 from overwash and damage during future storm and extreme high tide events; the level of protection would be dependent upon when and where sediment management activities are conducted and the type of storm event that occurs. A reduction in closures would allow access to hospitals, grocery stores, and other services accessed via NC 12 to be maintained or restored more quickly after storm and extreme high tide events. Because NC 12 would be less vulnerable to severe damage from such events, NCDOT would be better able to clear the road of sand and debris and reopen the road more quickly when compared to alternative A. This would allow for faster response of emergency supplies and personnel to areas in need after a major storm or extreme high tide event. As evidenced by the 2017 Beach Restoration to Protect NC Highway 12 at Buxton Project, the placement of nourishment projects may significantly reduce overwash and road closures for at least a couple years following the conclusion of the project.

Visitor and Resident Access and Experience

Over the life of alternative B, sediment placement may reduce road closures, temporarily helping to maintain continued access to beachfront communities and beaches of the Seashore. Because NC 12 is the only road into and out of the Seashore, reduced closures after storm events may improve overall access for residents and visitors. Because NC 12 may temporarily be less vulnerable to severe damage from storm events, NCDOT may be better able to clear the road of sand and debris and reopen the road more quickly when compared to alternative A. This may allow for faster response of emergency supplies and personnel to areas in need after a major storm event and may allow for evacuated residents to return more quickly. Although closures of NC 12 due to storm events would not be eliminated, access to destinations, grocery stores, and other services accessed via NC 12 may be maintained or restored more quickly after storm events, which would be a beneficial impact on resident and visitor experience.

The sediment placement authorized under alternative B may temporarily reduce erosion rates of Seashore beaches, thereby helping to maintain recreation access to beaches and areas for recreation such as sunbathing, walking, beachcombing, picnicking, surf fishing, ORV use, and surfing. NPS visitor facilities, including buildings and parking lots, may be at a reduced risk of damages related to erosion which may reduce the frequency and duration of closures. When NPS visitor facilities can reopen more quickly after storm events, the overall visitor experience of the Seashore would be improved when compared to alternative A.

In the unlikely event that sediment is brought to a site by truck instead of piped directly from a dredging operation, every million cubic yards would require approximately 65,000 15-cy dump truck loads delivered to the project site. It is likely a trucking project would disrupt local traffic patterns around the project site and could lead to additional wear and tear on roads within the Seashore. However, because there are limited upland sand resources within an economical distance to the Seashore it is likely that nearly all beach nourishment projects performed under alternatives B would be performed via dredge and fill operations.

Although sediment placement authorized under alternative B may increase the resiliency of some shoreline areas of the Seashore after storm events, it may also result in periodic, short-term disruptions to access at varying locations during beach nourishment activities. During implementation of these activities, sections of beaches actively undergoing sand placement and movement would be closed to the public, which would disrupt the visitor experience. The active work zone would be cordoned off for safety but sections of beach within approximately 200 ft of the work area would be free of equipment and remain open for public use. The open section of beach would have a single pipe running the length of the section back towards the landing pipe (from offshore). Sand ramps would be constructed across the pipe every 100-200 ft to provide ingress and egress for equipment and the public. The presence of construction equipment may also diminish the visitor and resident experience through visual and noise disruptions. These closures and disruptions may only last the duration of each beach nourishment project (less than one year) and would take place in incremental lengths of 600-800 ft (less than 0.2% of the Seashore). Overall, the total beach area affected would be approximately 6 miles, or less than 9% of the Seashore per year. At least 61 miles of the Seashore (91%) would remain available at any point, and of those 61 miles, 13 miles (approximately 20% of the Seashore) would be set aside as reference zones and not considered for sediment management activities (in all cases except for emergencies). In the event of a catastrophic event or extreme weather year, up to 12 miles of nourishment activities may take place no more frequently than every 5 years, which would result in additional areas of beach closure; however, the overall beach area affected would still be relatively small at only 18% of the total Seashore and only incremental areas being closed to access during active sand placement.

Socioeconomics and Private Property

Sediment placement along the shoreline would reduce wave runup resulting in a beneficial effect on nearby infrastructure and NC 12. The addition of sediment at various locations along the Seashore may temporarily benefit the local economy in Dare and Hyde Counties because, until the added sediment erodes away, properties may experience less adverse effects from human-caused erosion and storm events and access may be interrupted less frequently and/or for a shorter duration after storm events. The temporary beneficial impacts would be felt region-wide because of the dependence of Dare and Hyde Counties on tourism and access to the Seashore. NPS estimated that visitor spending at the Seashore supports 2,422 jobs in the area (NPS 2020a). Alternative B may result in the temporary reduction of the adverse effects of erosion, storm damage, and relative sea-level rise on these jobs (and recruitment potential) through improved reliability of access for consumers and employees when compared to alternative A. Because of the temporary but beneficial secondary impacts on local buildings and infrastructure from sediment management activities under alternative B, Seashore visitation and tourism would be less subject to interruption due to closures and damage.

Although damage to beachfront properties and infrastructure during future storm events would not be eliminated, sediment management activities may reduce damage to these properties and infrastructure by creating a wider beach profile and reducing wave runup, which would benefit private property. The number of years of reduced damage from erosion and storm events would depend on the frequency and magnitude of future storms, relative sea-level rise, and other human-caused impacts on natural shoreline processes. Benefits to private property would last as long as the sediment remains in place, which would vary from one location to another. However, overall, the sediment added to the Seashore under alternative B would be expected to reduce the frequency and severity of storm and erosion damages to buildings and infrastructure through a wider beach profile and higher dunes. It may also reduce the need for temporary emergency measures during storm events. Overall, costs resulting from damages or emergency protective measures and repairs may be reduced as a result of alternative B.

The magnitude of the beneficial impact would be dependent on how long any newly added sediment remains in place. Overall, the potential economic benefits of alternative B, specifically the resulting benefits for private properties and access along NC 12 over the life of the permitted projects, may offset the cost of individual beach nourishment projects.

Because the sediment management activities conducted under NPS permits would require closure of portions of Seashore beaches during such activities, there would be some limited adverse impacts to the local economy. Businesses or rental property owners adjacent to closed beach areas may see a reduction in tourist activity during the time of closure. However, impacts would not be widespread as only 600-800 ft of beaches (less than 0.2% of the Seashore) would be closed at any given time for each project. Overall, the total beach area affected would be approximately 6 miles, or less than 9% of the Seashore per year (and up to 12 miles in the event of a catastrophic event or extreme weather year – 18% of the Seashore), as described earlier in this chapter. Therefore, alternative B would not likely deter visitors to the area.

These localized impacts are expected to last only the duration of the sediment management activities, or less than one year for each project. Given the limited geographic area of impact at any given time and the limited timeframe, these impacts are not considered substantial.

Cumulative Impacts

The impacts from past, present, and reasonably foreseeable actions would be the same as those described for alternative A. Alternative B may reduce the frequency of road closures by protecting NC 12 from overwash and damage during future storm and extreme high tide events. The reduction in closures would allow access to hospitals, grocery stores, and other services accessed via NC 12 to be maintained or restored more quickly after such events. The sediment placement authorized under alternative B may temporarily reduce erosion rates of Seashore beaches, thereby helping to maintain recreation access to beaches. Although sediment placement under alternative B may increase the resiliency of some shoreline areas of the Seashore after storm events, it may also result in periodic, short-term disruptions to access at varying locations during beach nourishment activities. NC 12 and beach front properties may be temporarily less vulnerable to erosion and damage and these benefits to private property would last as long as the sediment remains in place, which would vary from one location to another. When the incremental impacts of alternative B are combined with the impacts of other past, present, and reasonably foreseeable actions, the overall cumulative impacts on structures and infrastructure would be temporary, localized and beneficial, with the incremental impacts of alternative B contributing most of the impacts.

Conclusion

Over the life of the sediment management framework (20 years), relative sea-level rise and more intense storm events would continue to result in erosion and overwash along the Seashore. While damages from these events cannot be eliminated, alternative B would result in a more resilient Seashore with additional protections for existing structures and infrastructure. These protections would primarily occur in localized areas where NC 12 is protected from overwash and damage by wider beaches where sediment placement is undertaken. These areas may be less subject to erosion during storm events, which may protect life and property from storm damage within the vicinity. Because NC 12 may be less subject to overwash and damage in these areas, emergency personnel may be able to more efficiently undertake recovery efforts, improving overall public health and safety in the Seashore. The local economy may be able to more quickly recover from storm events due to Seashore access via NC 12 being interrupted less frequently and/or for a shorter duration after storm events. Alternative B would be consistent with the Seashore's purpose of providing for recreational use and enjoyment because the NPS could more quickly restore access to recreational resources accessible by NC 12. The magnitude of these protections would be dependent upon the location of sediment placement activities in relation to local infrastructure as well as the frequency and intensity of future storm events. However, it is likely that the Seashore, residents, and the local economy would be better able to recover from major storm events under alternative B.

Alternative C

Under alternative C, sediment placement activities authorized by the NPS may temporarily reduce the current risk factors affecting the Seashore in the same manner as described under alternative B above. However, the protection would be of a lesser extent than under alternative B because sediment management activities would occur on up to 6 miles of beach every 5 years, rather than every year under alternative B. In addition, this alternative would not incorporate a holistic framework for the Seashore.

Public Health and Safety

Alternative C would have the same localized reduction in impacts on NC 12 from overwash and storm damage during future storm and extreme high tide events as described under alternative B. However, the level of protection under alternative C would be less than that of alternative B and may not reduce the frequency and duration of closures of NC 12 due to storm and extreme high tide events when compared with the existing conditions. Future storm and extreme high tide events would continue to result in closures of portions of NC 12, which may temporarily cut off access to evacuation routes, hospitals, grocery stores, and other resources for residents and visitors; the intensity, duration, and location of which would depend on the extent and nature of the storm damage. Protection of NC 12 would be highly localized and would only occur where nourishment projects are undertaken and would only last while the wider beach remains in place.

Visitor and Resident Access and Experience

Alternative C would have the same localized reduction in impacts to Seashore access from road closures as described under alternative B. However, the reduction in impacts would be to a lesser extent and would be more localized than alternative B because the frequency of nourishment would be reduced (every 5 years). Nourishment projects authorized under alternative C may not reduce the overall frequency and duration of closures of NC 12 due to storm and extreme high tide events when compared with the existing conditions. In these cases, residents and visitors would have limited access to the Seashore until the road is cleared and/or repaired. Lack of access to areas of the Seashore would limit recreational and tourism opportunities during the closures. Protection of Seashore access via NC 12 would be highly localized and would only occur where nourishment projects are undertaken and would only last while the wider beach remains in place.

Sediment management activities would result in the same periodic, short-term disruptions to access at various locations during beach nourishment activities as discussed under alternative B above. The low possibility of traffic disruptions and wear on Seashore roads is further reduced under this alternative. However, these disruptions to access and closure of beaches would occur in fewer areas or would occur less frequently than under alternative B because fewer miles of nourishment projects would be undertaken each year.

Socioeconomics and Private Property

Alternative C would result in the same secondary impacts related to protection of shoreline buildings, infrastructure, and NC 12 as discussed under alternative B. However, these impacts would be of a lesser extend under alternative C than under alternative B because fewer miles of nourishment projects would take place per year. Seashore visitation and tourism would be less subject to interruption due to closures and damage in the areas where nourishment activities are undertaken and while the wider beach remains in place. Similarly, increased protection of private property along the shoreline from overwash and erosion would be expected in the nourished areas in the same manner as described under alternative B. Under alternative C, these protections would include area of up to 6 miles of beach every 5 years, which may not reduce the overall interruption of Seashore visitation due to closures and damage each year compared to existing conditions.

Sediment management activities would result in the same periodic, short-term closures of portions of Seashore beaches during beach nourishment activities as discussed under alternative B above. Businesses or rental property owners adjacent to closed beach areas may see a reduction in tourist activity during the time of closure. However, these disruptions would occur in fewer areas or would occur less frequently than under alternative B because fewer miles of nourishment projects would be undertaken each year.

As under alternative B, these localized impacts are expected to last only the duration of the sediment management activities, or less than one year for each project. Given the limited geographic area of impact at any given time and the limited timeframe, these impacts are not considered substantial.

Cumulative Impacts

The impacts from past, present, and reasonably foreseeable actions would be the same as those described for alternative A. Alternative C would temporarily protect portions of NC 12 from overwash and damage during future storm and extreme high tide events. This protection would allow access to hospitals, grocery stores, and other services accessed via NC 12 to be maintained or restored more quickly after such events. The sediment placement authorized under alternative C may temporarily reduce erosion rates of Seashore beaches, thereby helping to maintain recreation access to beaches. Although sediment placement under alternative C may improve the resiliency of some shoreline areas of the Seashore after storm events, it may also result in periodic, short-term disruptions to access at varying locations during beach nourishment activities. NC 12 and beach front properties where nourishment projects are undertaken may be temporarily less vulnerable to erosion and damage and these benefits to private property would last as long as the sediment remains in place, which would vary from one location to another. When the incremental impacts of alternative C are combined with the impacts of other past, present, and reasonably foreseeable actions, the overall cumulative impacts on structures and infrastructure would be temporary, localized, and beneficial, with the incremental impacts of alternative C contributing only a portion of the impacts.

Conclusion

Over the life of the sediment management framework (20 years), relative sea-level rise and more intense storm events would continue to result in erosion and overwash along the Seashore. While damages from these events cannot be eliminated, alternative C would result in a more resilient Seashore with protections for existing structures and infrastructure than alternative A. These protections would primarily occur in localized areas where NC 12 is protected from overwash and damage by wider beaches where sediment placement is undertaken. These areas may be less subject to erosion during storm events, which may protect life and property from storm damage within the vicinity. However, alternative C may not reduce the overall frequency in which NC 12 is damaged or closed due to future storm and extreme high tide events when compared to the existing management conditions. Alternative C would be consistent with the Seashore’s purpose of providing for recreational use and enjoyment because the NPS could continue to work with NCDOT to restore access to recreational resources accessible by NC 12 after storm and extreme high tide events. This may not be the case for the Pea Island NWR portion of the Seashore, where the purpose is primarily to protect and enhance migratory waterfowl and habitats. The magnitude of these protections would be dependent upon the location of sediment placement activities in relation to local infrastructure as well as the frequency and intensity of future storm events.

Comparative Conclusion of Alternatives

Under all alternatives, there would be continued adverse impacts on Seashore resources, values, and infrastructure, as well as private property and NC 12 because of the erosion resulting at least partially from human activities, existing hardened structures along the Seashore, and storm and extreme high tide events. Under alternative B and alternative C, these impacts would be temporarily lessened in and near the locations of the sediment management project, while the sediment remains in place. Alternative B would result in the greatest reduction of impacts to structures and infrastructure.

Under all alternatives, NC 12 closures would cause residents and visitors to lose access to the Seashore, and emergency personnel would need to rely on alternate methods of providing relief such as by emergency ferry routes. These adverse situations may be less severe and less frequent under alternative B and alternative C, but they would not be eliminated.

Under all alternatives, beachfront buildings and other infrastructure would continue to suffer damages, requiring closures that would result in loss of revenue from tourism as well as costs incurred by property owners for emergency protection measures and repairs. These adverse situations may be less severe and less frequent under alternative B and alternative C but would not be eliminated.

Alternative B and, to a lesser extent, alternative C may result in beneficial impacts to Seashore access by creating wider beaches. This may have secondary, temporary beneficial impacts on NC 12, other roads, and infrastructure adjacent to the shoreline. Under alternative B and, to a lesser extent, alternative C, access to the Seashore by residents and visitors may be maintained or restored more quickly after storm events because NC 12 may be less vulnerable to storm damages. Emergency personnel and equipment may be better able to access areas in need, more quickly restoring power and other vital services. Beachfront businesses may also experience less damage, allowing them to reopen more quickly after damage does occur, reducing their overall revenue losses. Overall, the improved access to the Seashore may temporarily allow the tourism-based economy to be more resilient under alternative B and alternative C compared to alternative A.

UNAVOIDABLE ADVERSE IMPACTS

The NPS is required to consider if the proposal would result in impacts that could not be fully mitigated or avoided (NEPA section 102(2)(c)(ii)). The following discussion describes the potential unavoidable adverse impacts by alternative.

Alternative A (No-Action Alternative)

Under alternative A there would be unavoidable adverse impacts to littoral processes and barrier island morphology; EFH and benthic communities; sea turtles; shorebirds; and structures and infrastructure. The occurrence of long-term unavoidable adverse impacts to littoral processes and barrier island morphology is debated among scientists, and there are differing perspectives as to whether a highly engineered barrier island system is preferable to one with increased erosion, island narrowing, increased overwash events, and landward migration. Impacts include the permanent alteration of the Seashore's footprint which could also adversely impact its resources and associated infrastructure.

There would be long-term unavoidable impacts to certain types of EFH and benthic communities under alternative A because unabated erosion would result in a steeper beach profile, increased sedimentation, and recurrent inlet breaches. These changes would reduce certain types of EFH including intertidal mud flats, SAV, and tidal marsh, and would lead to a decline in the abundance and diversity of intertidal benthic communities.

Long-term unavoidable impacts to sea turtles and shorebirds would occur in the form of habitat loss where the beach cannot naturally migrate inland in response to relative sea-level rise. A long-term increase in the frequency and intensity of storm events may also increase the overwash/inundation of sea turtle nests and nests lost to erosion. Loss of shorebird habitat would adversely impact nesting, resting, foraging, migrating, and wintering, and shorebirds could be misplaced elsewhere.

There would also be unavoidable adverse impacts to infrastructure, public health and safety, socioeconomics, and visitor/resident experiences at the Seashore due to continued or worsening erosion and severe weather events. These impacts include a loss of access to the Seashore, damage to property and the increased cost of repairs or the resulting loss of revenue and reduced recreational opportunities.

Alternatives B and C (Action Alternatives)

Under alternatives B and C, there would be unavoidable adverse impacts to benthic organisms and EFH; shorebirds; and structures and infrastructures at the Seashore. Sediment management activities would have unavoidable adverse impacts on benthic communities and EFH by burying benthic organisms at the project site and by introducing more turbidity into the water column. These adverse impacts would be direct and short-term, anticipated to last between six months to several years. There would also be short-term adverse impacts to shorebirds from sediment management activities due to temporary construction activity and habitat disturbance, as well as disturbance to benthic communities vital for foraging shorebirds. These impacts are expected to last up to several years and would be confined to less than 9% (6 miles) of the total Seashore every year (potentially up to 18% [12 miles] of the Seashore no more frequently than every 5 years due to catastrophic damage). At least 61 miles of the Seashore (91%) would remain available at any point, and of those 61 miles, 13 miles (approximately 20% of the Seashore) would be set aside as references zones and not considered for sediment management activities (in all cases except for emergencies). Impacts from alternative C would be even less frequent and not exceed 9% of the Seashore. While long-term, unavoidable adverse impacts to structures and infrastructure would still be expected from erosion caused partially by human activities, existing hardened structures along the Seashore, and continued storms and extreme high tide events, the action alternatives are expected to lessen these impacts.

SUSTAINABILITY AND LONG-TERM MANAGEMENT

The NPS is required to consider the relationship between short-term uses of the environment and the maintenance and enhancement of long-term productivity (NEPA section 102(2)(C)(iv)). In doing so, the NPS considers the long-term impacts of its actions, and whether its actions involve tradeoffs between immediate use of resources and long-term productivity and sustainability of resources.

Alternative A (No-Action Alternative)

The NPS would not permit any sediment management actions under alternative A, thereby avoiding short-term uses of the environment. There is the possibility for sediment management project requests to occur during this NEPA compliance process, which would be handled under current management. Long-term productivity of the Seashore’s natural resources would remain generally intact, likely within the range of natural variability as dynamic littoral processes continued to shape the barrier island morphology and the ecosystems associated with this coastal system. Alternative A would not result in the long-term management and protection of the Seashore and associated recreational opportunities and nationally important resources.

Alternatives B and C (Action Alternatives)

Under alternatives B and C, the NPS would permit varying levels of sediment management activities at the Seashore. This would allow relocation of sediments from some part of the coastal system (subject to project-specific approvals) for nourishment of portions of the Seashore, mostly along ocean-facing beaches within high-erosion areas. The excess volume of sediment placed along beaches provides a reservoir to accommodate average annual erosion losses for a number of years before the sediments have been eroded away and returned to the system. Although this requires repeated short-term use of sediments (whether dredged or sourced elsewhere), the sediments are ultimately returned to the system; therefore, long-term sustainability of the system is not affected. The costs to repeatedly undertake these efforts may be somewhat offset by protecting the area's tourism-driven economic base and more reliable access via NC 12 when compared to alternative A.

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

The agencies must consider if the effects of the alternatives cannot be changed or are permanent (that is, the impacts are irreversible). The NPS must also consider if the impacts on park resources would mean that once gone, the resource could not be replaced; in other words, the resource could not be restored, replaced, or otherwise retrieved (NEPA section 102(2)(C)(v)).

Alternative A (No-Action Alternative)

Alternative A would not irreversibly nor irretrievably commit any resources. Although the islands may narrow and migrate over the long term, there is a debate among scientists as to whether this is preferable for the Seashore, its resources, infrastructure, and those communities within the Seashore.

Alternatives B and C (Action Alternatives)

Alternatives B and C each have the potential to result in irreversible and irretrievable commitment of resources related to sediment management activities because operation of dredging and sediment moving equipment would require the use of non-renewable fossil fuels. The sediments used under the action alternatives are ultimately returned to the system; however, not in its natural function, such as an offshore feature or biological habitat). Once the sand is dredged, that volume is typically no longer available as a resource in offshore borrow sites, for dredging or naturally.

CHAPTER 5: CONSULTATION AND COORDINATION

PUBLIC PARTICIPATION AND SCOPING

Scoping is an essential component of the NEPA planning process. The formal scoping process for this DEIS consisted of public scoping and consultation with federal, state, local and Tribal government agencies. The formal NEPA process and 30-day public scoping period was initiated on April 10, 2020, with the publication of a Notice of Intent in the *Federal Register* (85 FR 20298). In addition to the Notice of Intent, preliminary information regarding the DEIS was provided to the public and other interested parties through a press release and a public scoping newsletter. During the public scoping period, the NPS hosted four virtual meetings and received more than 140 pieces of correspondence. Comments were generally organized into the following topics: proposed action, no action, new alternatives, resource topic areas, purpose and need, and suggested references.

AGENCY CONSULTATION AND COOPERATION

Agency consultation is the early involvement of federal, state, local and Tribal government agencies that may be affected by the federal action. Similar to the public scoping process, this allows interested agencies or tribal governments to comment and contribute early in the decision-making process and helps NPS identify key issues or requirements to be considered in the NEPA process. During development of the DEIS, the NPS hosted an agency scoping meeting with the regulatory and consulting agencies to seek recommendations for streamlining regulatory requirements related to the actions being considered in this DEIS. A list of state and federal permits, licenses, and approvals relevant to this framework are described in appendix B.

The following agencies accepted cooperating agency status to assist with preparation and review of this framework and DEIS, as noted in chapter 1:

- USACE Wilmington District Regulatory and Planning Divisions
- FWS
- BOEM
- NCDOT Ferry and Highway Divisions
- NCWRC
- Dare County
- Hyde County

RECIPIENTS OF THE DRAFT ENVIRONMENTAL IMPACT STATEMENT

Upon publication of the notice of availability of the DEIS in the *Federal Register*, electronic notification will be provided to the media, federal departments/agencies, state and county governments, elected officials, tribal governments, organizations, businesses, and interested individuals via the NPS electronic mailing list and the NPS Project, Environment & Public Comment (PEPC) website. Hard copies of the DEIS will be distributed to USEPA Region 4.

LIST OF PREPARERS

Name	Title	Office Location
National Park Service		
Rebecca Beavers	Coastal Geology and Coastal Adaptation Coordinator, Geologic Resources Division/Climate Change Response Program	Washington Support Office
Julia Brunner	Policy & Regulatory Specialist, Geologic Resources Division, Natural Resource Stewardship and Science Directorate	Lakewood, CO
Henry Crawford	Geologic Hazards Scientist, Geologic Resources Division/Environmental Stewards	Lakewood, CO
Kelly Daigle	Project Manager/Environmental Protection Specialist, Environmental Quality Division	Washington Support Office
Mark Dowdle	Deputy Superintendent, Cape Hatteras National Seashore	Cape Hatteras National Seashore, NC
David Hallac	Superintendent, Cape Hatteras National Seashore	Cape Hatteras National Seashore, NC
Jami Hammond	Regional Environmental Coordinator, Interior Region 2 - South Atlantic Gulf	Atlanta, GA
Sabrina Henry	Environmental Protection Specialist, Cape Hatteras National Seashore	Cape Hatteras National Seashore, NC
Meaghan Johnson	Deputy Chief Resource Management and Science, Cape Hatteras National Seashore	Cape Hatteras National Seashore, NC
Monique LaFrance Bartley	Marine Ecologist, Ocean and Coastal Resources Branch, Water Resource Division, Natural Resource Stewardship and Science Directorate	Fort Collins, CO
Mike Martin	Hydrologist, Water Resource Division, Natural Resource Stewardship and Science Directorate	Fort Collins, CO
Linda York	Regional Coastal Geomorphologist, Interior Region 2 - South Atlantic Gulf	Atlanta, GA
Tracy Ziegler	Chief of Resource Management and Science, National Parks of Eastern North Carolina	Cape Hatteras National Seashore, NC
VHB, Inc.		
Candice Andre	Senior Project Planner	Raleigh, NC
Margaret Beavers	Environmental Scientist	Williamsburg, VA
Doug DeBerry	Senior Environmental Scientist	Williamsburg, VA
Erin Leatherbee	Preservation Planner	Williamsburg, VA
Tracy Littell	Environmental Planner	Williamsburg, VA
Sean Murray	Environmental Scientist	Williamsburg, VA
Kara Opel	Environmental Planner	Williamsburg, VA
R. Neville Reynolds	Senior Coastal Scientist	Williamsburg, VA
Coastal Science and Engineering, Inc. (CSE)		
Patrick Barrineau	Coastal Scientist	Columbia, SC
Tim Kana	Senior Coastal Scientist	Columbia, SC

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INDEX

GLOSSARY

accretion – The natural increase of land by accumulation of sediment, usually a gradual buildup over time.

alongshore – Along the shore or coast.

alternative – An option for addressing the issues and meeting the goals articulated in the purpose and need for action.

anthropogenic – Resulting from the influence or actions of human beings.

barrier island – A long, narrow island, parallel to the coastline that is built up by waves, currents, and winds and that protects the shore from the effects of the ocean.

beach nourishment – A process by which sediment, usually sand, lost through longshore drift or erosion is replaced from other sources.

benthic organisms – Organisms living on, or in, the bottom sediments.

borrow area – An area where material (e.g., sand) is removed for use at another location.

breach – Channels connecting the ocean to a bay, which typically form during powerful storms.

critical habitat – Specific areas occupied by the species at the time it is listed on the Endangered Species list, which contain physical or biological features essential to the conservation of the species and which may require special management considerations or protection.

critical wintering habitat – Wintering areas that are critical to the recovery of a species, the loss of which could hinder recovery of the species.

clutch – The number of eggs in a sea turtle's nest.

depredation – To prey upon.

distinct population segment – A portion of a species' or subspecies' population or range, usually described geographically rather than biologically.

dredging – The removal of sediments and debris from the bottom of lakes, rivers, harbors, and other water bodies.

dune – A mound or ridge of sand or other loose sediment formed by the wind along the sea coast.

ecosystem – A biological community of interacting organisms and their physical environment.

erosion – Removal of surface material from the earth's crust, primarily sediment and rock debris, and the transportation of the eroded materials by natural agencies from the point of removal.

escarpment – A transition zone between different areas that involves a sharp, steep elevation differential, characterized by a cliff or steep slope.

essential fish habitat (EFH) - Includes all waters and substrates needed for the spawning, breeding, foraging, and growth of species managed under the Magnuson-Stevens Act.

estuarine – Referring to the area of a water passage where the tide meets a river current; especially an arm of the sea at the lower end of a river.

false crawl – An aborted nesting attempt (emergence onto a beach by a sea turtle).

forage – To search widely for food.

foredune – A dune ridge that runs parallel to the shore. Foredunes consist of sand deposited by wind on a vegetated part of the shore.

framework – A set of procedures and guidelines that supports a particular approach to meeting established objectives or goals.

groin – A type of hardened structure installed with the intent to capture sediment locally to stabilize shorelines. They are typically installed perpendicularly to the shoreline and can be constructed of materials such as sheet piles or stones.

habitat area of particular concern (HAPC) – A designation that encompasses discrete subsets of essential fish habitat, which provide extremely important ecological functions or are especially vulnerable to degradation. The purpose of HAPCs is to focus increased scrutiny, study, or mitigation planning compared to surrounding areas because they represent high priority areas for conservation, management, or research and are necessary for healthy ecosystems and sustainable fisheries.

impact topic – Specific resources that would be affected by a proposed action or alternatives, including the alternative A, under consideration for implementation.

inlet – A narrow body of water between islands or leading inland from a larger body of water, often leading to an enclosed body of water, such as a sound, bay, lagoon or marsh. In sea coasts an inlet usually refers to the actual connection between a bay and the ocean and is often called an "entrance" or a recession in the shore of a sea, lake, or river.

intertidal – The area that is exposed to the air at low tide and underwater at high tide (for example, the area between tide marks).

issue topic – Problems, concerns, conflicts, obstacles, or benefits that may occur if the proposed action or alternatives, including the no action alternatives, are implemented.

jetty – A hardened structure, similar to groins, that are usually associated with protecting harbors or inlets.

littoral zone – The part of a sea, lake, or river that is close to the shore. In coastal environments, the littoral zone extends from the high water mark, which is rarely inundated, to shoreline areas that are permanently submerged.

outer continental shelf – The nearshore (near the shore or coast) zone that extends from three miles seaward of State coastline boundaries to 200 miles offshore.

overwash – Areas where water has transported sediment through a break in the dunes, or crested a berm or other structure, and does not flow directly back to the ocean.

pelagic – Fish inhabiting the upper layers of the open sea.

proposed action – The initial proposal to address a purpose and need.

relative sea-level rise – The height of the ocean rising or falling relative to the land at a particular location.

revetment – A sloping structure placed on banks or cliffs in such a way as to absorb the energy of incoming water.

sand placement – An element of beach nourishment, sand placement is the process of depositing sediment dredged from offshore or other sources to the study area.

sediment – Particles that can be transported by fluid flow and which are eventually deposited as a layer of solid particles on the bottom of a body of water.

sediment management actions/activities – The suite of activities proposed under the action alternatives, which includes: sound side and ocean side beach nourishment, dune restoration, filling island breaches, and habitat restoration.

sediment/sand budget – A sediment transport volume balance for a selected segment of the coast; refers to the sediment added to and removed from the coastal system.

Special Use Permit – A permit allowing activities to take place in a park area that requires written authorization and some degree of management control from the NPS in order to protect park resources and the public interest.

spit – An extended stretch of beach material that projects out to sea and is joined to the mainland at one end.

submerged aquatic vegetation – A diverse group of plants that lives entirely beneath the water surface.

substrate – An underlying layer of sediment or rock.

subtidal beach – An area of the beach most often submerged, exposed only briefly during extreme low tides around full and new moon events. This zone provides habitat to a diversity of plants and animals in contrast to the other zones.

swash zone – The zone of wave action on the beach, which moves as water levels vary. The zone is characterized by a turbulent layer of water that washes up on the beach after an incoming wave has broken.

turbidity – The measure of relative clarity of a liquid, caused by the presence of suspended particulates. Turbidity is a key test of water quality.

upland – An area of high land.

wave refraction – The bending of a wave as it spreads over different depths. As a wave moving in shallow water approaches the shore at an angle, it tends to be turned from its original direction. The part of the wave advancing in shallower water moves more slowly than the part still advancing in deeper water, causing the wave crest to bend toward parallel alignment with the shoreline.

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