Audubon NORTH CAROLINA
7741 Market Street, Unit D
Wilmington, NC 28411
910-686-7527

May 31, 2016

Via electronic mail
Mr. Tyler Crumbley
U.S. Army Corps of Engineers
69 Darlington Avenue
Wilmington, NC 28403

Re: Final Environmental Impact Statement for Ocean Isle Beach Shoreline Management Project, file number SAW-2011-01241.

Dear Mr. Crumbley,

Please accept these comments on behalf of the National Audubon Society's North Carolina State Office regarding the Final Environmental Impact Statement (FEIS) for the project known as "Town of Ocean Isle Beach Shoreline Management Project."

The Town of Ocean Isle Beach's preferred alternative is to construct a 750 foot-long terminal groin with a 300 foot shore anchorage system on the east end of Ocean Isle Beach and a beach nourishment regime that would place 264,000 cubic yards of sand west of the terminal groin on a five year interval. This alternative (Alternative 5), the stabilization of the inlet through channelization (Alternative 4), or beach nourishment activities (Alternatives 1, 2, 3, 4, 5) will have significant and lasting negative direct, indirect, and cumulative impacts on birds and other wildlife that depend on the dynamism of mid-Atlantic coastal inlets at critical points in their life cycles. The FEIS fails to accurately describe the negative impacts to birds and other wildlife for Alternatives 3, 4, and 5. Alternative 3 (nourishment every two years) would not allow enough time for the infauna community to recover, which negatively impacts birds that feed on these species, yet the FEIS fails to make this conclusion. Permanently modifying Shallotte Inlet through construction of a terminal groin (Alternative 5), or through channelization (Alternative 4), will significantly increase the erosion rate on the downdrift shoreline of Ocean Isle Beach, which will require nourishment on a shorter time-scale, yet the FEIS fails to make this conclusion. For the applicant's preferred alternative (Alternative 5), the models used in the FEIS show that Ocean Isle Beach will continue to experience erosion even with the construction of a terminal groin. Additionally, the construction of a 750 foot terminal groin at an estimated 30-

year cost of $46 million in an attempt to protect real estate valued at $7.4 million (Table 2.2 in the FEIS) is unfounded.

The FEIS takes the "make them go somewhere else" approach when addressing the impact of the preferred alternative and most of the other alternatives on birds. It perpetuates the common misconception that breeding and non-breeding shorebirds and waterbirds have alternative places to go when habitat is lost and that, because birds have wings, they will simply move somewhere else. The truth is that birds are already occupying alternative locations. They have been relentlessly forced to abandon high-quality habitats throughout their range because of habitat loss and degradation, exacerbated by the steady and increasing loss of habitat at inlets and on beaches, and the cumulative impacts of habitat loss along the Atlantic coast. Shorebirds like Piping Plovers, as well as terns and skimmers are now confined to a small fraction of the habitat once available to them, and if alternative locations were available, the birds would already be there. This is reflected in the elevated conservation status of many of the species that depend on inlets and barrier islands, including those that depend on Shallotte Inlet; nearly all are state listed, federally listed, listed as species of conservation concern, or similarly designated in documents such as the U.S. Shorebird Conservation Plan (Brown *et al*. 2001).

<u>Geophysical Impacts of Terminal Groins, Other Hard Structures, and Beach Renourishment</u>: In order to assess environmental impacts, it is necessary to accurately describe how terminal groins and other coastal engineering projects affect inlets and adjacent beaches. The FEIS fails to cite the applicable, most recent scientific literature and fails to accurately describe the impacts a terminal groin, beach renourishment, and inlet channelization would have on Shallotte Inlet and adjacent areas. Some of the impacts that are insufficiently addressed are the narrowing of downdrift oceanfront beach, loss of sediment from the inlet system, impacts to spits at ends of adjacent islands, loss of critical wildlife habitat, and cumulative impacts of the alternatives. Terminal groins are designed to interrupt longshore transport of sand. It is well documented that terminal groins actually accelerate erosion of the shoreline downdrift of the structure (McDougal *et al*. 1987, Kraus *et al*. 1994, Bruun 1995, Cleary and Pilkey 1996, Komar 1998, McQuarrie and Pilkey 1998, Pilkey *et al*. 1998, Brown and McLachlan 2002, Greene 2002, USACE 2002, Morton 2003, Morton *et al*. 2004, Basco and Pope 2004, Speybroeck *et al*. 2006, Rice 2009, Riggs *et al*. 2009, Riggs and Ames 2011, Ells and Murray 2012, Knapp 2012, Pietrafesa 2012, Berry *et al*. 2013), which in turn requires regular replenishment of sand to compensate for sand loss (Hay and Sutherland 1988, Bruun 1995, McQuarrie and Pilkey 1998, French 2001, Galgano 2004, Basco 2006, Riggs *et al*. 2009, Riggs and Ames 2011, Pietrafesa 2012).

An open letter on the subject of downdrift erosion signed by 43 of the leading coastal geologists in the U.S. states:

The negative impact of groins and jetties on downdrift shorelines is well understood. When they work as intended, sand moving along the beach in the so-called downdrift direction is trapped on the updrift side, causing a sand deficit and increasing erosion rates on the downdrift side. This *well-documented and unquestioned impact is widely cited in the engineering and geologic literature* (Young *et al*. 2007).

Fenster and Dolan (1996) found that inlets in Virginia and North Carolina exert influence over adjacent shorelines up to 5.4-13.0 km away and that they are a dominant factor in shoreline change for up to 4.3 km. Permanently modifying Shallotte Inlet through construction of a terminal groin, or through channelization (Nordstrom 2000), will significantly increase the erosion rate on the downdrift shoreline of Ocean Isle Beach. Longshore currents run predominantly westward in the area of Ocean Isle Beach, placing nearly all of the oceanfront homes on Ocean Isle Beach in danger from accelerated erosion, should a terminal groin be built.

The FEIS forecasts a five-year interval for beach renourishment for the alternative that includes a terminal groin (Alternative 5). Despite the well-known downdrift impact of terminal groins, the FEIS does not address the likelihood that in response to the terminal groin, the beach will narrow farther to the west and require additional and more frequent beach renourishment over the years. The proposed five-year interval for beach renourishment is also questionable given that Wrightsville Beach, Masonboro Island, Mason Inlet, southern Figure 8 Island, Oregon Inlet, and Ft. Macon, just to name a few, are dredged and replenished more frequently than five-year intervals. The near certainty that Ocean Isle Beach will need to mine sand from Shallotte Inlet and replenish the downdrift beach on Ocean Isle Beach more frequently than every five years has not been accurately assessed in the FEIS.

Downdrift effect can be seen elsewhere in North Carolina where terminal groins have been installed. At Fort Macon, three years after the completion of the terminal groin a beach renourishment project occurred because the groin itself was exacerbating erosion, and from 1973-2007, seven renourishment projects have occurred at Fort Macon at the cost of nearly $45 million (Pietrafesa 2012).

The FEIS cites Oregon Inlet, NC as an example of a successful terminal groin project that has not "caused adverse impacts to the shoreline" (p. 177). One need only drive Highway 12 along Pea Island to see the fallacy of this conclusion. Riggs and Ames (2011) also provide an excellent review of the impacts of the modifications to Oregon Inlet. The FEIS relies exclusively on one source—Overton (2011) and personal communications with Overton—to make this assertion. Recent and relevant literature is available, and the conclusions are different than those cited in the FEIS. To minimize impacts of the Oregon Inlet terminal groin on the downdrift shoreline of Pea Island, sediment from routine Oregon Inlet channel dredging has been placed either directly on the Pea Island beach or in shallow nearshore disposal area near northern Pea Island (Riggs and Ames 2011). Human efforts have only temporarily slowed the process of shoreline recession in a small portion of northern Pea Island by the regular addition of dredged sand at a very high cost, but each new beach nourishment project has quickly eroded away (Riggs and Ames 2009, Riggs *et al*. 2009). Based on several studies, the data strongly suggests that the terminal groin itself is contributing to the accelerated erosion and shoreline recession problems on Pea Island (Riggs and Ames 2003, 2007, 2009; Riggs *et al*. 2008, 2009; Mallinson *et al*. 2005, 2008, 2010; Culver *et al*. 2006, 2007; Smith *et al*. 2008).

In addition to impacts on downdrift shorelines, hard structures at inlets permanently remove sand from the inlet system, reducing or eliminating shoal systems from affected inlets (Pilkey *et al*. 1998) and accelerating the loss of saltmarsh in the vicinity of the inlet (Hackney and Cleary 1987). The loss of saltmarsh at Shallotte Inlet would have significant negative impacts on fisheries, other wildlife, recreation, small businesses, and the local economy. These impacts and the loss of saltmarsh resulting from removal of sand from Shallotte Inlet have not been assessed for the preferred or other alternatives in the FEIS.

The loss of ebb and flood tidal shoals is illustrated clearly by the case of Masonboro Inlet. A terminal groin was installed on the north end of Masonboro Island; construction of the groin was completed in April 1981 (Cleary and Marden 1999). At the time, the north end of the island featured an extensive sand spit, wide beach, and extensive flood and ebb tidal deltas. In less than one year following the completion of the terminal groin, the spit at the north end of Masonboro Island vanished, and the amount of intertidal shoals in the inlet, already diminished by other coastal engineering projects, had decreased as well. Downdrift of the terminal groin, Masonboro Island's oceanfront beach formed the expected fillet immediately adjacent to the terminal groin, while narrowing significantly along the downdrift beach.

The FEIS also fails to address the cumulative impacts of sand mining and the proposed terminal groin at Shallotte Inlet on the adjacent downdrift beach. The regular removal of sand from Shallotte Inlet and the proposed terminal groin at the east end of Ocean Isle Beach would disrupt the longshore transport of sand and potentially threaten Ocean Isle Beach—the adjacent downdrift shoreline—and the real estate thereon.

There are at least 100 published studies that address the impacts of terminal groins on inlets, beaches, and natural resources. The majority (78%) of peer-reviewed literature we collected regarding the impacts of hard structures at inlets concluded that terminal groins do not function in the manner presented in the FEIS and cause more harm than good. The wealth of literature on the impacts of terminal groins is not discussed nor cited in the FEIS. A complete review of the relevant literature is necessary to accurately and objectively evaluate all alternatives presented in the FEIS.

<u>Impacts to Birds</u>: Natural, unmodified coastal inlets are essential to many shorebird species (sandpipers, plovers, and their allies), as well as other coastal species because they provide the variety of habitat types these species require at critical times of their annual and lifecycles. Inlets have expansive, low-energy intertidal flats which are rich with invertebrate prey that wintering and migrating shorebirds require to fuel their migratory flights, sustain them during winter, and support adults and chicks during the nesting season. Inlets have open, sandy spits that serve as resting and roosting sites that shorebirds need to rest, digest, and conserve energy; and they have open or sparsely vegetated sandy habitat that many shorebird species, as well as terns and skimmers require for nesting (Gochfeld and Burger 1994, Thompson *et al*. 1997, Elliott-Smith and Haig 2004, Nol and Humphrey 2012).

Shorebird communities require habitat heterogeneity to meet their basic and varied fundamental needs for survival, which is why unmodified inlets containing a mosaic of habitat types are essential to sustaining shorebird communities (VanDusen *et al*. 2012). Many shorebird species breed in the far north in order to exploit the seasonal abundance of food resources and they stopover around inlets during migration in order to refuel before continuing migration (Colwell 2010). Proximity between foraging and roosting sites has been found to be a key element in determining habitat suitability and use for shorebird species such as the Piping Plover (Cohen *et al*. 2008), Dunlin (*Calidris alpina*) (Dias *et al*. 2006), Red Knot (Rogers *et al*. 2006), and others. In short, natural inlets provide all the resources and habitats shorebirds require in a small geographic area and at the locations essential to meeting their spatial and temporal energetic needs. These resources are generally not available or not sufficient to meet the energetic needs of shorebirds at other coastal features.

Reflecting this fact, the occurrence and numbers of shorebirds that use coastal habitats in the southeastern U.S. is greater at inlets than most other coastal features. Seven shorebird species: the Threatened Piping Plover (*Charadrius melodus*) and the Threatened Red Knot (*Calidris canutus rufa*), as well as Black-bellied Plovers (*Pluvialis squatarola*), Ruddy Turnstones (*Arenaria interpres*), Snowy Plovers (*Charadrius alexandrinus*), Western Sandpipers (*Calidris mauri*), and Wilson's Plovers (*Charadrius wilsonia*) are significantly more abundant at inlets than other coastal habitats (Harrington 2008). Multiple studies support the significance of inlets to birds, designating inlets as essential habitat by Red Knots, as well as breeding and non-breeding Piping Plovers (Nicholls and Baldassarre 1990, Harrington 2008, Kisiel 2009a, 2009b, Riggs *et al*. 2009, Niles *et al*. 2010, Maslo *et al*. 2011, USFWS 2012, 2013).

Piping Plovers: Piping Plovers are an excellent example of a species that relies on inlet-associated habitats throughout the year. During nesting, Piping Plovers are often associated with natural coastlines, including unmodified inlets and overwash fans. In New Jersey, Piping Plovers nest primarily near inlets, particularly those that were not stabilized with structures: 70.6% of all Piping Plover pairs nested closer to an unstabilized inlet than a stabilized inlet (Kisiel 2009a, 2009b). Piping Plovers in North Carolina also exhibit a pattern of nesting near inlets, and the majority of Piping Plover nests in Cape Hatteras National Seashore and Cape Lookout National Seashore were located near inlets (NPS 2014a, 2014b), largely because suitable nesting habitat does not exist elsewhere on the coast.

Piping Plovers spend up to nine months out of the year away from nesting grounds (Elliott-Smith and Haig 2004). During this time, Piping Plovers engage in two essential behaviors, foraging and roosting (resting). A core wintering area or stopover site must provide habitat suitable for roosting, typically backshore above the high-tide line, and foraging, typically wet sand in low-energy intertidal areas that support invertebrates such polychaetes which are an important prey item for wintering and migrating Piping Plovers (Elliott-Smith and Haig 2004).

There is a robust body of peer-reviewed scientific literature showing use of inlets and associated low-energy intertidal flats by Piping Plovers, particularly migrating or wintering Piping Plovers (Haig and Oring 1985, Johnson and Baldassarre 1988, Nicholls and Baldassarre 1990), indicating that Piping Plovers have a small home range during the non-breeding season and use a variety of habitats throughout the tidal cycle (Drake *et al*. 2001, Rabon 2006, Cohen *et al*. 2008, Maddock *et al*. 2009). Foraging activity is strongly associated with mud or sandflats (Nicholls and Baldassarre 1990), and roost sites are most used by Piping Plovers when located within close proximity to foraging areas (Cohen *et al*. 2008). Piping Plovers also exhibit strong site fidelity both during the same year and across several years (Drake *et al*. 2001, Noel and Chandler 2006). These characteristics demonstrate that Piping Plovers depend on very specific places that with these habitats, and that these places are important year after year as the same birds return to them every migration or winter.

<u>Modification of Inlets and Beaches</u>: Despite the importance of natural inlets to birds such as the Piping Plover, inlets are one of the most anthropogenically altered features on the coast. In North Carolina, 85% of inlets have been modified, and 57% of Atlantic coast inlets in the migration and winter range of the Piping Plover have been modified, including 43% that have been stabilized with hard structures (Rice 2012a). At least 32% of sandy beach habitat in the winter range of the Piping Plovers has received beach nourishment (Rice 2012b), which causes direct mortality of the infaunal prey these birds consume in order to survive.

The cumulative impacts of the preferred alternative have not been accurately assessed in the FEIS. A cumulative impact is the "…impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions." The cumulative impacts of terminal groin construction along the coast of North Carolina and along the Atlantic Coast of the U.S. have been one of the most significant contributing factors to the loss of habitat for birds that rely on inlets at critical times of their life and annual cycles.

Many shorebird populations, especially the many species that occur at inlets, are declining and are of conservation concern (Brown *et al*. 2001, Winn *et al*. 2013). Loss or degradation of habitat, including that associated with coastal engineering projects, is identified as a primary threat in all shorebird conservation and management planning documents, including those addressing Piping Plovers and Red Knots. The cumulative impacts of the loss and degradation of habitats that are essential to inlet-dependent wildlife jeopardizes the recovery of federally-listed species, threatens the existence of federally-listed species, and contributes to the decline of state-listed species, none of which are evaluated in the FEIS.

<u>Impacts on Infauna</u>: The FEIS overlooks impacts of the alternatives on the infaunal community (species that live within the sediment) at Ocean Isle Beach and consistently marginalizes and understates impacts to these organisms. The infaunal community is comprised of multiple different species that have variable recovery rates. The FEIS repeatedly uses the terms "short-term," "rapid recovery," and "rapid recolonization" (for examples, see pages 115, 137, 145, 149, 151, 166, 185, 186) when addressing the impacts to the infaunal community, which is misleading because some organisms take up to four years to recover (Jaramillo *et al*. 1987, Peterson *et al*. 2014).

The majority of peer-reviewed literature demonstrates that infaunal species are negatively impacted by beach nourishment, and that the length of time for recovery varies by species (Hayden and Dolan 1974, Jaramillo *et al*. 1987, Rakocinski *et al*. 1996, Peterson *et al*. 2000a, Peterson *et al*. 2000b, Bishop *et al*. 2006, Dolan *et al*. 2006, Peterson *et al*. 2006, Bertasi *et al*. 2007, Colosio *et al*. 2007, Cahoon *et al*. 2012, Leewis *et al*. 2012, Schlachler *et al*. 2012, Manning *et al*. 2014, Petersen *et al*. 2014, Viola *et al*. 2014). In North Carolina, *Emerita talpoida* (mole crab) abundance recovered within months on nourished beaches compared to control beaches, but *Donax* spp. (coquina clam) and amphipods did not recover within the time frame of the study (Peterson *et al*. 2006). Peterson *et al*. (2014) monitored the recovery of a sandy beach community for 3-4 years following nourishment and documented that haustoriid amphipods (small crustaceans) and *Donax* spp. had reduced densities for 3-4 years following nourishment, *E. talpoida* had lower densities for 1-2 years following nourishment, and ghost crabs had lower abundances for four years.

For all alternatives, beach nourishment is proposed at an interval ranging from 2-5 years. Historically, Ocean Isle Beach was nourished every three years under the Federal storm damage reduction project. For the preferred Alternative 5, the FEIS states that nourishment will occur every five years. However, at inlets where terminal groins were constructed, the beach nourishment cycle is every 1-4 years (Riggs *et al*. 2009, Riggs and Ames 2011, Pietrafesa 2012). Pea Island was renourished every year from 1990-2004, and Fort Macon was renourished every 2-6 years from 1973-2007 (Pietrafesa 2012). If some species of the infaunal community recover in 3-4 years, the cumulative impact to the infaunal community due to nourishment at such sites is that the community cannot recover before the next nourishment cycle. In some cases, local extinction of benthic species has occurred (Colosio *et al*. 2007). The FEIS fails to recognize that if nourishment occurs every two years (Alternative 3), some of the infaunal community will not recover, which will negatively impact birds and fishes that feed on these species. Instead, the FEIS states that the implementation Alternative 3 would provide a positive impact to shorebirds since there will be an increase in dry beach width (p. 165). Birds will not benefit from an increased dry beach width because birds using the oceanfront beach only use the intertidal zone for foraging and nourishment does not increase the width of the intertidal zone.

The compaction of sand by heavy machinery and changes in grain size and shape, permeability, and penetrability are other common results of beach nourishment that impact infaunal organisms (Greene 2002, McLachlan and Brown 2006). Further, though timing of activity is important to avoid periods of larval recruitment, all work is assumed to take place within existing environmental windows. The potential for additional impacts both from more frequent nourishments and out-of-season nourishments should be addressed by the FEIS.

Beach nourishment degrades beach habitats, thus decreasing densities of invertebrate prey for shorebirds. Each shorebird species has its own foraging microhabitat as well as its own feeding techniques. Shorebirds that collect food from specific depths beneath the sand can no longer rely on food from traditional habitats on nourished beaches (Peterson *et al*. 2006). This will negatively impact species that often forage in oceanfront intertidal and swash habitats, specifically Sanderlings (Macwhirter *et al*. 2002), Willets (Lowther *et al*. 2001), and the threatened Red Knot (Baker *et al*. 2013). Speybroeck *et al*. (2006) documented that the mortality of just one species of polychaete due to nourishment resulted in decreased abundances of foraging Sanderlings. Piping Plovers forage less on oceanfront beaches than other habitats during non-breeding months (Haig and Oring 1985, Cohen *et al*. 2008), but they have been documented foraging occasionally on oceanfront beaches. Therefore, renourishment activities also affect this Piping Plover foraging habitat.

Decreased abundances of shorebirds after nourishment may be due to decreased foraging area, decreased prey densities, and the occurrence of coarse sediments further reducing foraging habitat (Peterson *et al*. 2006). Coastal armoring caused beach widths to narrow significantly in southern California, which resulted in the loss of intertidal habitat available to macroinvertebrates, and, therefore, the abundance of macroinvertebrates decreased (Dugan and Hubbard 2006, Dugan *et al*. 2008). The diversity and abundance of shorebirds on beaches was positively correlated with the diversity and abundance of macroinvertebrate prey, and since a decline in prey was observed, a decrease in foraging shorebirds, gulls, and other seabirds was also observed (Dugan and Hubbard 2006, Dugan *et al*. 2008). These authors concluded that increasing coastal armoring accelerates beach erosion and increases ecological impacts to sandy beach communities.

Any hard structure placed in a coastal environment modifies physical processes there, and these changes will impact the species composition, abundance, and structure of invertebrate communities, and therefore birds that consume these prey will also be impacted. Hard-engineered structures are thought to be responsible for the loss of more than 80% of sandy beach shorelines globally (Brown and McLachlan 2002). Additionally, the placement of a terminal groin as called for in Alternative 5 will result in the loss of the spit on the east end of Ocean Isle Beach. Although it's been stated above, it bears repeating that the modeling reported for Alternative 5 indicates that a significant amount of sediment would be lost from the system, resulting in the loss of habitat, primarily low-energy shoals and sandbars which provide habitat for a variety of benthic invertebrates that are consumed by shorebirds and fishes. Despite this, the FEIS preferred Alternative (5) and most other alternatives assert few impacts on infauna, and impacts that are acknowledged are marginalized.

Every recovery or management plan that pertains to species of shorebirds that use the coast recognizes the importance of infaunal organisms and their habitats. These species include the Piping Plover (USFWS 1996, 2001, 2003, 2009), Red Knot (USFWS 2013), Sanderling (Payne 2010), and Dunlin (Fernández *et al*. 2010).

Audubon North Carolina conducted an extensive review of literature regarding the impacts of hardened structures and beach fill activities with a focus on scientific, peer-reviewed articles. We found 49 peer-reviewed articles and included three reports regarding the impacts of renourishment on benthic organisms. Of these 52 documents, 40 (77%) found an impact to one or more species of benthic organism, 4 (8%) found no impact, and 8 (15%) were ambiguous or found equivocal results.

A recent 15 month study of the effects of beach nourishment on intertidal invertebrates demonstrated that nearly all taxa showed major declines in abundance immediately following nourishment, and the polychaete community showed a strong reduction in abundance that persisted through the end of the study (Wooldridge *et al*. 2016). Such declines may have far reaching consequences for sandy beach ecosystems, as they can reduce prey availability for shorebirds and fishes. These authors recommend longer study periods and more cautious estimates regarding the magnitude, variability, and duration of impacts of beach nourishment for management decision-making (Wooldridge *et al*. 2016).

In its treatment of impacts to the infauna, the FEIS relies nearly exclusively on outdated literature that is generally not peer-reviewed, and it omits the many recent, peer-reviewed scientific papers that are available on the subject. Peterson and Bishop (2005) suggested that weaknesses in nourishment studies are due to studies being conducted by project advocates with no peer review process and the duration of monitoring being inadequate to characterize the fauna before and after nourishment. Thus, uncertainty surrounding biological impacts of nourishment can be attributed to the poor quality of monitoring studies, not an absence of impacts.

<u>Impacts on Sea Turtles</u>: Threatened loggerhead sea turtles (*Caretta caretta*) nest along the length of North Carolina's coast, including on Ocean Isle Beach and Holden Beach. Information on the impacts of hard structures to sea turtles is extremely limited, but the few studies that exist found negative impacts to sea turtles. Lamont and Houser (2014) documented that loggerhead turtle nest site selection is dependent on nearshore characteristics, therefore any activity that alters the nearshore environment, such as the construction of groins or jetties, may impact loggerhead nest distribution. Loggerhead nesting activity decreased significantly in the presence of exposed pilings, and a 41% reduction in nesting occurred where pilings were present (Bouchard *et al*. 1998). In a study of the impact of coastal armoring structures on sea turtle nesting behavior, Mosier (1998) demonstrated that fewer turtles emerged onto beaches in front of seawalls than onto adjacent, non-walled beaches, and of those that did emerge in front of seawalls, more turtles returned to the water without nesting. Loggerhead sea turtle nests on North Carolina beaches increased in number as distance from hard structures including piers and terminal groins increased (Randall and Halls 2014). Studies in Florida have also found avoidance behavior and decreased hatching success associated with a managed inlet (Herren 1999).

Beach renourishment also negatively impacts loggerhead sea turtle nesting. Renourishment can cause beach compaction, which can decrease loggerhead nesting success, alter nest chamber geometry, and alter nest concealment, and nourishment can create escarpments, which can prevent turtles from reaching nesting areas (Crain *et al*. 1995). Nourishment can decrease survivorship of eggs and hatchlings by altering characteristics such as sand compaction, moisture content, and temperature of the sand (Leonard Ozan 2011), all of which are variables that can affect the proper development of eggs. The success of incubating eggs may be reduced when the sand grain size, density, shear resistance, color, gas diffusion rates, organic composition, and moisture content of the nourished sand is different from the natural beach sand (Nelson 1991). Negative impacts from beach renourishment include decreases in nesting activity and decreases in hatching success due to the use of incompatible material, sand compaction, and suboptimal beach profile (NMFS and USFWS 1991).

Sea turtles may be impacted by construction on beaches or dredge equipment, especially when work takes place outside the environmental window for sea turtles. During the spring and summertime construction phase of the Bald Head Island terminal groin, an adult female was trapped inside the construction zone for one day and a nest was destroyed when it was dug up by construction equipment (Sarah Finn pers. com. 2015). Pipeline and other obstructions placed on the beach may obstruct hatchling emergences or impede their path to the ocean (NMFS and USFWS 1991). Hopper and cutterhead dredges may also kill sea turtles during dredge work (NMFS and USFWS 1991). The loggerhead sea turtle recovery plan emphasizes that the only beneficial impacts of nourishment are in cases where beaches are so highly eroded, there is "a complete absence of dry beach" (NMFS and USFWS 1991).

The FEIS does not address the impacts to sea turtles should beach renourishment intervals turn out to be similar to those at other North Carolina inlets with hardened structures, rather than at the five-year intervals it forecasts. Nesting activity on nourished beaches decreased for one to three years following a nourishment event due to changes in the sand compaction, escarpment, and beach profile (NMFS and USFWS 1991, Steinitz *et al*. 1998, Trindell *et al*. 1998, Rumbold 2001, Brock *et al*. 2009). The FEIS also does not address the impacts to sea turtle nesting should the east end of Ocean Isle Beach experience downdrift erosion that would narrow the beach west of the groin where nesting occurs. The loggerhead recovery plan does include these negative impacts: "In preventing normal sand transport, these structures accrete updrift beaches while causing accelerated beach erosion downdrift of the structures [groins and jetties] (Komar 1983, Pilkey *et al*. 1984, National Research Council 1987), a process that results in degradation of sea turtle nesting habitat" (NMFS and USFWS 1991).

<u>Impacts on Fishes</u>: Fishes would be negatively impacted by the construction of a terminal groin and the subsequent beach nourishment projects at Shallotte Inlet in the following ways: 1) the groin would interrupt larval transport through the inlet, therefore impacting recruitment; 2) the native fish community would be replaced with a completely different structure-associated fish community; and 3) surf zone fishes would suffer from direct mortality. Hard structures reduce the successful passage of fish larvae from the open ocean to the estuarine nurseries they inhabit until reaching maturity (Hettler and Barker 1993, Pilkey *et al*. 1998). Inlets are critical pathways for adult fishes to get to offshore spawning sites and larvae immigrate through inlets to get to estuarine nurseries (Able *et al*. 2010).

Many surf zone fishes are larval and juvenile individuals that benefit from the shallow water nursery habitat because it provides refuge from predators and foraging areas (Layman 2000). Due to their early weak swimming ontogenetic stage, fish larvae are not adapted for high mobility in response to habitat burial or increased turbidity levels. Studies have shown that beach nourishment degrades the important swash-zone feeding habitat for both probing shorebirds and demersal surf fishes (Quammen 1982, Manning *et al*. 2013, VanDusen *et al*. 2014). Surf habitats with hardened structures typically support a different community of fishes and benthic prey.

Impacted species would include Atlantic menhaden, striped anchovy, bay anchovy, rough silverside, Atlantic silverside, Florida pompano, spot, Gulf kingfish, and striped mullet. Florida pompano and Gulf kingfish use the surf zone almost exclusively as a juvenile nursery area and as juveniles, they are rarely found outside the surf zone (Hackney *et al*. 1996). The dominant benthic prey for pompano and kingfish were coquina clams (*Donax*) and mole crabs (*Emerita*). Despite the fact that fishes in the surf zone are adapted to a high energy environment, rapid changes in their habitat can still cause mortality and other negative impacts. There are documented negative impacts of renourishment on some of the invertebrates (especially mole crabs and coquinas) that are major foods of the fishes (Reilly 1978, Baca *et al*. 1991); therefore, negative impacts could be indirectly transferred to the surf zone fish community.

Manning *et al*. (2013) states:

Beach nourishment can degrade the intertidal and shallow subtidal foraging habitats for demersal surf fishes by three major processes: (1) inducing mass mortality of macrobenthic infaunal prey through rapid burial by up to 1 m or more of dredged fill materials; (2) modifying the sedimentology of these beach zones through filling with excessive proportions of coarse, often shelly sediments that are incompatible with habitat requirements of some important benthic invertebrates, such as beach bivalves; and (3) incorporating into the beach fill excessive quantities of fine sediments in silt and clay sizes, which can induce higher near-shore turbidity during periods of erosion as onshore winds or distant storms generate wave action, thereby inhibiting detection of prey by visually orienting fishes. The opinion repeated in many environmental impact statements and environmental assessments that marine benthic invertebrates of ocean beach habitats are well adapted to surviving the sediment deposition of beach nourishment because of evolutionary experience with frequent erosion and deposition events associated with intense storms and high waves is unsupportable. A recent review of the literature on impacts of storms on ocean-beach macrofauna (Harris et al. 2011) reveals that about half the studies report massive reductions of beach infaunal populations after storms.

<u>Conclusion</u>: A unique ecological community exists at Shallotte Inlet that is connected to the base of the food chain. The base of the food chain (infaunal community) requires 1-4 years to recover from a nourishment event, and that has not been the case at the Ocean Isle beach. If the base of the food chain is absent or largely absent due to nourishment activities every two years, then the organisms that consume them, like birds and fishes, will not be present either. The FEIS fails to make this connection. Alternatives 3, 4, and 5 as presented in the FEIS would negatively impact birds, as well as infauna, fishes, and sea turtles.

The FEIS omits the vast majority of the ample body of scientific literature that is available to describe the well-known and accepted physical impacts of terminal groins and beach fill. It then fails to accurately describe the direct, indirect, and cumulative impacts that these activities would have on biological resources within Shallotte Inlet, particularly the Piping Plover and Red Knots. Instead, adverse impacts to Piping Plovers, Red Knots, other bird species, and their prey (infauna) are largely dismissed or ignored. The best, most recent data and peer-reviewed literature available to assess those impacts are omitted or misrepresented, and the recommendations of multiple management and recovery plans, including USFWS recovery plans, are largely disregarded.

Alternatives 3, 4, and 5 as presented in the FEIS would jeopardize the recovery and/or persistence of the Great Lakes breeding population of Piping Plover, the Atlantic coast breeding population of Piping Plover, Seabeach Amaranth, and Red Knot; and a terminal groin would permanently eliminate habitats for these species listed under the Endangered Species Act without any chance of restoration or reformation in other areas. The alternatives in the FEIS that involve hard structures, channelization (Alternatives 5 and 4) or nourishment on a two-year cycle (Alternative 3) at Shallotte Inlet should be permanently removed from further consideration and other alternatives should be considered.

Thank you for your time and consideration.

Sincerely,

Walker Golder
Deputy Director

Literature Cited

Able, K.W., Wilber, D.H., Muzeni-Corino, A., and Clarke, D.G. 2010. Spring and Summer Larval Fish Assemblages in the Surf Zone and Nearshore off Northern New Jersey, USA. Estuaries and Coasts, 33: 211-222.

Baca, B.J., Dodge, R.E., and Mattison, C. 1991. Predicting Environmental Impacts from Beach Nourishment Projects. Proceedings of the 4th National Beach Preservation Technical Conference. Florida Shore and Beach Preservation Association, Tallahassee, FL, 249-310.

Baker, A., Gonzalez, P., Morrison, R.I.G., and Harrington, B.A. 2013. Red Knot (*Calidris canutus*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/563

Basco, D.R. 2006. Seawall Impacts on Adjacent Beaches: Separating Fact from Fiction. Journal of Coastal Research, SI 39: 741-744.

Basco, D.R. and Pope, J. 2004. Groin Functional Design Guidance from the Coastal Engineering Manual. Journal of Coastal Research, SI 33: 121-130.

Berry, A., Fahey, S., and Meyers, N. 2013. Changing of the Guard: Adaptation Options that Maintain Ecologically Resilient Sandy Beach Ecosystems. Journal of Coastal Research, 29(4): 899-908.

Bertasi, F., Colangelo, M.A., Abbiati, M., and Ceccherelli, V.U. 2007. Effects of an Artificial Protection Structure on the Sandy Shore Macrofaunal Community: The Special Case of Lido di Dante (Northern Adriatic Sea). Hydrobiologia, 586: 277-290.

Bishop, M.J., Peterson, C.H., Summerson, H.C., Lenihan, H.S., and Grabowski, J.H. 2006. Deposition and Long-Shore Transport of Dredge Spoils to Nourish Beaches: Impacts on Benthic Infauna of an Ebb-Tidal Delta. Journal of Coastal Research, 22(3): 530-546.

Bouchard, S., Moran K., Tiwari, M., Wood, D., Bolten, A., Eliazar, P, and Bjorndal, K. 1998. Effects of Exposed Pilings on Sea Turtle Nesting Activity at Melbourne Beach, Florida. Journal of Coastal Research, 14(4): 1343-1347.

Brown, S., Hickey, C., Harrington, B., and Gill, R. 2001. United States Shorebird Conservation Plan. Manomet Center for Conservation Sciences. 64 p.

Brown, A.C. and McLachlan, A. 2002. Sandy Shore Ecosystems and the Threats Facing Them: Some Predictions for the Year 2025. Environmental Conservation, 29(1): 62-77.

Brock, K.A., Reece, J.S., and Ehrhart, L.M. 2009. The Effects of Artificial Beach Nourishment on Marine Turtles: Differences between Loggerhead and Green Turtles. Restoration Ecology, 17(2): 297-307.

Bruun, P. 1995. The Development of Downdrift Erosion. Journal of Coastal Research, 11(4): 1242-1257.

Cahoon, L.B., Carey, E.S., and Blum, J.E. 2012. Benthic Microalgal Biomass on Ocean Beaches: Effects of Sediment Grain Size and Beach Renourishment. Journal of Coastal Research, 28(4): 853-859.

Cleary, W.J. and Marden, T.P. 1999. Shifting Shorelines: A Pictorial Atlas of North Carolina's Inlets, NC Sea Grant Program Publication No. UNC-SG-99-04, Raleigh, NC. 51 p.

Cleary, W.J. and Pilkey, O.H. 1996. Environmental Coastal Geology: Cape Lookout to Cape Fear, North Carolina, Regional Overview. *In:* Environmental Coastal Geology: Cape Lookout to Cape Fear, NC. Cleary, W.J., (ed), Carolina Geological Society Field Guidebook: 73-107.

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

Colosio, F., Abbiati, M., and Airoldi, L. 2007. Effects of Beach Nourishment on Sediments and Benthic Assemblages. Marine Pollution Bulletin, 54: 1197-1206.

Colwell, M.A. 2010. Shorebird Ecology, Conservation and Management. University of California Press, Berkeley, USA. 344 p.

Crain, D.A., Bolten, A.B., and Bjorndal, K.A. 1995. Effects of Beach Nourishment on Sea Turtles: Review and Research Initiatives. Restoration Ecology, 3(2): 95-104.

Culver, S.J., Ames, D.V., Reide Corbett, D., Mallison, D.J., Riggs, S.R., Smith, C.G., and Vance, D.J. 2006. Foraminiferal and Sedimentary Record of Late Holocene Barrier Island Evolution, Pea Island, North Carolina: The Role of Storm Overwash, Inlet Processes, and Anthropogenic Modification. Journal of Coastal Research, 22(4): 836-846.

Culver, S.J., Grand Pre, C.A., Mallinson, D.J., Riggs, S.R., Corbett, D.R., Foley, J., Male, M., Ricardo, J., Rosenberger, J., Smith, C.G., Smith, C.W., Snyder, S.W., Twamley, D., Farrell, K., and Horton, B.P. 2007. Late Holocene Barrier Island Collapse: Outer Banks, North Carolina, U.S.A. The Sedimentary Record, 5(4): 4-8.

Dias, M.P., Granadeiro, J.P., Lecoq, M., Santos, C.D., and Palmeirim, J.M. 2006. Distance to High-tide Roosts Constrains the Use of Foraging Areas by Dunlins: Implications for the Management of Estuarine Wetlands. Biological Conservation, 131(3): 446-452.

Dolan, R., Donogue, C., and Stewart, D. 2006. Long-term Impacts of Tidal Inlet Bypassing on the Swash Zone Filter Feeder *Emerita talpoida* Oregon Inlet and Pea Island, North Carolina. Shore and Beach, 74(1): 23-27.

Drake, K.R., Thompson, J.E., and Drake, K.L. 2001. Movements, Habitat Use, and Survival of Nonbreeding Piping Plovers. The Condor, 103: 259-267.

Dugan, J.E. and Hubbard, D.M. 2006. Ecological Responses to Coastal Armoring on Exposed Sandy Beaches. Shore and Beach, 74(1): 10-16.

Dugan, J.E., Hubbard, D.M., Rodil, I.F., Revell, D.L., and Schroeter, S. 2008. Ecological Effects of Coastal Armoring on Sandy Beaches. Marine Ecology, 29 (Suppl. 1): 160-170.

Elliott-Smith, E. and Haig, S.M. 2004. Piping Plover (*Charadrius melodus*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/002

Ells, K. and Murray, A.B. 2012. Long-term, Non-local Coastline Responses to Local Shoreline Stabilization. Geophysical Research Letters, 39: L19401.

Fenster, M. and Dolan, R. 1996. Assessing the Impact of Tidal Inlets on Adjacent Barrier Island Shorelines. Journal of Coastal Research, 12(1): 294-310.

Fernández, G., Buchanan, J.B., Gill, R.E., Jr., Lanctot, R., and Warnock, N. 2010. Conservation Plan for Dunlin with Breeding Populations in North America (*Calidris alpina arcticola, C. a. pacifica,* and *C. a. hudsonia*), Version 1.1. Manomet Center for Conservation Sciences, Manomet, Massachusetts.

French, P.W. 2001. Coastal Defences: Processes, Problems and Solutions. Routledge, London. 388 p.

Galgano, F.A., Jr. 2004. Long-term Effectiveness of a Groin and Beach Fill System: A Case Study Using Shoreline Change Maps. Journal of Coastal Research, SI 33: 3-18.

Gochfeld, M. and Burger, J. 1994. Black Skimmer (*Rynchops niger*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/108

Greene, K. 2002. Beach Nourishment: A Review of the Biological and Physical Impacts. Washington (DC): Atlantic States Marine Fisheries Commission. ASMFC Habitat Management Series No. 7. 174 p.

Hackney, C.T. and Cleary, W.J. 1987. Saltmarsh Loss in Southeastern North Carolina Lagoons: Importance of Sea Level Rise and Inlet Dredging. Journal of Coastal Research, 3: 93-97.

Hackney, C.T., Posey, M.H., Ross, S.W., and Norris, A.R. 1996. A Review and Synthesis of Data on Surf Zone Fishes and Invertebrates in the South Atlantic Bight and the Potential Impacts from Beach Nourishment. Prepared for U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC. 111 p.

Haig, S.M. and Oring, L.W. 1985. Distribution and Status of the Piping Plover Throughout the Annual Cycle. Journal of Field Ornithology, 56(4): 334-345.

Harrington, B.R. 2008. Coastal Inlets as Strategic Habitat for Shorebirds in the Southeastern United States. DOER Technical Notes Collection. ERDC TN-DOER-E25. Vicksburg, MS: U.S. Army Engineer Research and Development Center, available at http://el.erdc.usace.army.mil/elpubs/pdf/doere25.pdf.

Hay, M.E. and Sutherland, J.P. 1988. The Ecology of Rubble Structures of the South Atlantic Bight: A Community Profile. U.S. Fish and Wildlife Service Biological Report 85(7.20). 67 p.

Hayden, B. and Dolan, R. 1974. Impact of Beach Nourishment on Distribution of *Emerita talpoida*, the Common Mole Crab. Journal of the Waterways, Harbors and Coastal Engineering Division, 100: 123-132.

Herren, R.M. 1999. The Effect of Beach Nourishment on Loggerhead (*Caretta caretta*) Nesting and Reproductive Success at Sebastian Inlet, Florida. M.S. Thesis. University of Central Florida. 150 p.

Hettler, W.F., Jr. and Barker, D.L. 1993. Distribution and Abundance of Larval Fishes at Two North Carolina Inlets. Estuarine, Coastal and Shelf Science, 37: 161-179.

Jaramillo, E., Croker, R.A., and Hatfield, E.B. 1987. Long-term Structure, Disturbance, and Recolonization of Macroinfauna in a New Hampshire Sand Beach. Canadian Journal of Zoology, 65: 3024-3031.

Johnson, C.M. and Baldassarre, G.A. 1988. Aspects of the Wintering Ecology of Piping Plovers in Coastal Alabama. Wilson Bulletin, 100: 214-223.

Kisiel, C.L. 2009a. The Spatial and Temporal Distribution of Piping Plovers in New Jersey: 1987-2007. M.S. Thesis. New Brunswick, New Jersey, The State University of New Jersey, Rutgers. 75 p.

Kisiel, C.L. 2009b. The Role of Inlets in Piping Plover Nest Site Selection in New Jersey 1987-2007. New Jersey Birds, 35(3): 45-52.

Knapp, K. 2012. Impacts of Terminal Groins on North Carolina's Coasts. M.E.M. Thesis. Durham, North Carolina, Duke University. 49 p.

Komar, P.D. 1998. Beach Processes and Sedimentation. Prentice-Hall, Inc., Upper Saddle River, New Jersey. 544 p.

Kraus, N.C., Hanson, H., and Blomgren, S.H. 1994. Modern Functional Design of Groin Systems. Proceedings of the 24th International Conference on Coastal Engineering, American Society of Civil Engineers: New York, 1327-1342.

Lamont, M.M. and Houser, C. 2014. Spatial Distribution of Loggerhead Turtle (*Caretta caretta*) Emergences along a Highly Dynamic Beach in the Northern Gulf of Mexico. Journal of Experimental Marine Biology and Ecology, 453: 98-107.

Layman, C.A. 2000. Fish Assemblage Structure of the Shallow Ocean Surf-Zone on the Eastern Shore of Virginia Barrier Islands. Estuarine, Coastal and Shelf Science, 51: 201-213.

Leewis, L., van Bodegoma, P.M., Rozema, J., and Janssen, G.M. 2012. Does Beach Nourishment Have Long-term Effects on Intertidal Macroinvertebrate Species Abundance? Estuarine, Coastal and Shelf Science, 113: 172-181.

Leonard Ozan, C.R. 2011. Evaluating the Effects of Beach Nourishment on Loggerhead Sea Turtle (*Caretta caretta*) Nesting in Pinellas County, Florida. M.S. Thesis. Tampa, Florida, University of South Florida. 60 p.

Lowther, P.E., Douglas, H.D., III, and Gratto-Trevor, C.L. 2001. Willet (*Tringa semipalmata*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/579

Macwhirter, B., Austin-Smith, P., Jr., and Kroodsma, D. 2002. Sanderling (*Calidris alba*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/653

Maddock, S., Bimbi, M., and Golder, W. 2009. South Carolina Shorebird Project, Draft 2006-2008 Piping Plover Summary Report. Audubon North Carolina and U.S. Fish and Wildlife Service, Charleston, South Carolina. 135 p.

Mallinson, D.J., Culver, S.J., Riggs, S.R., Walsh, J.P., Ames, D., and Smith, C.W. 2008. Past, Present and Future Inlets of the Outer Banks Barrier Islands, North Carolina: A White Paper. East Carolina University, Greenville, North Carolina. 22 p.

Mallinson, D.J., Culver, S.J., Riggs, S.R., Thieler, E.R., Foster, D., Wehmiller, J., Farrell, K.M., and Pierson, J. 2010. Regional Seismic Stratigraphy and Controls on the Quaternary Evolution of the Cape Hatteras Region of the Atlantic Passive Margin, USA. Marine Geology, 268: 16-33.

Mallinson, D.A., Riggs, S.R., Thieler, E.R., Culver, S.J., Foster, D., Corbett, D.R., Farrell, K., and Wehmiller, J. 2005. Late Neogene Evolution of the Northeastern Coastal System: Filling the Northern Albemarle Sound. Marine Geology, 217: 97-117.

Manning, L.M., Peterson, C.H., and Bishop, M.J. 2014. Dominant Macrobenthic Populations Experience Sustained Impacts from Annual Disposal of Fine Sediments on Sandy Beaches. Marine Ecology Progress Series, 508: 1-15.

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

Maslo, B., Handel, S.N., and Pover, T. 2011. Restoring Beaches for Atlantic Coast Piping Plovers (*Charadrius melodus*): A Classification and Regression Tree Analysis of Nest-Site Selection. Restoration Ecology, 19(201): 194-203.

McDougall, W.G., Sturtevant, M.A., and Komar, P.D. 1987. Laboratory and Field Investigations of the Impact of Shoreline Stabilization Structures on Adjacent Properties. Coastal Sediments '87, American Society of Civil Engineers: New York, 961-973.

McLachlan, A., and Brown, A.C. 2006. The Ecology of Sandy Shores. Academic Press, Burlington, MA. 392 p.

McQuarrie, M. and Pilkey, O.H. 1998. Evaluation of Alternative or Non-Traditional Devices for Shoreline Stabilization. Journal of Coastal Research, SI 26: 269-272.

Morton, R.A. 2003. An Overview of Coastal Land Loss: With Emphasis on the Southeastern United States. USGS Open File Report 03-337. U.S. Geological Survey Center for Coastal and Watershed Studies, St. Petersburg, FL, Available at <http://pubs.usgs.gov/of/2003/of03-337/pdf.html>.

Morton, R.A., Miller, T.L., and Moore, L.J. 2004. National Assessment of Shoreline Change: Part 1: Historical Shoreline Changes and Associated Coastal Land Loss Along the U.S. Gulf of Mexico. Open-file report 2004-1043. U.S. Geological Survey Center for Coastal and Watershed Studies, St. Petersburg, FL, Available at <http://pubs.usgs.gov/of/2004/1043/>.

Mosier, A.E. 1998. The Impact of Coastal Armoring Structures on Sea Turtle Nesting Behavior at Three Beaches on the East Coast of Florida. M.S. Thesis. St. Petersburg, Florida, University of South Florida. 112 p.

National Marine Fisheries Service [NMFS] and U.S. Fish and Wildlife Service [USFWS]. 1991. Recovery Plan for U.S. Population of Loggerhead Turtle. National Marine Fisheries Service, Washington, D.C. 64 p.

National Park Service [NPS]. 2014a. Piping Plover 2014 Annual Report from Cape Hatteras. Cape Hatteras National Seashore. 13 p.

National Park Service [NPS]. 2014b. Piping Plover (*Charadrius melodus*) Monitoring at Cape Lookout National Seashore 2014 Summary Report. Cape Lookout National Seashore. 23 p.

Nelson, D.A. 1991. Issues Associated with Beach Nourishment and Sea Turtle Nesting. Proceedings of the Fourth Annual National Beach Preservation Technology Conference. Florida Shore and Beach Association, Tallahassee, FL, p. 277-294.

Nicholls, J.L. and Baldassarre, G.A. 1990. Habitat Selection and Interspecific Associations of Piping Plovers Wintering in the United States. Wilson Bulletin, 102: 581-590.

Niles, L., Sitters, H., Dey, A., and Red Knot Status Assessment Group. 2010. Red Knot Conservation Plan for the Western Hemisphere (*Calidris canutus*), Version 1.1. Manomet Center for Conservation Sciences, Manomet, Massachusetts, USA.

Noel, B.L. and Chandler, C.R. 2008. Spatial Distribution and Site Fidelity of Non-breeding Piping Plovers on the Georgia Coast. Waterbirds, 31: 241-251.

Nol, E. and Humphrey, R.C. 2012. American Oystercatcher (*Haematopus palliatus*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/082

Nordstrom, K.F. 2000. Beaches and Dunes of Developed Coasts. Cambridge University Press, Cambridge, UK. 338 p.

Payne, L.X. 2010. Conservation Plan for the Sanderling (*Calidris alba*).Version 1.1. Manomet Center for Conservation Sciences, Manomet, Massachusetts.

Peterson, C.H. and Bishop, M.J. 2005. Assessing the Environmental Impacts of Beach Nourishment. BioScience, 55: 887-896.

Peterson, C.H., Bishop, M.J., D'Anna, L.M., and Johnson, G.A. 2014. Multi-year Persistence of Beach Habitat Degradation from Nourishment Using Coarse Shelly Sediments. Science of the Total Environment, 487: 481-492.

Peterson, C.H., Bishop, M.J., Johnson, G.A., D'Anna, L.M., and Manning, L.M. 2006. Exploiting Beach Filling as an Unaffordable Experiment: Benthic Intertidal Impacts Propagating Upwards to Shorebirds. Journal of Experimental Marine Biology and Ecology, 338: 205-221.

Peterson, C.H., Hickerson, D.H.M., and Johnson, G.G. 2000a. Short-Term Consequences of Nourishment and Bulldozing on the Dominant Large Invertebrates of a Sandy Beach. Journal of Coastal Research, 16: 368-378.

Peterson, C.H., Summerson, H.C., Thomson, E., Lenihan, H.S., Grabowski, J., Manning, L., Micheli, F., and Johnson, G. 2000b. Synthesis of Linkages between Benthic and Fish Communities as a Key to Protecting Essential Fish Habitat. Bulletin of Marine Science, 66: 759-774.

Pietrafesa, L.J. 2012. On the Continued Cost of Upkeep Related to Groins and Jetties. Journal of Coastal Research, 28(5): iii-ix.

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

Quammen, M.L. 1982. Influence of Subtle Substrate Differences on Feeding by Shorebirds on Intertidal Mudflats. Marine Biology, 71: 339-343.

Rabon, D.R. (compiler). 2006. Proceedings of the Symposium on the Wintering Ecology and Conservation of Piping Plovers. U.S. Fish and Wildlife Service, Raleigh, NC.

Rakocinski, C.F., Heard, R.W., LeCroy, S.E., McLelland, J.A., and Simons, T. 1996. Responses by Macrobenthic Assemblages to Extensive Beach Restoration at Perdido Key, Florida, U.S.A. Journal of Coastal Research, 12(1): 326-353.

Randall, A.L. and Halls, J.N. 2015. Modeling the Nesting Suitability of Loggerhead Sea Turtles (*Caretta caretta*) in North Carolina Using Geospatial Technologies. Presentation: NC Sea Turtle Holders' Permit Meeting. Fort Macon, North Carolina.

Reilly, F.J. 1978. A Study of the Ecological Impact of Beach Nourishment with Dredged Material on the Intertidal Zone. M.S. Thesis. Greenville, North Carolina. East Carolina University. 108 p.

Rice, T.M. 2009. Best Management Practices for Shoreline Stabilization to Avoid and Minimize Adverse Environmental Impacts. Prepared for the USFWS, Panama City Ecological Services Field Office. 22 p.

Rice, T.M. 2012a. Inventory of Habitat Modifications to Tidal Inlets in the Coastal Migration and Wintering Range of the Piping Plover (*Charadrius melodus*). Appendix 1B *in* Draft Comprehensive Conservation Strategy for the Piping Plover (*Charadrius melodus*) Coastal Migration and Wintering Range, U.S. Fish and Wildlife Service. 35 p.

Rice, T.M. 2012b. The Status of Sandy, Oceanfront Beach Habitat in the Coastal Migration and Wintereing Range of the Piping Plover (*Charadrius melodus*). Appendix 1C *in* Draft Comprehensive Conservation Strategy for the Piping Plover (*Charadrius melodus*) Coastal Migration and Wintering Range, U.S. Fish and Wildlife Service. 40 p.

Riggs, S.R. and Ames, D.V. 2003. Drowning of North Carolina: Sea-Level Rise and Estuarine Dynamics. NC Sea Grant College Program, Raleigh, NC, Pub. No. UNC-SG-03-04. 152 p.

Riggs, S.R. and Ames, D.V. 2007. Effect of Storms on Barrier Island Dynamics, Core Banks, Cape Lookout National Seashore, North Carolina, 1960-2001. U.S.

Geological Survey Scientific Investigations Report 2006-5309. 78 p.

Riggs, S.R. and Ames, D.V. 2009. Impact of the Oregon Inlet Terminal Groin on Downstream Beaches of Pea Island, NC Outer Banks. A White Paper. East Carolina University, Greenville, North Carolina. 19 p.

Riggs, S.R. and Ames, D.V. 2011. Consequences of Human Modifications of Oregon Inlet to the Down-drift Pea Island, North Carolina Outer Banks. Southeastern Geology, 48(3): 103-128.

Riggs, S.R., Ames, D.V., Culver, S.J., Mallinson, D.J., Corbett, D.R., and Walsh, J.P. 2009. Eye of a Human Hurricane: Pea Island, Oregon Inlet, and Bodie Island, Northern Outer Banks, North Carolina, *in* Kelley, J.T., Pilkey, O.H., and Cooper, J.A.G., eds., America's Most Vulnerable Coastal Communities: Geological Society of America Special Paper 460: 43-72.

Riggs, S.R., Culver, S.J., Ames, D.V., Mallinson, D.J., Corbett, D.R., and Walsh, J.P. 2008. North Carolina's Coasts in Crisis: A Vision for the Future. A White Paper. East Carolina University, Greenville, North Carolina. 28 p.

Rogers, D.I., Piersma, T., and Hassell, C.J. 2006. Roost Availability May Constrain Shorebird Distribution: Exploring the Energetic Costs of Roosting and Disturbance Around a Tropical Bay. Biological Conservation, 133(2): 225-235.

Rumbold, D.G., Davis, P.W., and Perretta, C. 2001. Estimating the Effect of Beach Nourishment on *Caretta Caretta* (Loggerhead Sea Turtle) Nesting. Restoration Ecology, 9(3): 304-310.

Schlacher, T.A., Noriega, R., Jones, A., and Dye, T. 2012. The Effects of Beach Nourishment on Benthic Invertebrates in Eastern Australia: Impacts and Variable Recovery. Science of the Total Environment, 435-436: 411-417.

Smith, C.G., Culver, S.J., Riggs, S.R., Ames, D., Corbett, D.R., and Mallinson, D. 2008. Geospatial Analysis of Barrier Island Width of Two Segments of the Outer Banks, North Carolina, USA: Anthropogenic Curtailment of Natural Self-sustaining Processes. Journal of Coastal Research, 24(1): 70-83.

Speybroeck, J., Bonte, D., Courtens, W., Gheskiere, T., Grootaert, P., Maelfait, J., Mathys, M., Provoost, S., Sabbe, K., Stienen, E., VanLancker, V., Vincx, M., and Degraer, S. 2006. Beach Nourishment: An Ecologically Sound Coastal Defence Alternative? A Review. Aquatic Conservation: Marine and Freshwater Ecosystems, 16: 419-435.

Steinitz, M.J., Salmon, M., and Wyneken, J. 1998. Beach Renourishment and Loggerhead Turtle Reproduction: A Seven Year Study at Jupiter Island, Florida. Journal of Coastal Research, 14(3): 1000-1013.

Thompson, B.C., Jackson, J.A., Burger, J., Hill, L.A., Kirsch, E.M., and Atwood, J.L. 1997.

Least Tern (*Sternula antillarum*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/290

Trindell, R., Arnold, D., Moody, K., and Morford, B. 1998. Post-construction Marine Turtle Nesting Monitoring Results on Nourished Beaches. Pages 77-92 in Tait, L.S. (compiler), Rethinking the Role of Structures in Shore Protection. Proceedings of the 1998 National Conference on Beach Preservation Technology. Florida Shore and Beach Preservation Association, Tallahassee, Florida.

U.S. Army Corps of Engineers. [USACE]. 2002. Coastal Engineering Manual. Engineer Manual 1110-2-1100. USACE, Washington, DC, Available at <http://chl.erdc.usace.army.mil/cem>.

U.S. Fish and Wildlife Service. [USFWS]. 1996. Piping Plover (*Charadrius melodus*), Atlantic Coast Population, Revised Recovery Plan. Hadley, Massachusetts.

U.S. Fish and Wildlife Service. [USFWS]. 2001. Final Determination of Critical Habitat for Wintering Piping Plover. Federal Register 66 (132): 36037-36086.

U.S. Fish and Wildlife Service. [USFWS]. 2003. Recovery Plan for the Great Lakes Piping Plover (*Charadrius melodus*). U.S. Fish and Wildlife Service, Fort Snelling, Minnesota.

U.S. Fish and Wildlife Service. [USFWS]. 2009. Piping Plover (*Charadrius melodus*) 5-Year Review: Summary and Evaluation. Hadley, Massachusetts and East Lansing, Michigan.

U.S. Fish and Wildlife Service. [USFWS]. 2012. Comprehensive Conservation Strategy for the Piping Plover (*Charadrius melodus*) in its Coastal Migration and Wintering Range in the Continental United States. East Lansing, Michigan.

U.S. Fish and Wildlife Service. [USFWS]. 2013. Endangered and Threatened Wildlife and Plants; Proposed Threatened Status for the Rufa Red Knot (*Calidris canutus rufa*). Federal Register Vol. 78, No. 189: 60024-60098.

Van Dusen, B.M., Fegley, S.R., and Peterson, C.H. 2012. Prey Distribution, Physical Habitat Features, and Guild Traits Interact to Produce Contrasting Shorebird Assemblages among Foraging Patches. PLoS ONE, 7(12): e52694.

Viola, S.M., Hubbard, D.M., Dugan, J.E., and Schooler, N.K. 2014. Burrowing Inhibition by Fine Textured Beach Fill: Implications for Recovery of Beach Ecosystems. Estuarine, Coastal and Shelf Science, 150: 142-148.

Winn, B., Brown, S., Spiegel, C., Reynolds, D., and Johnston, S. 2013. Atlantic Flyway Shorebird Conservation Business Strategy. Manomet Center for Conservation Sciences. 26 p.

Wooldridge, T., Henter, H.J., and Kohn, J.R. 2016. Effects of Beach Replenishment on Intertidal Invertebrates: A 15-month, Eight Beach Study. Estuarine, Coastal and Shelf Science, 175: 24-33.

Young, P.G. *et al*. 2007. Coastal Scientist Groin Statement.Western Carolina University Program for the Study of Developed Shorelines. http://www.wcu.edu/WebFiles/PDFs/Coastal_Scientist_Groin_Statement.pdf