Wilmington Harbor, North Carolina
Navigation Improvement Project

Integrated
Section 203 Study
&
Environmental Report

APPENDIX I

ESSENTIAL FISH HABITAT ASSESSMENT

February 2020

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1 INTRODUCTION

The North Carolina State Ports Authority (NCSPA) has prepared this Essential Fish Habitat (EFH) Assessment in accordance with in accordance with the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), as amended by the Sustainable Fisheries Act of 1996, to address the effects of the proposed Wilmington Harbor Navigation Improvement Project (WHNIP) on EFH and federally managed fisheries. The proposed project would deepen the existing federally authorized navigation channel from the lower end of the Anchorage Basin at the Port of Wilmington to the seaward limit of the ocean entrance channel, and create a new approximately (~) 9-mile seaward extension of the ocean entrance channel for purposes of accommodating a larger class of container vessels. This EFH Assessment has been prepared as a component of the WHNIP Integrated Feasibility and Environmental Study under the authority of Section 203 of the Water Resources Development Act (WRDA) of 1986 [Public Law (PL) 99-662] as amended.

1.1 Background

The existing Wilmington Harbor federal navigation channel extends 38.1 miles from the Atlantic Ocean offshore of Cape Fear to the City of Wilmington (Figure 1). Construction of the federal navigation channel to its current dimensions was originally authorized as three separate projects by the WRDA 86 Public Law 99-662 and 1996 (WRDA 96) Public Law 104-303. Public Law 105-62, The Energy and Water Development Appropriations Act of 1998, combined the Wilmington Harbor Northeast Cape Fear River Project (WRDA 1986), the Wilmington Harbor Channel Widening Project (WRDA 1996), and the Cape Fear-Northeast (Cape Fear) Rivers Project (WRDA 1996) under a single project known as the Wilmington Harbor 96 Act Project. Improvements under the Wilmington Harbor 96 Act Project included deepening the ocean entrance channel and the lower inner harbor channel up through the Battery Island reach from -40 to -44 feet (ft); deepening the inner harbor channel from the Battery Island reach up to the Cape Fear Memorial Bridge from -38 to -42 ft; and widening various channel reaches, turns, and bends. Additional authorized improvements to the -32-foot and -25-foot channel reaches that comprise the remainder of the federal project from the Cape Fear Memorial Bridge to the upper project limit in the Northeast Cape Fear River were deferred due to a marginal cost to benefit ratio.

The Port of Wilmington has experienced significant growth in cargo volume and in the size of vessels calling at the port since the last major channel improvements were completed under the Wilmington Harbor 96 Act Project. The NCSPA has made major investments in landside infrastructure to accommodate growth at the Port of Wilmington and the region that it serves. At the present time, the Port of Wilmington is the largest port in North Carolina (NC) and is a major component of the state’s economy. Due to expansion of the Panama Canal and harbor deepening projects at all other major United States (US) East Coast ports, the US East Coast to Asia shipping alliances are transitioning to vessels that are substantially larger than those that the existing -42-foot Wilmington Harbor channel was designed to accommodate. Inadequate channel capacity is currently impacting trade at the Port of Wilmington and is projected to have a greater detrimental impact on trade in the future as ocean carriers continue to transition from the existing fleet of 8,000 Twenty-foot Equivalent Unit (TEU) vessels to a new fleet of larger 12,400 TEU vessels. The proposed improvements to the federal navigation channel would accommodate larger cargo vessels at Wilmington Harbor and enable the Port of Wilmington to continue as a port-of-call for shipping alliances with direct service to Asian markets.

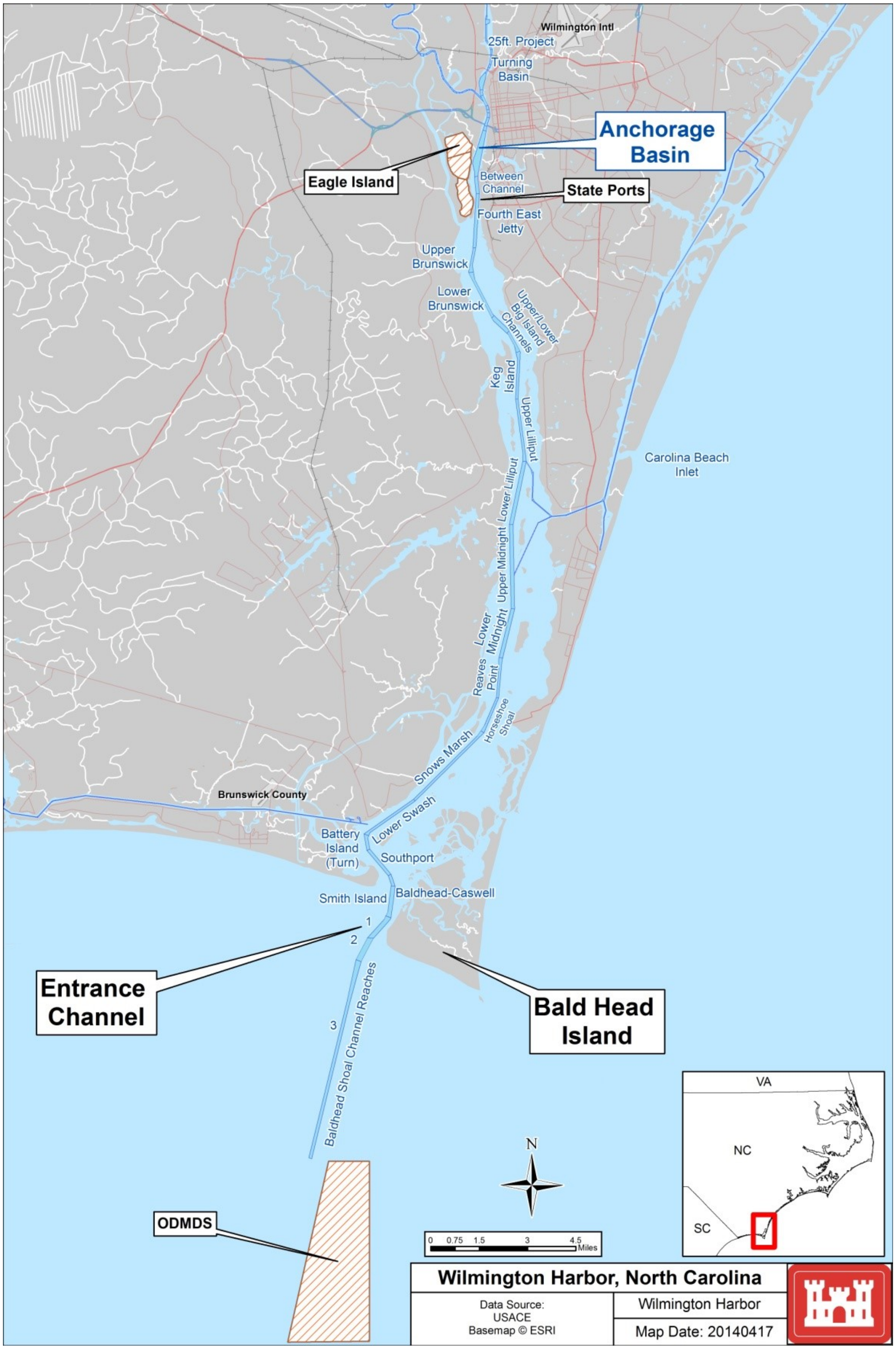


Figure 1
Existing Wilmington Harbor Navigation Project

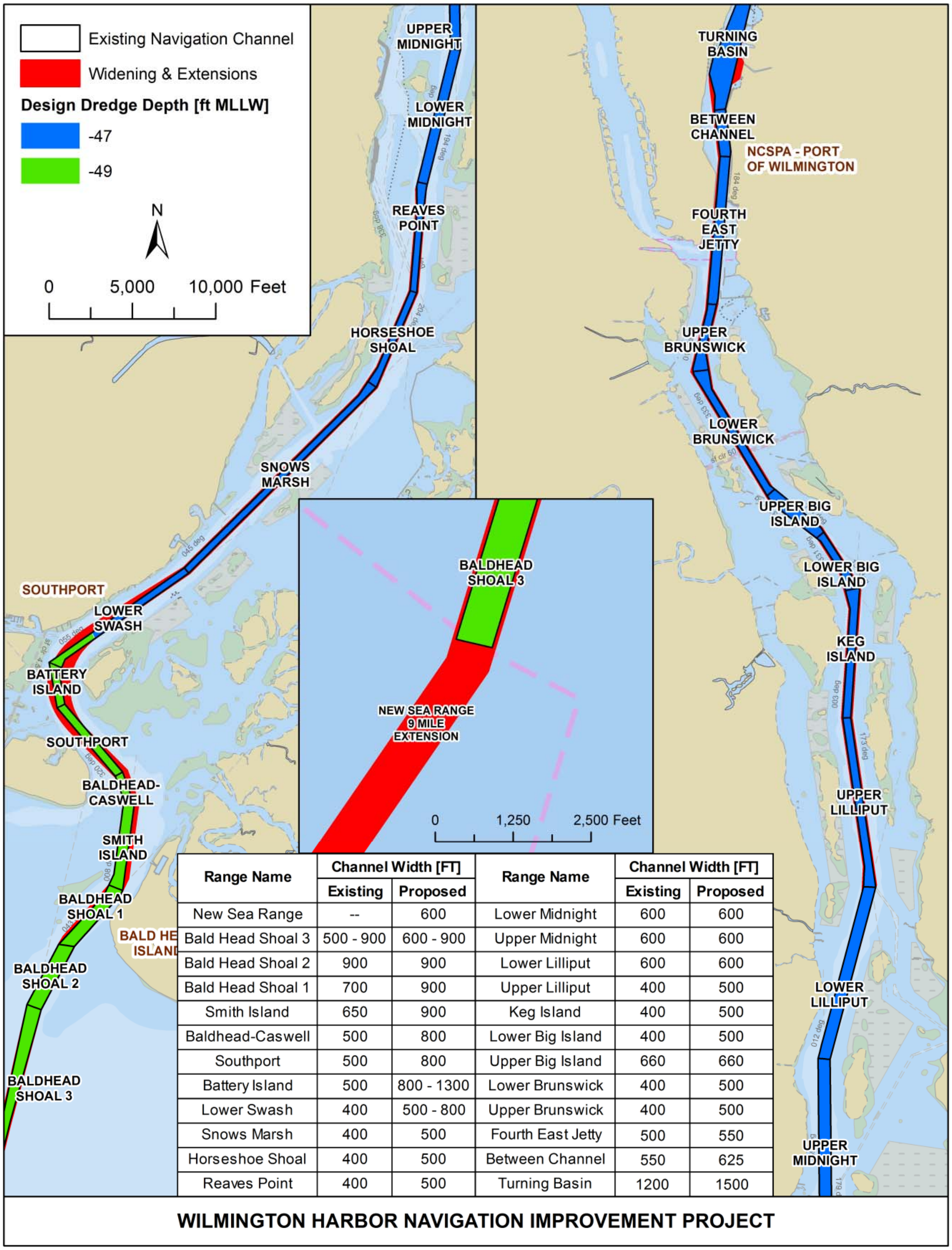
2 PROPOSED ACTION

2.1 Channel Design

Under the proposed action (Figure 2), improvements to accommodate larger vessels would include deepening the federal navigation channel from the Port of Wilmington to the seaward limit of the ocean entrance channel (~33 miles), extending the ocean entrance channel an additional 9.1 miles offshore, and expanding wideners at turns along the channel. The existing -42-foot channel from the lower Anchorage Basin at the Port of Wilmington to the inland boundary of the Battery Island reach (~23 miles) would be deepened to -47 ft. The existing -44-foot channel from the inland boundary of the Battery Island reach to the seaward terminus of the existing ocean entrance channel (~10 miles) would be deepened to -49 ft. The increased depth of -49 ft in the channel seaward of Battery Island is required to account for the effects of ocean waves on under keel clearance. The entrance channel would be extended an additional 9.1 miles offshore at the same -49-foot depth. In relation to the existing Baldhead Shoal 3 outer entrance channel reach, the alignment of the extension reach would be shifted ~16 degrees (°) to the southwest. The proposed alignment and length of the extension reach represent the shortest route to waters that are consistently deeper than the proposed entrance channel depth of -49 ft. Proposed increases in the authorized bottom width of the channel (Table 1) are based on model simulated 12,400 TEU vessel operations in the improved channel and are designed to accommodate the maneuver capabilities of individual larger class vessels. The Battery Island reach and portions of the adjoining Lower Swash and Southport reaches would be reconfigured as part of a 4,000-foot radius curve redesign of the Battery Island turn. The remaining reaches that are proposed for widening would retain their existing alignments.

2.2 Dredging and Dredged Material Disposal

Construction of the proposed Wilmington Harbor navigation improvements would employ hydraulic pipeline (cutterhead), mechanical (bucket), and hopper dredges. Associated disposal operations would include hydraulic (cutterhead) loading of barges for offshore transport to the Offshore Dredged Material Disposal Site (ODMDS), mechanical (bucket dredge) scow loading for offshore transport to the ODMDS, direct transport to the ODMDS via self-propelled hopper dredges, and direct hydraulic (cutterhead) pipeline disposal to the beaches of Bald Head Island and Oak Island and waterbird nesting islands in the lower estuary. Table 2 provides a breakdown of dredging and disposal operations by equipment type, channel reach, and applicable environmental work windows. The use of hopper dredges would be limited to the outer Baldhead Shoal 2 and 3 entrance channel reaches and the proposed offshore extension reach. Construction of the remaining channel reaches would be accomplished predominantly by cutterhead dredges. Mechanical (bucket) dredges would be used for the specific purpose of removing pre-treated rock from the ~4.4-mile Keg Island to Lower Brunswick channel reach. Hopper dredging operations would adhere to the established Wilmington Harbor hopper dredge environmental work window of 1 December to 15 April. Pursuant to established fisheries environmental work windows for Wilmington Harbor, cutterhead dredging would occur year-round in the channel reaches below Snows Cut and from 1 July to 31 January in the reaches above Snows Cut. Bucket dredge operations are not subject to any environmental work window restrictions, and thus could occur year-round depending on the need for pre-treated rock removal.



Range Name	Channel Width [FT]		Range Name	Channel Width [FT]	
	Existing	Proposed		Existing	Proposed
New Sea Range	--	600	Lower Midnight	600	600
Bald Head Shoal 3	500 - 900	600 - 900	Upper Midnight	600	600
Bald Head Shoal 2	900	900	Lower Lilliput	600	600
Bald Head Shoal 1	700	900	Upper Lilliput	400	500
Smith Island	650	900	Keg Island	400	500
Baldhead-Caswell	500	800	Lower Big Island	400	500
Southport	500	800	Upper Big Island	660	660
Battery Island	500	800 - 1300	Lower Brunswick	400	500
Lower Swash	400	500 - 800	Upper Brunswick	400	500
Snows Marsh	400	500	Fourth East Jetty	500	550
Horseshoe Shoal	400	500	Between Channel	550	625
Reaves Point	400	500	Turning Basin	1200	1500

Figure 2
Proposed Navigation Channel Improvements (-47-Foot Plan)

Table 1
WHNIP Proposed Increases in Authorized Channel Bottom Width

Channel Reach	**Channel Widths[1] [ft]**		**Widening Details[2]**
	Existing	**Proposed**	
Entrance Channel Extension	N/A	600	New
Bald Head Shoal Reach 3	500 - 900	600 - 900	Symmetric
Bald Head Shoal Reach 2	900	900	No Change
Bald Head Shoal Reach 1	700	900	West Side Only
Smith Island	650	900	East Side Only
Bald Head - Caswell	500	800	East Side Only
Southport	500	800	Re-orientation East and West Sides Asymmetric
Battery Island	500	800 - 1300	New 4,000-ft radius curve East and West Sides Asymmetric
Lower Swash	400	800 - 500	West Side (lower) and Symmetric (upper)
Snows Marsh	400	500	Symmetric
Horseshoe Shoal	400	500	Symmetric
Reaves Point	400	500	Symmetric
Lower Midnight	600	600	No Change
Upper Midnight	600	600	No Change
Lower Lilliput	600	600	No Change
Upper Lilliput	400	500	Symmetric
Keg Island	400	500	Symmetric
Lower Big Island	400	500	Symmetric
Upper Big Island	660	660	No Change
Lower Brunswick	400	500	Symmetric
Upper Brunswick	400	500	Symmetric
Fourth East Jetty	500	550	West Side Only
Between Channel	550	625	West Side Only
Anchorage Basin	625	625 - 1500	No Change

[1] Authorized channel widths are defined by the channel bottom width only, excluding the channel slopes.

Table 2
Proposed Action Dredging and Disposal Summary

Construction Activity	Channel Reaches	Environmental Work Window	Reason for Window
Hopper dredging with ODMDS disposal	Baldhead Shoal 2 Baldhead Shoal 3 Entrance channel extension reach	1 Dec – 15 April	Minimization of sea turtle entrainment risk
Cutterhead dredging with ODMDS disposal via barges	Baldhead Shoal 3 Battery Island Lower Swash Snows marsh Horseshoe Shoal	Year round	NA
Cutterhead dredging with ODMDS disposal via barges	Reaves point Lower Midnight Upper Midnight Lower Lilliput Upper Lilliput Keg Island Lower Big Island Upper Big Island Lower Brunswick Upper Brunswick Fourth East Jetty Between Reach Anchorage Basin	1 Aug – 31 Jan	Avoidance of anadromous fish spawning period
Cutterhead dredging with direct beach disposal	Baldhead Shoal 1 Smith Island Baldhead-Caswell Southport	16 Nov - 30 April	Avoidance of sea turtle nesting season
CU blasting with drill barge	Keg Island Lower Big Island Upper Big Island Lower Brunswick	1 Aug – 31 Jan	Avoidance of anadromous fish spawning period
Bucket dredging with ODMDS disposal via scows	Keg Island Lower Big Island Upper Big Island Lower Brunswick	Year round	NA

2.2.1 Dredged Material Volumes

The estimated total volume of material to be dredged in constructing the channel improvements is 26.9 million cubic yards; including 22.7 million cubic yards of unconsolidated sand and silt and 4.2 million cubic yards of rock (siltstone and sandstone). Dredged material volume estimates are based on the proposed channel dimensions with an additional one-foot buffer added to reaches where rock is likely to be encountered and an additional two feet of allowable overdredge depth added to the remaining reaches. All dredged material other than beneficial use material would be taken offshore for disposal in the Wilmington ODMDS. Estimated construction and maintenance volumes are well within the capacity of the ODMDS.

2.2.2 Rock Pre-treatment

Confined underwater blasting would be used as a pretreatment measure to break up hardened rock for subsequent removal by cutterhead and mechanical (bucket) dredges. Areas potentially requiring confined blasting encompass ~188 acres of rock surface area within the Keg Island, Lower Big Island, Upper Big Island, and Lower Brunswick channel reaches (Figure 3). These four reaches comprise a contiguous ~4.4-mile section of the navigation channel from a point ~18 miles above the estuary mouth to a point approximately two miles below Eagle Island. Confined underwater blasting operations would employ stemmed charges and charge delays to reduce the magnitude of blast shock waves. Drill holes containing the individual charges would be stemmed (capped) with angular rock or other suitable material for the purpose of containing blast energy within the rock. Studies indicate that the use of stemmed charges with confined blasting can reduce shock wave peak pressure by 60 to 90 percent (%) in relation to unconfined open water blasts (Nedwell and Thandavamoorthy 1992, Hempen et. al. 2005). The use of delays between individual charge detonations limits the development of cumulative blast pressure. Pursuant to the established fisheries environmental work window for Wilmington Harbor, confined underwater blasting operations would be conducted from 1 July to 31 January.

2.2.3 Beneficial Uses of Dredged Material

Beneficial uses of dredged material during channel construction would include beach disposal on Bald Head Island and Caswell Beach/Oak Island and the restoration and enhancement of waterbird nesting islands in the lower estuary (Figure 4). Beach compatible dredged material from the Southport, Baldhead-Caswell, Smith Island, and Baldhead Shoal 1 channel reaches would be placed on the beaches on Bald Head Island and Caswell Beach/Oak Island via direct cutterhead pipeline disposal (Figure 5). Beach disposal of navigation dredged material on the beaches of Bald Head Island and Caswell Beach/Oak Island is an ongoing practice that was initiated by the Wilmington Harbor Sand Management Plan (SMP) [United States Army Corps of Engineers (USACE) 2000]. Pursuant to the SMP, Bald Head Island receives material on a two, four, and eight-year cycle; while Oak Island receives material on a six-year cycle (USACE 2000a). Beach disposal of dredged material under the proposed action would occur during Year 2 of the three-year channel construction project and subsequently every two years in accordance with the existing SMP maintenance cycle. Due to an increase in volumetric availability, beach disposal during construction Year 2 would be expanded to encompass an additional 1.5 to 2.5 linear miles of beach in relation to typical ongoing maintenance events under the existing SMP. Based on projected channel shoaling rate increases, post-construction maintenance beach disposal volumes would increase by five percent in relation to current beach disposal operations

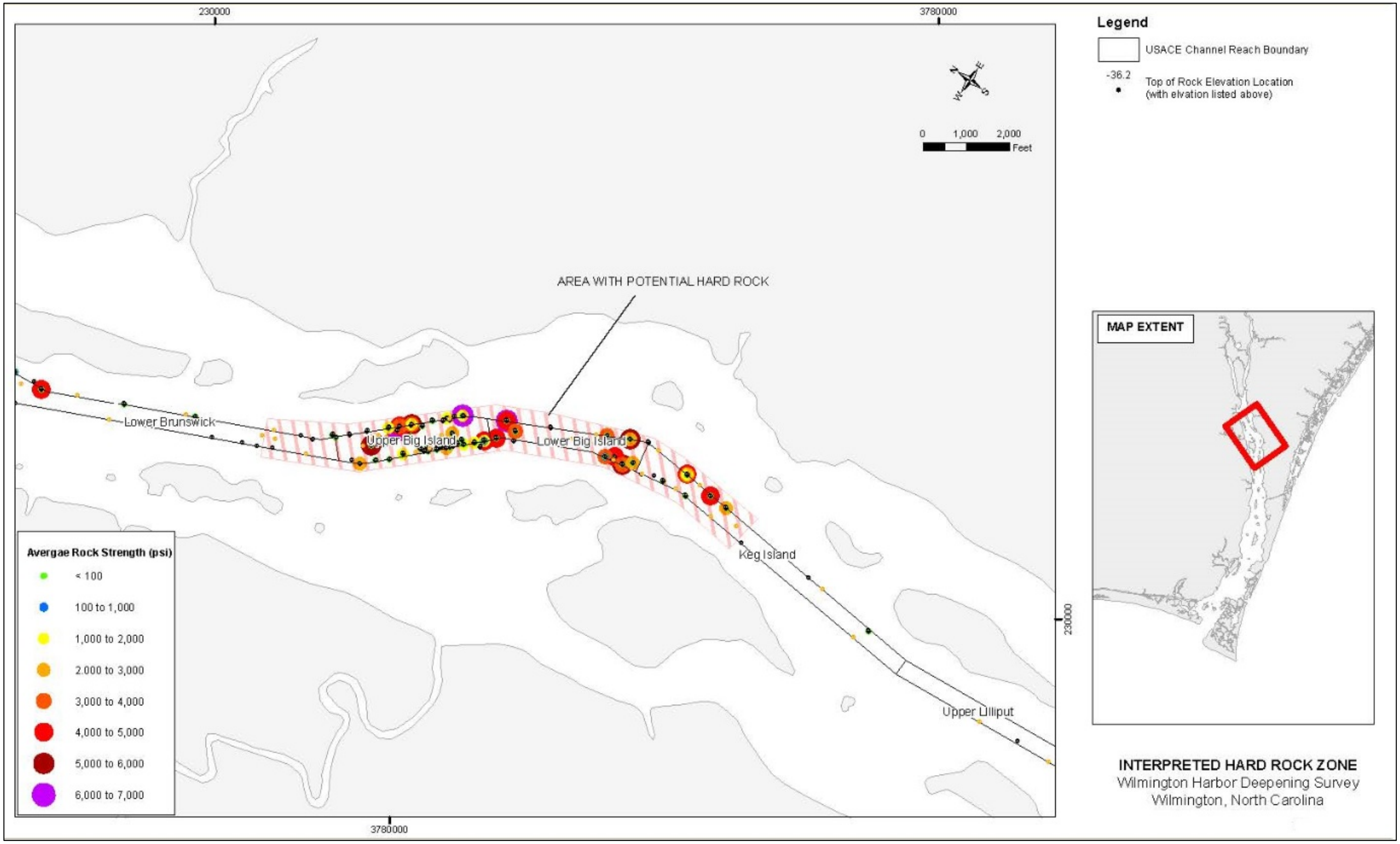


Figure 3

Rock Pre-Treatment Areas - Wilmington Harbor Navigation Improvement Project

Figure 4
Beneficial Use of Dredged Material Sites

Figure 5
Beach Disposal Areas on Bald Head Island and Caswell Beach/Oak Island Beach

under the existing SMP. A five percent volumetric increase would equate to an additional 0.14 mile of beach disposal on Bald Head Island or an additional 0.25 mile of disposal on Oak Island, thus indicating that maintenance beach disposal operations under the proposed action would not differ significantly from current operations under the existing SMP. Beneficial uses in the lower estuary would include the restoration and/or enhancement of eroding waterbird nesting islands via direct cutterhead pipeline disposal of dredged material. Disposal on the western shoreline of Battery Island would be used to buffer waterbird nesting habitats against ongoing and future shoreline erosion, and thin layer disposal would be used to restore subsiding marshes on Battery, Striking, and Shellbed Islands.

2.3 Construction Schedule

The proposed improvements to the Wilmington Harbor navigation channel would be constructed over a period of three years. The proposed three-year construction schedule (Table 3) is based on equipment types, production rates, and the previously described environmental work windows (Table 2). The proposed schedule is considered to be representative of a typical construction plan in that it uses the most likely equipment and maximizes dredging efficiency. However, the schedule would not be a requirement of the Contract and may not be the plan that is implemented.

Table 3
WHNIP Proposed Construction Schedule

Equipment Type	Year 1	Year 2	Year 3
	Channel Reach		
Hopper Dredge	Entrance Extension	Baldhead Shoal 2	Baldhead Shoal 3
Cutterhead Suction Dredge 1	Baldhead Shoal 3 Battery Island Lower Swash Snows Marsh	Baldhead Shoal 1 Smith Island Baldhead-Caswell Southport	Lower Lilliput Upper Lilliput
Cutterhead Suction Dredge 2	Horseshoe Shoal Reaves Point Lower Midnight Upper Midnight	Keg Island Lower Big Island Upper Big Island Lower Brunswick	Upper Brunswick Fourth East Jetty Between Reach Anchorage Basin
Drill Barges and Mechanical Dredge	---	Keg Island Lower Big Island Upper Big Island Lower Brunswick	---

3 DESCRIPTION OF THE ACTION AREA

The action area encompasses areas potentially affected by proposed harbor channel modifications and associated dredged material disposal activities; including the Cape Fear River estuary, the barrier island beaches of Bald Head Island and Oak Island, and offshore areas encompassing the ocean entrance channel and Wilmington ODMDS (Figure 6). As defined for purposes of this study, the Cape Fear River estuary encompasses the tidally affected river systems and wetlands of the lower Cape Fear River basin; including the mainstem Cape Fear River from the Atlantic Ocean up to Lock and Dam #1 at Kelly, NC (~60 river miles), the Northeast Cape Fear River from its confluence with the Cape Fear River up to NC HWY 53 (~48 river miles), and the Black River from its confluence with the Cape Fear River up to NC HWY 53 (~24 river miles).

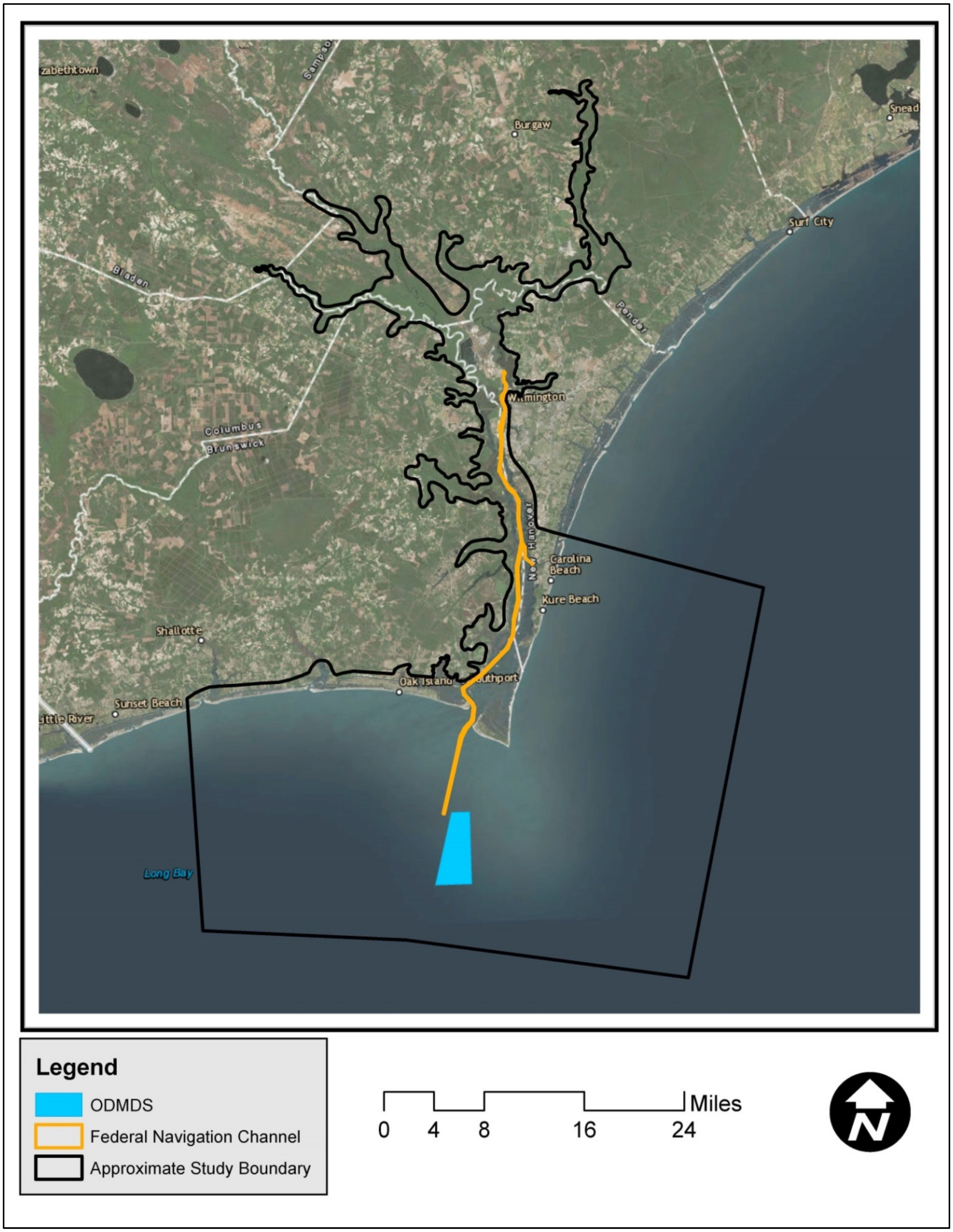


Figure 6
Action Area - Wilmington Harbor Navigation Improvement Project

4 MANAGED FISHERIES AND EFH IN THE ACTION AREA

The action area encompasses a diverse assemblage of estuarine and marine habitats, many of which are designated as EFH and/or Habitat Areas of Particular Concern (HAPCs) in Fishery Management Plans (FMPs) developed by the South Atlantic Fisheries Management Council (SAFMC), Mid-Atlantic Fishery Management Council (MAFMC), and/or NMFS (Table 4). The MSFCMA defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." Habitat Areas of Particular Concern comprise a more specific subset of EFH that are considered to be especially critical due to factors such as rarity, susceptibility to human-induced degradation, and/or high ecological importance. This section describes the federally managed species and associated EFH/HAPC habitats that occur in the vicinity of the action area.

4.1 Federally Managed Species

4.1.1 Penaeid Shrimp

Federally managed penaeid shrimp in North Carolina include the brown shrimp, pink shrimp (*F. duorarum*), and white shrimp. Adults spawn offshore in high salinity oceanic waters during the winter or spring (SAFMC 1981). Ocean-spawned planktonic larval and post-larval shrimp are transported by currents to inshore estuarine habitats where they maintain a benthic existence. Juveniles are most abundant in estuarine waters with intermediate salinities and mud-silt substrates, where they congregate at the highly productive marsh-water interface. As their size increases, shrimp move toward high-salinity oceanic waters, eventually migrating offshore in the fall. Essential Fish Habitat for penaeid shrimp includes important inshore estuarine nursery habitats, important offshore habitats for spawning and growth, and all interconnecting water bodies. Designated EFH and HPACs in the action area include estuarine tidal marshes, subtidal and intertidal non-vegetated flats (soft bottom), Cape Fear River Inlet, and all state-designated Primary and Secondary Nursery Areas.

4.1.2 Red Drum

Red drum spawning areas include high salinity waters in the vicinity of major inlets and potentially high salinity waters inside estuaries. Eggs and larvae are transported throughout the inshore estuaries by tidal and wind driven currents, with the majority of the larvae being carried to the upper reaches of the estuaries where they settle in shallow, low-salinity nursery habitats. In North Carolina, juvenile one- and two-year-old red drums are distributed year-round over a wide range of salinities and habitats, but they generally prefer shallow shoreline waters in bays and rivers and shallow grass flats behind barrier islands (Ross and Stevens 1992). Some juveniles also migrate to the ocean after their first year, where they occur along beaches from late fall through early spring. Adult red drums spend less time in the estuaries and more time in the ocean; spending spring, early summer, and fall along the beaches and wintering offshore. In the fall and spring, red drum congregate around inlets, shoals, capes, and along ocean beaches from the surf zone to several miles offshore. Designated EFH and HAPCs for red drum in the action area include estuarine tidal marshes, subtidal and intertidal non-vegetated flats (soft bottom), oyster reefs and shell banks, unconsolidated soft bottom habitats, the ocean high salinity surf zone, Cape Fear River Inlet, and all state-designated Primary and Secondary Nursery Areas.

Table 4
EFH and HPAC in the Vicinity of the Action Area

EFH/HAPC	Fisheries Management Plan (s)	Management Authority
EFH		
Estuarine Emergent Wetlands (Intertidal Marshes)	Shrimp, Red drum, Snapper-Grouper	SAFMC
Submerged Aquatic Vegetation (Seagrasses)	Shrimp, Red drum, Snapper-Grouper, Cobia	SAFMC
Subtidal and Intertidal Non-Vegetated Flats	Shrimp	SAFMC
Oyster Reefs and Shell Banks	Red drum, Snapper-Grouper	SAFMC
Unconsolidated Bottom	Red drum, Snapper-Grouper	SAFMC
Hardbottom	Snapper-Grouper	SAFMC
Artificial Reefs	Snapper-Grouper	SAFMC
Ocean High Salinity Surf Zone	Red drum, Coastal migratory pelagics	SAFMC
Coastal Inlets	Coastal migratory pelagics	SAFMC
NC Primary/Secondary Nursery Areas	Coastal migratory pelagics	SAFMC
High Salinity Estuaries	Cobia	SAFMC
Continental Shelf Waters, Estuaries	Bluefish, Summer flounder	MAFMC
Continental Shelf Waters	Highly Migratory Species (Sharks) Atlantic sharpnose Blacknose Blacktip Bonnethead Common thresher Dusky Finetooth Great hammerhead Sand tiger Sandbar Scalloped Spinner Tiger White	NMFS
HAPC		
Coastal Inlets	Shrimp, Red drum, Snapper-Grouper, Coastal migratory pelagics	SAFMC
High Salinity Estuaries	Spanish Mackerel	SAFMC
NC Primary/Secondary Nursery Areas	Shrimp, Red drum, Snapper-Grouper, Coastal migratory pelagics	SAFMC
Submerged Aquatic Vegetation (Seagrasses)	Red drum, Snapper-Grouper	SAFMC
	Summer flounder	MAFMC
Oyster Reefs and Shell Banks	Snapper-Grouper	SAFMC
Hardbottom	Snapper-Grouper	SAFMC

4.1.3 Snapper-Grouper Complex

The snapper-grouper complex is an assemblage of 59 species that share a common association with hardbottom or reef habitats during part of their life cycle. Generally, snappers , groupers (Serranidae), porgies (Sparidae), and grunts inhabit offshore hardbottom habitats; whereas, nearshore ocean hardbottoms at depths of ~18 m along NC have cooler temperatures, less diverse invertebrate populations, and a fish community dominated primarily by black sea bass (*Centropristis striata*), scup, and associated temperate species (Sedberry and Van Dolah 1984). Most snapper-grouper species spawn in aggregations in the water column above offshore and shelf-edge reefs (Jaap 1984). Planktonic larval stages typically occur in the offshore water column, whereas juveniles and adults are typically demersal and associated with moderate to high relief hard structures on the outer continental shelf. However, the juveniles of some managed species such as black sea bass, gray snapper (*L. griseus*), and gag grouper reside in estuarine nursery areas where they typically inhabit SAV or oyster reef habitats (SAFMC 1998, NCDMF 2006). Juveniles of these estuarine-dependent species emigrate from the estuary to near shore hardbottom habitats in the fall, and eventually move to offshore hard/live bottom habitats. Designated EFH and HPACs for estuarine-dependent snapper-grouper species in the action area include attached estuarine tidal marshes, subtidal and intertidal non-vegetated flats (soft bottom), oyster reefs and shell banks, unconsolidated soft bottom habitats, hard bottom, artificial reefs, Cape Fear River Inlet, and all state-designated Primary and Secondary Nursery Areas.

4.1.4 Coastal Migratory Pelagics

The coastal migratory pelagics management unit includes king mackerel (*Scomberomorus cavalla*), Spanish mackerel (*S. maculates*), and cobia (*Rachycentron canadum*). Adult coastal pelagics occur in coastal waters from shore out to the edge of the continental shelf. The distribution of coastal pelagics on the shelf is governed by temperature and salinity, with all species generally occurring in high salinity waters with temperatures above 20 degrees Centigrade (°C). Coastal migratory pelagics are fast swimming, schooling, and piscivorous predators. Spanish mackerel spawn in groups over the inner continental shelf, beginning in April off the Carolinas. Larvae grow quickly and are most commonly found in nearshore ocean waters at shallow depths less than 30 ft. Most juveniles remain in nearshore ocean waters, but some use high salinity estuaries as nursery areas. Adult Spanish mackerel spend most of their lives in the open ocean but are also found in tidal estuaries and coastal waters [Atlantic States Marine Fisheries Commission (ASMFC) 2011a and b, Mercer et al. 1990]. King mackerel are primarily a coastal species, with smaller individuals of similar size forming significant schools over areas of bottom relief and reefs; while larger solitary individuals prefer anthropogenic structures and/or wrecks. Cobia are abundant in warm waters along the United States coast from Chesapeake Bay south through the Gulf of Mexico. Cobia are found over the continental shelf and in high salinity estuarine waters, preferring waters in the vicinity of reefs and around structures such as pilings, buoys, platforms, anchored boats, and flotsam. Spawning off the North Carolina coast occurs during May and June, primarily in offshore ocean waters; however, spawning has also been observed in estuaries and shallow bays with the young moving offshore soon after hatching (SAFMC 1983 and 2011). Designated EFH and HAPCs for all coastal migratory pelagics in the action area include the sandy shoals of Cape Fear (Frying Pan Shoals), offshore bars and barrier island ocean-side waters, and the Cape Fear River Inlet complex.

4.1.5 Highly Migratory Species

The highly migratory species (HMS) complex encompasses tuna [albacore (*Thunnus alalunga*), bluefin (T. *thynnus*), bigeye (*T. obesus*), skipjack (*Katsuwonus pelamis*), and yellowfin (*T. albacres*)], swordfish (*Xiphias gladius*), billfish [blue marlin (*Mokaira nigricans*), white marlin (*Tetrapturus albidus*), sailfish (*Istiophorus platypterus*), and longbill spearfish (*T. pfluegeri*), and 39 species of sharks that are divided into three groups: large coastal sharks, small coastal sharks, and pelagic sharks. Of these species, 14 managed shark species have designated EFH consisting of nearshore continental shelf waters along the NC coast. Sharks are found in a wide variety of coastal and ocean habitats; including estuaries, nearshore and continental shelf waters, and the open ocean. Although managed sharks move primarily through the open ocean, several species move to shallow coastal waters and estuaries to pup. These nearshore/estuarine habitats also function as nursery areas for the developing young, with neonates typically remaining in these areas throughout their early life stages (NMFS 2009). Subtidal bottom in nearshore waters along the southern NC coast serve as pupping grounds for the Atlantic sharpnose shark (*Rhizoprionodon terraenovae*), bonnethead shark (*Sphyrna tiburo*), blacknose shark (*Carcharhinus acronotus*), spinner shark (*C. brevipinna*), dusky shark (*C. obscurus*), blacktip shark (*C. limbatus*), sandbar shark (*C. plumbeus*), and scalloped hammerhead shark (*S. lewini*). Neonates from southern NC waters are found primarily in June and July (Beresoff and Thorpe 1997, Thorpe et al. 2004).

4.1.6 Bluefish

Bluefish are a migratory, pelagic species found in temperate and semi-tropical continental shelf waters around the world with the exception of the north and central Pacific. In North America, bluefish range from Nova Scotia to Florida in the Atlantic Ocean and from Florida to Texas in the Gulf of Mexico (MAFMC 1990). Spawning in the South Atlantic Bight occurs near the shoreward edge of the Gulf Stream primarily during April and May (Kendall and Walford 1979). Larval development takes place in outer continental shelf waters within six meters of the surface. Transitional pelagic juveniles eventually move to estuarine and nearshore oceanic waters, which serve as the principal nursery habitats for juvenile development (Kendall and Walford 1979). Estuarine juveniles are most commonly associated with sandy soft bottom habitats; but also use mud and silt soft bottom habitats, SAV, marine macroalgae, oyster reefs, and tidal marsh grass (Shepherd and Packer 2006). Juvenile bluefish are common in high salinity estuaries along the southern NC coast during summer and fall and are common in the nearshore ocean from spring through mid-winter. Adults use both inshore estuarine and offshore oceanic habitats. Adults are common in the nearshore ocean along the NC coast from spring through mid-winter (MAFMC 1990). Adults undertake seasonal migrations, generally moving northward during spring and summer and southward during fall and winter. Designated EFH habitats for juvenile and adult bluefish in the action area include the Cape Fear River estuary and pelagic ocean waters overlying the inner continental shelf of Long Bay.

4.1.7 Summer Flounder

Summer flounder are found in shallow estuarine and outer continental shelf waters along the Atlantic coast from Nova Scotia to Florida and along the northern Gulf coast of Mexico [Northeast Fisheries Science Center (NEFSC) 1999]. Summer flounder are concentrated in estuaries and sounds from late spring through early fall, before migrating to offshore wintering spawning habitats on the outer continental shelf (NEFSC 1999, ASFMC 2011c). Offshore spawning occurs during fall and early winter, and the larvae are transported by wind-driven currents to coastal waters. Post-larval and juvenile development occurs primarily in estuaries (NEFSC 2011). Larvae recruit to inshore waters from October to May where they bury into the sediment and develop into juveniles. Late larval and juvenile flounder actively prey on crustaceans, copepods, and polychaetes (NEFSC 1999). Juveniles prefer sandy shell substrates; but also inhabit marsh creeks, mud flats, and seagrass beds. Juveniles often remain in North Carolina estuaries for 18 to 20 months (NEFSC 1999, ASFMC 2011d). Adults primarily inhabit sandy substrates, but have been documented in seagrass beds, tidal marsh creeks, and sand flats (ASFMC 2011c and d, NEFSC 1999). Adults inhabit estuarine waters before moving to offshore wintering grounds on the outer continental shelf. Essential Fish Habitat for all life stages of summer flounder includes ocean waters overlying the continental shelf. Designated EFH and HPACs for juvenile and adult summer flounder in the action area include estuarine waters with salinities >0.5 ppt, marine macroalgae, and tidal/freshwater macrophytes.

4.2 EFH and HPAC

4.2.1 Water Column

4.2.1.1 Water Levels and Tides

The Cape Fear River estuary is strongly affected by lunar semidiurnal ocean tides that propagate ~60 miles up the Cape Fear River mainstem to Lock and Dam #1 near Kelly, ~25 miles up the Black River to the vicinity of the NC HWY 53 Bridge, and ~50 miles up the Northeast Cape Fear River to the vicinity of Holly Shelter Creek. Mean tidal range increases from 4.3 ft at the river mouth to 5.1 ft at Wilmington. Mean tidal range in the mainstem Cape Fear River steadily declines above Wilmington, reaching a low of approximately one foot at Lock and Dam #1. The diurnal tidal cycle drives regular reversals of flow in the river, except during periods of high freshwater discharge. Strong tidal currents can exceed three feet per second in the relatively narrow Cape Fear River channel above Wilmington. The Cape Fear River estuary may exhibit partial mixing under some flow conditions, but generally exhibits a well-defined salinity gradient with depth. Upstream density currents along the channel bottom have been observed in the lower estuary. Tide gauge records show a near doubling of the mean tidal range at Wilmington [river kilometer (rkm) 47] from 2.8 ft to 5.1 ft since the late 1800s, but only a slight increase of 0.2 ft near the ocean at Southport since the 1920s (Famikhalili and Talke 2016). Similarly, mean high water (MHW) at Wilmington has increased at a rate of 1.38 ft/century since the mid-1930s, more than double the rate of sea level rise at Wilmington (0.66 ft/century) during the same period (Flick et al. 2003). A recent modeling study indicates that the disproportionate increase in tidal range at Wilmington is predominantly attributable to the incremental deepening of the harbor channel since the late 1800s (Famikhalili and Talke 2016).

Based on tide gauge sea level data from 1935-2017, the relative sea level trend at Wilmington is 2.3 mm/yr or 0.75 ft/century. The National Oceanic and Atmospheric Administration (NOAA) sea level rise trends are based on sea level changes relative to a local fixed reference point on land, and thus are referred to as relative sea level rise (RSLR). Per USACE guidance (ER 1100-2-8162), this assessment considers a range of potential future sea level rise scenarios (low, intermediate, and high). The "low" scenario represents future sea level rise at the measured historical rate. Per USACE guidance, sea level change rates for the "intermediate" and "high" scenarios were derived from the extrapolation of rate curves developed by the National Research Council (NRC) (1987). Projected RSLR increases through the end of the 50-year project life (2077) range from 0.34 ft under the low scenario to 2.57 ft under the high scenario.

4.2.1.2 Salinity and Water Quality

Salinity levels and the position of the upper mixing zone boundary in the Cape Fear River estuary are continually changing in response to variability in tidal conditions and freshwater inflow. During ten years (2000-2010) of salinity monitoring in the estuary for the Wilmington Harbor 96 Act Project, periods of drought-induced low flow and extreme flooding significantly impacted water levels, tidal conditions, and salinities in the Cape Fear River and Northeast Cape Fear River; especially at the uppermost monitoring stations where substantial effects on water levels were observed (Leonard et al. 2011). During normal to high flow conditions, salinities in the mainstem Cape Fear River at stations above Eagle Island [Indian Creek (P7), Dollisons Landing (P8), Black River (P9)] were generally less than 0.3 parts per thousand (ppt). During a 12-month period (June 2004-May 2005), when discharge was comparable to the 30-yr average, salinities at the upper P8 and P9 stations did not exceed 0.2 ppt; while salinities at the lower P7 station exceeded 0.2 ppt only during the month of August (max=1.8 ppt). In contrast, during 2007-2008, a period of severe drought, flow releases from Jordan Lake were reduced and salinities as high as 9.8 and 10.5 ppt were measured at the P7 and P8 stations, respectively. Salinities at the uppermost Cape Fear River station (P9) near the mouth of the Black River did not exceed 0.2 ppt during 2007/2008. Upper monitoring stations in the Northeast Cape Fear River at Fishing Creek (P13) and Prince George Creek (P14) were more susceptible to salinity intrusion during the ten-year monitoring period (Leonard et al. 2011). During the more typical discharge period of June 2004-May 2005, salinities at the uppermost P14 station did not exceed 0.2 ppt; however, salinities as high as 8.6 ppt were measured at P13 during the fall. During the drought-induced low flow year of 2007-2008, salinities as high as 20.1 and 9.4 ppt were detected at stations P13 and P14, respectively.

Although Total Maximum Daily Loads (TMDLs) have not been established for the Cape Fear River estuary, the ~15-mile mainstem estuary reach from the lower end of Keg Island upriver to Navassa, including the Brunswick River, is listed as an impaired water body on the NC 303d list; in part due to exceedances of the state water quality standard for DO (>5.0 mg/L). Exceedances of the state DO standard typically occur during the summer when water temperatures are the highest and oxygen solubility is the lowest. According to Mallin (2014), factors other than seasonal high water temperatures that contribute to summer exceedances of the DO standard include the discharge of organic industrial effluent at Riegelwood, organic-rich blackwater inputs from the Black River and Northeast Cape Fear River, and algal blooms that form in the summer behind Lock and Dam #1. Low flow conditions and associated increases in salinity and stratification can also contribute to low DO concentrations, as oxygen solubility decreases with increasing salinity, and stratification typically reduces the delivery of oxygen to the bottom layer via mixing. The Keg Island to Navassa reach is also listed as impaired due to exceedances of the state water quality standard for pH, and the mainstem estuary from Greenfield Creek to Southport is listed as impaired due to exceedances of the state water quality standards Copper, Nickel, and Arsenic. Class SA commercial shellfishing waters in the Cape Fear River below Federal Point are assigned a Shellfish Growing Area Status of Approved, Conditional, or Prohibited based on North Carolina Division of Marine Fisheries (NCDMF) Shellfish Sanitation fecal coliform criteria. A total of 1,200 acres of SA waters in the lower estuary along with a number of additional areas in tidal creeks are designated as Prohibited on the NC 2016 303d list.

4.2.2 Unconsolidated Bottom

4.2.2.1 Estuarine Soft Bottom

Estuarine soft bottom consisting of unvegetated, unconsolidated sediments comprises all subtidal benthic habitat in the existing and proposed inner harbor channel reaches, as well as the vast majority of the subtidal benthic habitat in the overall Cape Fear River estuary. Estuarine intertidal flats and shallow subtidal soft bottom habitats support a highly productive benthic microalgal community. Benthic microalgae, along with imported primary production in the form of phytoplankton and detritus, support a diverse community of benthic infaunal and epifaunal invertebrates; including nematodes, copepods, polychaetes, amphipods, decapods, bivalves, gastropods, and echinoderms [South Atlantic Fishery Management Council (SAFMC) 1998, Peterson and Peterson 1979]. Large mobile invertebrates such as blue crabs and penaeid shrimp move between intertidal and subtidal habitats with the changing tides. Mobile predatory gastropods (e.g., whelks and moon snails) occur along the lower margins of submerged tidal flats, and fiddler crabs (*Uca* spp.) are common on exposed flats during low tide (Peterson and Peterson 1979). Benthic invertebrates are an important food source for numerous predatory fishes that move between intertidal and subtidal habitats; including spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogonias undulatus*), flounders (*Paralichthys albigutta, P. dentatus, and P. lethostigma*), inshore lizardfish (*Synodus foetens*), pinfish (*Lagodon rhomboides*), red drum (*Sciaenops ocellatus*), and southern kingfish (*Menticirrhus americanus*). Shallow unvegetated flats provide an abundant food source and are relatively inaccessible to large predators (SAFMC 1998). Intertidal and subtidal flats function as an important nursery area for numerous benthic oriented estuarine-dependent species, especially Atlantic croaker, flounder, spot, and penaeid shrimp.

4.2.2.2 Marine Soft Bottom

Marine unconsolidated soft bottom comprises essentially all benthic habitat in the existing and proposed ocean entrance channel reaches, as well as the vast majority of the ocean subtidal benthic habitat within the overall action area. Marine soft bottom habitats support a diverse community of benthic invertebrate infauna (burrowing organisms that live within the sediment) and epifauna (organisms that live on the surface of the sediment). Nearshore soft bottom communities along the southeastern NC coast are dominated by deposit- and filter-feeding invertebrates, including polychaetes, bivalve mollusks, nematodes, amphipod crustaceans, echinoderms (sand dollars), and gastropods (snails) (Hague and Massa 2010, Posey and Alphin 2002, Peterson and Wells 2000, and Peterson et al. 1999). Soft bottom sites also provide important habitat for large, mobile decapod crustaceans (e.g., crabs and shrimp). Based on annual trawl surveys conducted by Posey and Alphin (2002), the large decapod assemblage in nearshore Long Bay is dominated by white shrimp (*Litopenaeus setiferus*), brown shrimp (*Farfantepenaeus aztecus*), and the iridescent swimming crab (*Portunus gibbesii*). Offshore benthic sampling conducted by the USACE as part of the new Wilmington ODMDS site selection process identified 311 taxa within a 28-nm^2 area (Rickman 2000). Polychaetes accounted for 39.7% of the total taxa richness, followed by arthropod malacostracans (23.7%), gastropods (14.1%), and bivalves (1.9%). Total abundance was dominated by gastropods

(34.3%), polychaetes (30.7%), and bivalves (18.4%). Dominant species included the gastropod *Caecum pulchellum*, the bivalve *Lucina radians*, and the polychaete *Apoprionospio pygmaea*. Mean densities ranged from 538 to 6,019 organisms per square meter and generally increased with distance from shore. Statistical analysis showed a significant inverse relationship between total density and sediment grain size (i.e., higher densities were associated with fine sediments). Marine soft bottom habitats and their associated benthic invertebrate communities provide important habitat and food resources for many species of demersal (bottom-dwelling) fishes.

4.2.3 Hard Bottom

Hardbottom habitats exhibit varying degrees of colonization by marine algae and sessile invertebrates (e.g., sponges, soft corals, and hard corals). Marine macroalgae are the dominant colonizing organisms on NC hardbottoms with attached, sessile invertebrates typically accounting for ten percent or less of the total coverage (Peckol and Searles 1984). Dominant large, attached invertebrates include the soft corals *Titandeum frauenfeldii* and *Telesto fructiculosa* and the hard coral *Oculina arbuscula*. The small macroinvertebrate community is dominated by mollusks, polychaetes, and amphipods (Kirby-Smith 1989), and the most common large mobile invertebrates are the purple-spined sea urchin (*Arbacia punctulata*) and green sea urchin (*Lytechinus variegatus*). Hard and soft corals are less prevalent on nearshore hardbottoms in NC compared to offshore and more southerly hardbottoms. In the nearshore environment, cooler water temperatures limit the growth of tropical reef-building corals (Kirby-Smith 1989, Fraser and Sedberry 2008), and macroalgae outcompete the hard coral *Oculina arbuscula* (Miller and Hay 1996). Along the NC coast, tropical reef-building corals are restricted to deep offshore waters (>20 miles from shore) (MacIntyre and Pilkey 1969, MacIntyre 2003).

Hardbottoms along the NC coast provide important foraging habitat and protective cover for tropical, subtropical, and warm-temperate reef fishes. Inner-shelf hardbottoms support a higher proportion of temperate species such as black sea bass, spottail pinfish (*Diplodus holbrookii*), and estuarine-dependent migratory species (Huntsman and Manooch 1978, Grimes et al. 1982). Lindquist et al. (1989) reported 30 species representing 14 families at a nearshore hardbottom site in Onslow Bay. Common species included juvenile grunts (*Haemulidae* spp.), round scad (*Decapterus punctatus*), tomtate (*Haemulon aurolineatum*), spottail pinfish, black sea bass, scup (*Stenotomus* spp.), pigfish, cubbyu (*Equetus umbrosus*), belted sandfish (*Serranus subligarius*), and sand perch (*Diplectrum formosum*). Nearshore hardbottom sites support spawning of smaller and more temperate reef species such as black sea bass and sand perch, and also provide larval settlement sites and juvenile nursery habitats for reef-associated fishes, including taxa that are thought to spawn in deeper offshore waters (Powell and Robins 1998).

Comprehensive remote sensing hardbottom surveys of the existing navigation channel and proposed channel expansion areas were conducted in 2017 and 2018 (Appendix H: Hardbottom Resources). Analysis of the survey data did not identify any natural hardbottom habitats within the existing or proposed channel areas; however, the surveys did identify several dredged material rubble mounds and scattered rock along the existing channel in the old ODMDS (Figure 7) (Appendix H: Hardbottom Resources). Two of the larger rubble mounds (Figure 8) that have relief of 1.0 to 1.5 meters support typical hardbottom benthic assemblages, and additional loosely scattered rocks along the old ODMDS channel reach have varying degrees of sessile invertebrate coverage. Based on towed video surveys, these naturalized hardbottom features have been colonized by marine algae, tunicates (*Urochordata* spp.), echinoderms (*Arbacia punctulata*, *Luidia clathrate*) octocorals (*Leptogorgia vergulata*, *L. hebes*, *Phyllangia americana*, *Astrangia* sp.) and other sessile and motile invertebrates that are common to natural nearshore hardbottom habitats. Several fish species that are typical of nearshore hardbottoms were also observed; including black sea bass (*Centropristis striata*), sheepshead (*Archosargus probatocephalus)*, belted sand fish (*Serranus subligarius*), and pinfish (*Lagodon rhomboides*). These naturalized hardbottom habitats in the old ODMDS were the only hardbottom features identified within the existing and proposed channel areas. Prior remote sensing surveys conducted by the USACE did not identify any hardbottom habitats within the new ODMDS (USEPA and USACE 2001). Figure 9 depicts additional hardbottom survey data for the action area that were compiled by the USACE during the new ODMDS site selection process. Although action area survey coverage is not comprehensive, the distribution of identified hardbottoms is restricted to areas approximately two to three miles west of the existing ocean entrance channel and proposed offshore extension reach.

4.2.4 Shell Bottom

Shell bottom habitats include oyster reefs, aggregations of non-reef-building shellfish species [e.g., clams and scallops (*Argopecten irradians*, *A. gibbus*)], and surface concentrations of broken shell (i.e., shell hash). The eastern oyster (*Crassostrea virginica*) is the dominant and principal reef-building species of estuarine shell bottom habitats in NC. Non-reef-building shellfish species that occur at densities sufficient to provide structural habitat for other organisms include scallops, pen shells [saw-toothed (*Atrina seratta*) and stiff (*A. rigida*)] and rangia clams (*Rangia cuneata*) (SAFMC 2009). Shell bottom habitats perform important ecological functions such as water filtration, benthic-pelagic coupling, sediment stabilization, and erosion reduction (NCDEQ 2016, SAFMC 2009, and Coen et al. 2007). By filtering and consuming particulate matter, phytoplankton and microbes; oysters and other suspension-feeding bivalves reduce turbidity and transfer material and energy from the water column to the benthic community. Shell bottom structural relief moderates waves and currents, traps sediments, and reduces shoreline erosion. Existing shell bottom habitats function as important larval settlement and accumulation sites for recruiting oysters and other shellfish (NCDMF 2008). Shell bottom structure concentrates macroinvertebrates [e.g., grass shrimp (*Palaemonetes* spp.), and mud crabs (*Scylla* spp.)] and small forage fishes (pinfish and gobies) which, in turn, attract larger predatory fish such as Atlantic croaker, black drum (*Pogonias cromis*), pigfish, (*Orthopristis chrysoptera*), southern flounder (*Paralichthys lethostigma*), summer flounder (*P. dentatus*), and spotted seatrout (*Cynoscion nebulosus*). Numerous finfish and decapod crustaceans including anchovies, black sea bass (*Centropristis striata*), blennies, gobies, oyster toadfish (*Opsanus tau*), pinfish, red drum, sheepshead (*Archosargus probatocephalus*), spot, weakfish (*C. regalis*), penaeid shrimp, blue crabs (*Callinectes sapidus*), and stone crabs (*Menippe mercenaria*) also utilize shell bottom habitats as nursery areas (NCDEQ 2016).

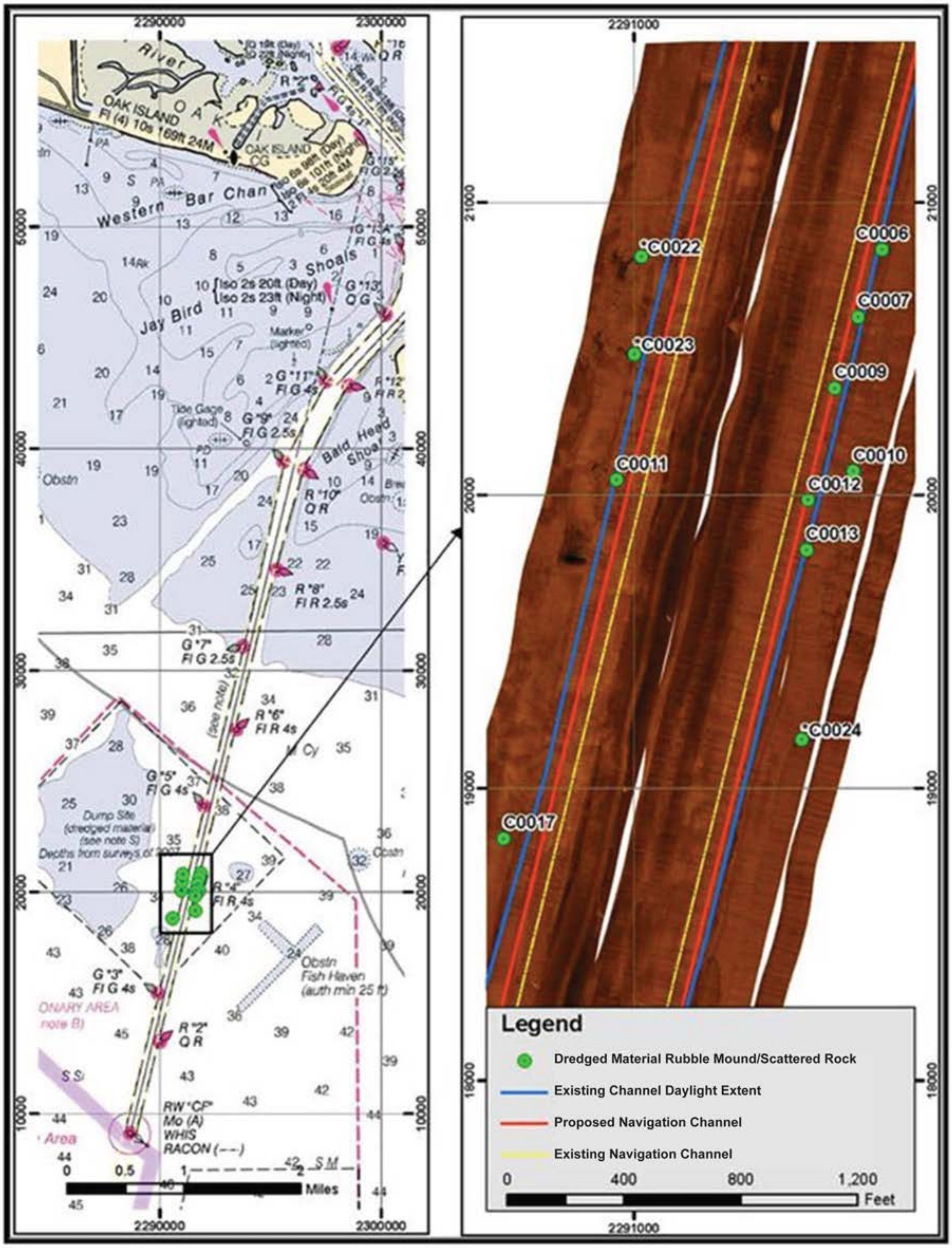


Figure 7
Side Scan Sonar Survey - Dredged Material Rubble Deposits Identified in the Old ODMDS

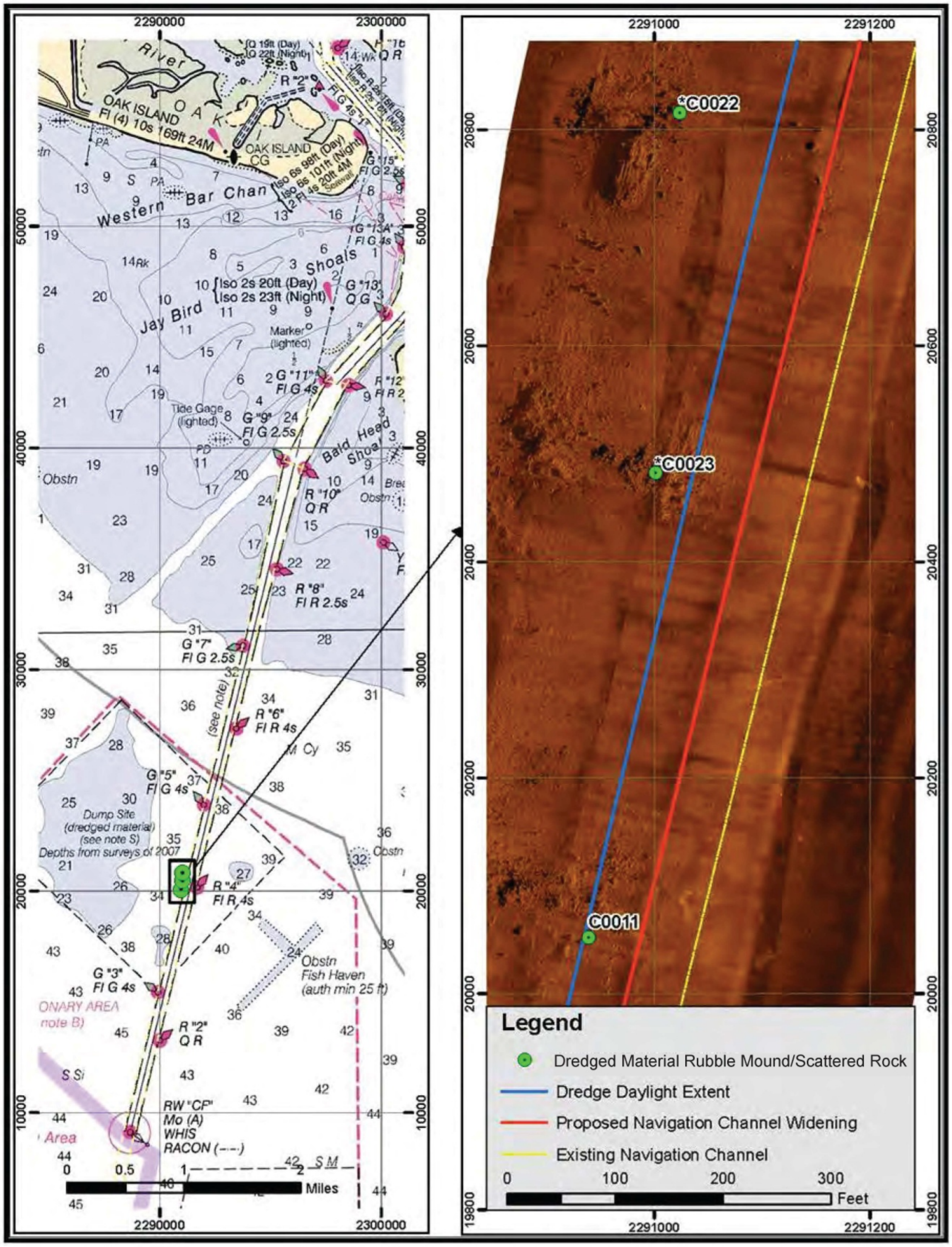


Figure 8
Old ODMDS Moderate Relief Dredged Material Rubble Mounds (C0022 and C0023)

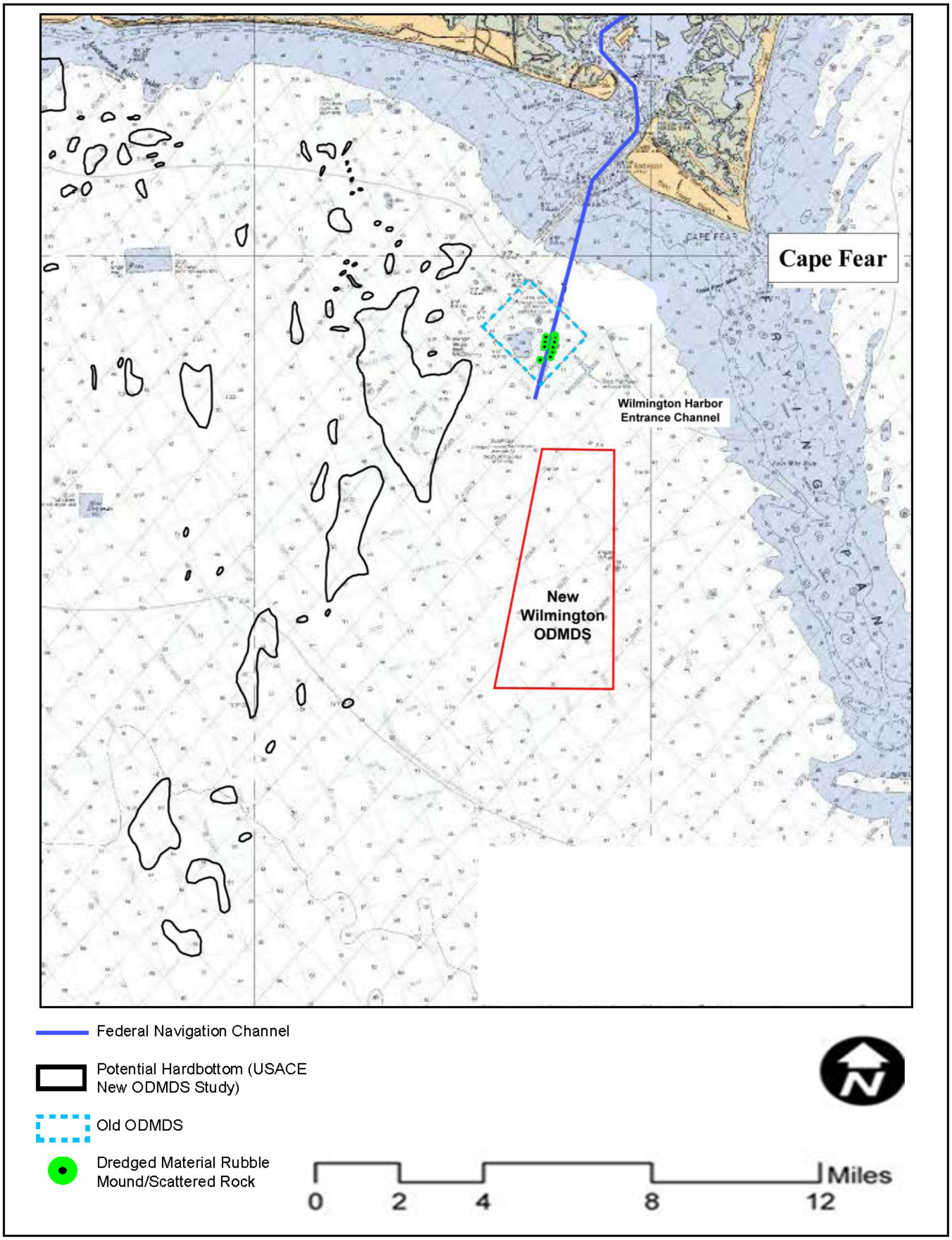


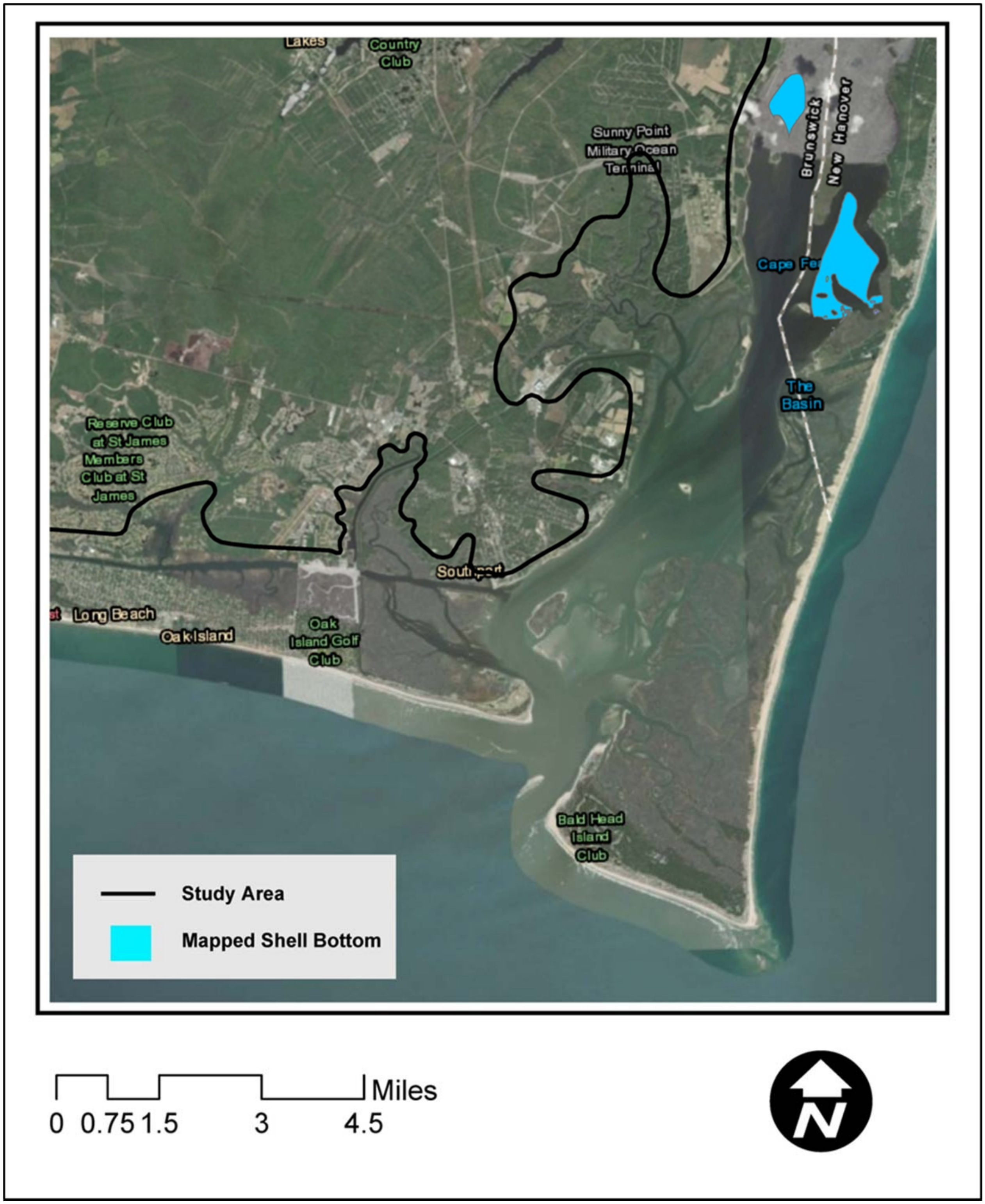
Figure 9
Potential Hardbottom Areas in the Vicinity of the Action Area

Shell bottom habitats in the Cape Fear River estuary are generally confined to the lower estuary below Snows Cut. The distribution of oyster reefs in the estuary is limited by low salinity and a lack of hard substrate for larval settlement. Live oyster reefs that provide the structural functions described above are confined to the lowermost ~10-mile reach of the estuary from Peters Point to the river mouth. Rodriguez (2009) indicates that the absence of live functional oyster reefs in the estuary above Peters Point is likely related to extended periods of low salinity. Although oysters can tolerate salinities ranging from five to 35 ppt, they are unable to survive at salinities below five ppt. Furthermore, it has been reported that the mortality rate of oyster larvae in waters ≤10 ppt is 100% within two weeks (Davis 1958). According to Rodriguez (2009), over the course of six years (2000–2003, 2005–2007) of salinity monitoring at Lower Cape Fear River Program Station M35 between Snows Cut and Peters Point, mean monthly salinities of less than five ppt were measured during 11 months. The optimal salinity range for oysters is 12 to 25 ppt (NCDMF 2011). The waters below Federal Point are designated Class SA commercial shellfishing waters. SA waters are assigned a Shellfish Growing Area status of approved, conditional, or prohibited based on NCDMF Shellfish Sanitation fecal coliform criteria. A total of 1,200 acres of SA waters in the lower estuary along with a number of additional areas in tidal creeks are designated as Prohibited on the NC 2016 303d list. Analyses of remote sensing survey data did not identify any structural shell bottom habitats within the existing channel or the proposed channel expansion areas. NCDMF benthic habitat maps depict two areas of shell bottom habitat between Snows Cut and Federal Point; including one area along the western margin of the existing Upper Midnight channel reach, and a second area ~2,500 ft east of the Reaves Point channel reach (Figure 10). NCDMF shell bottom habitat mapping has not been completed for the remainder of the lower estuary below Federal Point.

4.2.5 Submerged Aquatic Vegetation

Submerged Aquatic Vegetation (SAV) encompasses a number of species of rooted aquatic vascular plants that occur in North Carolina estuaries; including eelgrass (*Zostera marina*), shoalgrass (*Halodule wrightii*), and widgeon grass (*Ruppia maritima*). SAV beds occur on subtidal and occasionally intertidal sediments in sheltered estuarine waters. Environmental requirements include unconsolidated sediments for root and rhizome development, adequate light reaching the bottom, and moderate to negligible current velocities (Thayer et al. 1984, Ferguson and Wood 1994). SAV beds provide important structural fish habitat and perform important ecological functions such as primary production, sediment and shoreline stabilization, and nutrient cycling (NCDEQ 2016). SAV habitats are important nursery areas for the juveniles of ocean-spawned estuarine-dependent species; including many important commercial and recreational species such as Atlantic croaker, black sea bass, bluefish (*Pomatomus saltatrix*), flounders, gag grouper (*Mycteroperca microlepis*), herrings, mullets, red drum, snappers (*Lutjanidae* spp.), spot, spotted seatrout, weakfish, southern kingfish, and penaeid shrimp. Bay scallops, hard clams, and blue crabs are also strongly associated with SAV; and large predatory species such as bluefish, flounders, red drum, and spotted seatrout are attracted to SAV beds for their concentrations of juvenile finfish and shellfish prey (Thayer et al. 1984).

NCDMF benthic habitat maps show small scattered patches of SAV throughout the lower Cape Fear River estuary; however, NCDMF has determined that the mapped occurrences are aerial imagery-based misidentifications of marine macroalgae (Personal communication, Ann Deaton,



Source: NCDMF 2019

Figure 10
Mapped Shell Bottom Habitat in the Cape Fear River Estuary

NCDMF Habitat Protection and Enhancement Section, 19 Feb 2019). NCDMF has concluded that SAV are absent from the lower estuary. The only confirmed SAV beds in the Cape Fear River estuary, consisting of slender naiad (*Najas gracillima*), are located in the Brunswick River near the US HWY 74/76 Bridge. Slender naiad is a species of tidal freshwater to oligohaline habitats (Brush and Hilgartner 2000). Identified beds in the Brunswick River occupy shallow subtidal flats along the shoreline of Eagle Island.

4.2.6 Estuarine Emergent Wetlands

Human activities and sea level rise over the last two centuries have dramatically altered the composition and distribution of tidal wetland communities in the Cape Fear River estuary (Hackney and Yelverton 1990). The initial impact of European settlement, beginning in the late 1700s, was the conversion of essentially all tidal freshwater swamp forests in the lower to middle estuary to rice plantations. In the late 1800s, the USACE initiated major navigation dredging modifications of the river channel for access to the Port of Wilmington. Incremental channel deepening and sea level rise since the late 1800s have increased the tidal range in Cape Fear River, resulting in salinity intrusion and the conversion of tidal freshwater swamp forests to brackish marsh along the middle to upper reaches of the estuary. Hackney and Yelverton (1990) suggest that the distribution of former rice fields is a reliable indicator of the pre-settlement extent of tidal freshwater wetlands along the river, as rice is incapable of growing in fields that are flooded by saline water >1 ppt. Based on this indicator, tidal freshwater wetlands would have been present at least as far downriver as Orton Plantation ~12 miles above the river mouth. Baseline studies for the currently proposed project included the development of an updated baseline tidal wetland classification for the action area. ENVI image analysis software and field surveys were employed in a Geographic Information System (GIS)-based supervised classification of the entire tidally affected estuarine/freshwater river-floodplain system. The final classification identified 66,671 acres of tidal wetlands distributed among six wetland classes (Table 5). Figure 11 depicts an overview of the classification results for the entire assessment area.

Table 5
Action area Tidal Wetland Classification

Tidal Wetland Class	Area (acres)	Percent
Smooth Cordgrass Dominant	12,733	19.1
Brackish Mix	696	1.0
Cattail Dominant	6,066	9.1
Common Reed	2,403	3.6
Freshwater Marsh	1,379	2.1
Swamp Forest	43,394	65.1
Total	**66,671**	**100**

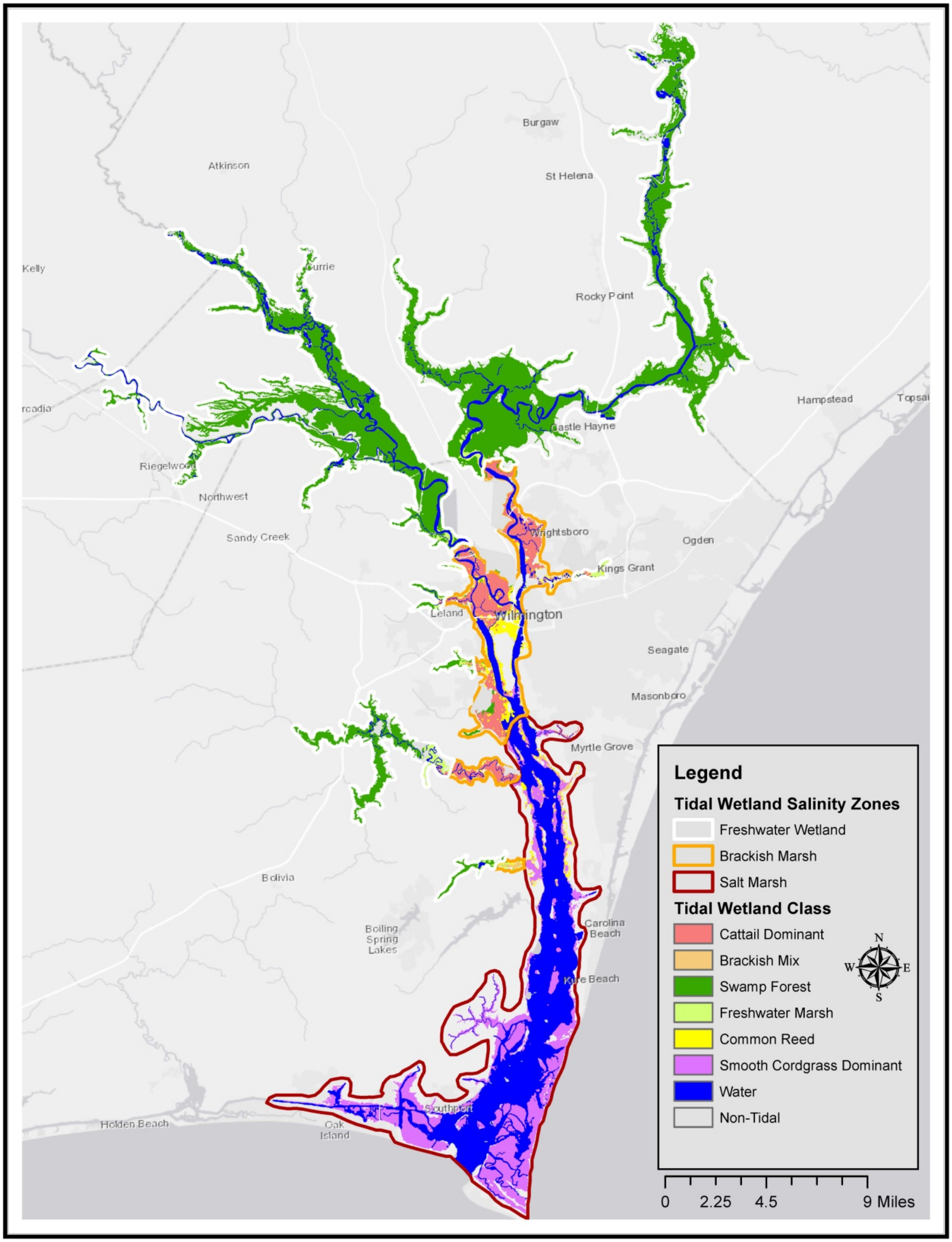


Figure 11
Baseline Tidal Wetland Classification

The composition of tidal wetland communities in the Cape Fear River estuary is largely determined by their position along salinity gradients. Salt marshes consisting of nearly monospecific stands of smooth cordgrass (*Spartina alterniflora*) strongly dominate the contiguous tidal floodplains along the polyhaline and lower mesohaline reaches of the Cape Fear River mainstem from the river mouth up to Barnards Creek (~21 river miles). Along the upper portion of the mesohaline salt marsh reach, small patches of black needlerush are interspersed among the smooth cordgrass marshes, and big cordgrass (*S. cynosuroides*) and saltmarsh bulrush (*Bolboschoenus robustus*) occur intermittently on the slightly elevated river banks immediately adjacent to the channel. The reach above Barnards Creek is characterized by the decline of smooth cordgrass and the rapid establishment of narrow-leaved cattail (*Typha angustifolia*) as the primary dominant species. The marshes above Barnards Creek exhibit distinct vegetation zones; including a narrow fringing smooth cordgrass zone along the edge of the river channel; a narrow top-of-bank zone dominated by big cordgrass and salt-marsh bulrush; and a broad outer marsh zone dominated by narrow-leaved cattail. Cattail is a strong dominant of the oligohaline brackish marshes along the ~10-mile mainstem reach above Barnards Creek, forming vast monospecific stands across large sections of the tidal floodplain. The cattail-dominated marshes are interspersed with dense patches of the non-native common reed (*Phragmites australis australis*) and areas of mixed brackish marsh that are dominated by variable combinations of cattail, common reed, black needlerush, big cordgrass, and salt-marsh bulrush. Along the upper portion of the mainstem Cape Fear River oligohaline reach (above the mouth of the Northeast Cape Fear River), species that are characteristic of more diverse freshwater marsh communities begin to occur sporadically along the margins of the channel; including wild rice (*Zizania aquatica*), bull-tongue arrowhead (*Sagittaria lancifolia*), pickerelweed (*Pontederia cordata*), and arrow-arum (*Peltandra virginica*). Dense patches of non-native common reed are interspersed throughout the salt and brackish marsh estuarine zones. Common reed is restricted to deposits of dredged material and other fill that are slightly higher than the natural tidal floodplain and somewhat protected from exposure to high salinity waters.

The transition from cattail-dominated brackish marshes to tidal freshwater marsh and tidal swamp forest occurs ~1.5 miles above Eagle Island along the mainstem Cape Fear River mainstem. In the NECFR, the transition to tidal freshwater marsh and tidal swamp forest occurs ~8 miles above its confluence with the CFR. Freshwater marshes are primarily confined to a narrow (~100-ft-wide) zone along the edge of the channel, with freshwater swamp forests occupying the vast majority of tidal floodplains. Fringing tidal freshwater marshes extend ~4 miles upriver along both the CFR and NECFR before being displaced entirely by tidal swamp forests. The tidal freshwater marshes are characterized by a diverse assemblage of species; including wild rice, bull-tongue arrowhead, arrow-arum, pickerelweed, sawgrass (*Cladium jamaicense*), Olney’s three-square (*Schoenoplectus americanus*), dotted smartweed (*Persicaria punctatum*), tussock sedge (*Carex stricta*), water parsnip (*Sium suave*), marsh mallow (*Kosteletzkya pentacarpos*), salt-marsh fleabane (*Pluchea odorata*), salt-marsh aster (*Symphyotrichum tenuifolium*), water primrose (*Ludwigia bonariensis*), and salt-marsh water-hemp (*Amaranthus cannabinus*). The tidal swamp forest communities are strongly dominated by bald cypress (*Taxodium distichum*), water tupelo (*Nyssa aquatica*), and swamp tupelo (*N. biflora*).

4.2.7 Primary and Secondary Nursery Areas

The Cape Fear River estuary is an important nursery area for many estuarine-dependent fish and invertebrate species that spawn offshore and use estuarine habitats for juvenile development. Ocean-spawned larvae are transported shoreward by the prevailing currents and eventually pass through tidal inlets and settle in estuarine nursery habitats. Juveniles remain in the estuarine nursery areas for one or more years before moving offshore and joining the adult spawning stock (NCDEQ 2016). The majority of the waters in the CFR estuary above Lilliput Creek are state-designated Primary Nursery Areas (PNAs) (Figure 12). Additionally, waters east of the navigation channel in the lower estuary between Federal Point and Snow's Cut are a state-designated Special Secondary Nursery Area (SSNA). Primary Nursery Areas are defined as "those areas in the estuarine system where initial post-larval development takes place" [15 North Carolina Administrative Code (NCAC) 3I .0101(b)(20)(E)]. Primary Nursery Areas support uniform populations of very early juveniles and are typically located in the upper reaches of the estuarine system. In the case of many estuarine-dependent species, larval settlement occurs in the uppermost reaches of shallow tidal creek systems (Weinstein 1979, Ross and Epperly 1985). Secondary Nursery Areas (SNAs) are defined as "those areas in the estuarine system where later juvenile development takes place." Secondary Nursery Areas support uniform populations of developing subadults that have moved from PNAs to the middle portion of the estuarine system. The majority of the Primary and Secondary Nursery Areas in NC are comprised of shallow soft bottom habitats that are surrounded by salt/brackish marsh (NCDEQ 2016).

Weinstein (1979) and Weinstein et al. (1980) described the nekton communities of shallow nursery habitats in the ~21-mile reach of the lower Cape Fear River estuary between Bald Head Island and Barnards Creek. Sixteen taxa accounted for over 96% of the total combined catch at 17 stations, with ocean-spawning estuarine-dependent species comprising 70% of the dominants. The overall dominant species were generally ubiquitous to the lower estuary but had centers of abundance that varied along salinity gradients. Pigfish, white mullet (*Mugil curema*), red drum, and southern blue crab; along with two permanent marsh residents [Atlantic silverside (*Menidia menidia*) and striped killifish (*Fundulus majalis]*); were primarily associated with high salinity waters of the lower estuary. Additionally, a number of seasonally present marine species were restricted to the lower polyhaline estuary [sergeant major (*Abudefduf saxatilis*), barracuda, Atlantic spadefish (*Chaetodipterus faber*), lookdown (*Selene vomer*), lane snapper (*Lutjanus synagris*), gag grouper, and others). Although not numerically dominant, the seasonal presence of marine species contributed to relatively high species richness at the lowermost Bald Head (n=56) and Battery Island (n=63) stations. Species exhibiting a preference for low salinity waters at the upper stations (Walden Creek and Barnards Creek) included Atlantic croaker, southern flounder, 0 year class Atlantic menhaden (*Brevoortia tyrannus*),, and inland silverside (*M. beryllina*). Also associated with the low salinity sites were freshwater species that were seasonally present at salinities up to 5.1 ppt; including largemouth bass (*Micropterus salmoides*), pumpkinseed (*Lepomis gibbosus*), bluegill (*L. macrochirus*), yellow perch (*Perca flavescens*), white catfish (*Ictalurus catus*), and golden shiner (*Notemigonus crysoleucas*).

Rozas and Hackney (1984) and Ross (2003) indicate that oligohaline marshes of the upper estuary are also important nursery habitats for estuarine dependent species. These studies indicate that densities of juvenile spot, Atlantic croaker, flounder, and other estuarine dependent species in the upper oligohaline marshes and creeks are comparable to or higher than densities in

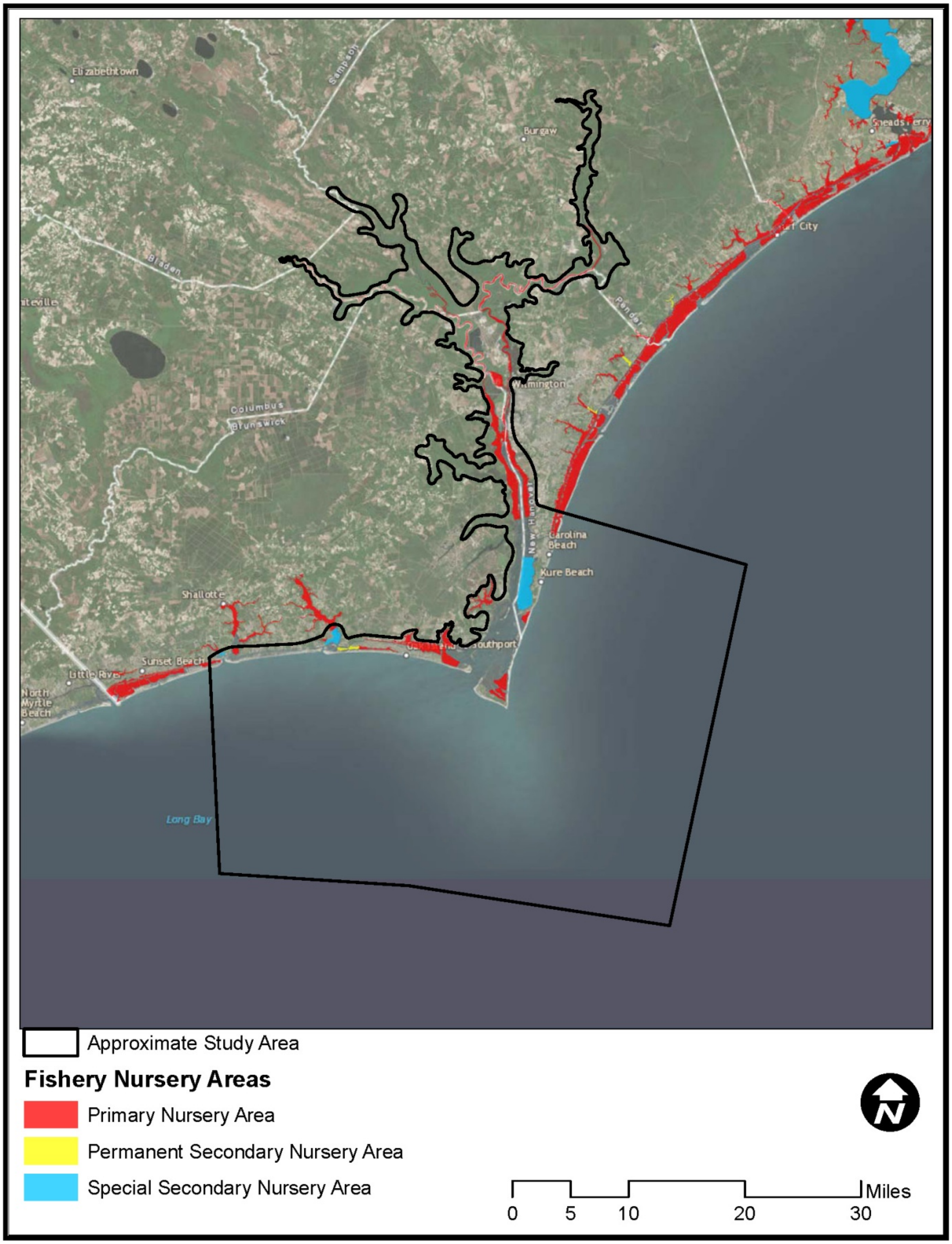


Figure 12
State Designated Nursery Areas

the salt marshes and mesohaline to polyhaline creeks of the mid to lower estuary. In the specific case of spot and croaker, Ross (2003) reported that the upper oligohaline nursery areas were the most valuable for juvenile development. Rozas and Hackney (1984) reported three seasonal peaks in numerical abundance in oligohaline marsh rivulets; including a spring peak associated with the influx of juvenile spot, Atlantic menhaden, Atlantic croaker, and southern flounder; a summer peak attributable to high numbers of grass shrimp; and fall peak attributable to high numbers of bay anchovy and grass shrimp. The most abundant species were spot, grass shrimp, bay anchovy (*Anchoa mitchilli*), and Atlantic menhaden. Average densities of spot and Atlantic menhaden in the oligohaline rivulets at the peak of juvenile recruitment were comparable to those reported for salt marshes.

5 EFFECTS OF THE PROPOSED ACTION ON ESSENTIAL FISH HABITAT

5.1 Estuarine and Marine Water Column

5.1.1 Water Levels

Under the proposed action, the DELFT 3D model results indicate that channel deepening will cause relative increases in both MHW and MLW. Under the RSLR1 scenario and typical flow conditions, the largest projected relative MHW increase is 0.11 ft (1.3 in) in the Anchorage Basin and adjoining Battleship reach (Table 6). The magnitude of relative MHW increase declines rapidly in the estuary above the Battleship reach, with relative increases of 0.04 ft (0.5 inches) and 0.0 ft projected in the uppermost estuary at data points CFR02 and CFR03, respectively. Relative MHW increases are also steadily reduced through the down-estuary reach below the Anchorage Basin, with a projected increase of just 0.02 ft in the lower end of the estuary at Battery Island. Although MLW levels are projected to rise under the proposed action, the increases are smaller than those projected under the FWOP scenario. Thus, the model results show a relative decrease in MLW levels under the proposed action. Under the RSLR1 scenario and typical flow conditions, the largest relative MLW decrease is -0.17 ft (-2.0 inches) in the Anchorage Basin (Table 6). Relative MLW decreases are steadily reduced in the up-estuary and down-estuary reaches above and below the Anchorage Basin. The relative decrease in MLW is caused by channel deepening and a resulting increase in channel hydraulic efficiency. Despite the reduction in MLW rise, the net effect of the combined MHW and MLW changes under the proposed action is a relative increase in tidal range. The largest relative increases of 0.28 ft and 0.26 ft are projected to occur in the Anchorage Basin and Battleship channel reaches, respectively. Relative tidal range increases are rapidly reduced through the up-estuary and down-estuary reaches above and below the Anchorage Basin and Battleship reaches. Under the RSRL2 and RSRL3 scenarios, the relative effects of channel deepening and increased hydraulic efficiency are moderated by increases in flow volume and frictional damping. As a result, the relative effects of the proposed action on water levels are slightly reduced.

5.1.2 Water Quality

Under the proposed action, the typical flow RSLR1 scenario model results indicate that middle and bottom layer DO concentrations would decrease by 0.3 mg/L or less in relation to the No Action Alternative. The largest relative decreases of 0.3 mg/L are projected at stations in the Battleship, Anchorage Basin, and Lower Big Island channel reaches. Maximum relative decreases are reduced to 0.2 mg/L in the Lilliput and Lower Midnight reaches below, and projected decreases throughout the remainder of the estuary are ≤0.1 mg/L. Projected relative decreases in surface layer DO concentrations are ≤0.1 mg/L throughout the action area. The maximum projected decreases occur during the winter months when DO concentrations are typically the highest of the year. Model-projected absolute DO concentrations under the typical flow RSLR1 scenario are on the order of 8 to 10 mg/L during these months; thus indicating that reduced DO concentrations would not be a factor significantly affecting water column habitat functions in the action area. Model results for the dry year RSLR1 scenario show slightly smaller DO decreases of ≤0.2 mg/L, thus the relative effects of the proposed action are slightly reduced. The relative effects of the proposed action are also slightly reduced under the RSLR2 and RSLR3 scenarios. Given the small decreases in DO that are projected, and the timing of maximum decreases during the winter, the TSP would not be expected to adversely affect water quality.

Projected salinity changes under both the FWOP and FWP conditions and all flow and RSLR scenarios generally follow a similar longitudinal pattern, with the largest projected increases occurring in the bottom to mid-depth layers in the vicinity of Anchorage Basin and maximum surface salinity increases of reduced magnitude occurring in the down-estuary Lower Lilliput to Lower Midnight reaches. Projected salinity increases in all three layers are steadily reduced in the up-estuary and down-estuary reaches above and below the projected maxima. This general pattern reflects both longitudinal tidal range variability and vertical stratification within the estuary. Although similar in pattern to FWOP scenario, the FWP increase in channel hydraulic efficiency allows saline ocean water to penetrate farther into the estuary. The modeling results indicate that channel deepening would increase surface, mid-depth, and bottom salinities in relation to the FWOP scenario. Under the typical flow year RSLR1 scenario, the maximum relative increases in average annual salinity occur in the mid-depth (3.9 ppt) and bottom (4.1 ppt) layers in the vicinity of the Anchorage Basin (Table 7). A maximum relative increase in surface salinity of 1.2 ppt is also projected in the Anchorage Basin. Projected increases in all three layers are rapidly reduced in the reaches above and below the Anchorage Basin. Under the RSLR2 scenario, the relative salinity increases under the proposed action are very slightly reduced by 0.1 to 0.3 ppt at all depths throughout the estuary. Under the RSLR3 scenario, the relative salinity impacts under the TSP are reduced by 0.5 to 0.9 ppt at all depths throughout the estuary. The smaller salinity increases under the higher RSLR scenarios are the result of increased frictional damping as the laterally expanding water surface area encounters more resistance.

Although Total Maximum Daily Loads (TMDLs) have not been established for the lower Cape Fear River, the ~15-mile mainstem Cape Fear River reach from the lower end of Keg Island upriver to Navassa is listed as an impaired water body on the NC 303d list; in part due to summer exceedances of the state water quality standard for DO (>5.0 mg/L). Exceedances of the state water quality standard typically occur during the summer when water temperatures are the highest and oxygen solubility is the lowest. According to Mallin (2014), factors other than seasonal high water temperatures that contribute to summer exceedances of the DO standard include the discharge of organic industrial effluent at Riegelwood, organic-rich blackwater inputs from the Black River and Northeast Cape Fear River, and algal blooms that form in the summer behind Lock and Dam #1. Low flow conditions and associated increases in salinity and stratification can also contribute to low DO concentrations, as oxygen solubility decreases with increasing salinity, and stratification typically reduces the delivery of oxygen to the bottom layer via mixing.

5.1.3 Turbidity

The extent and duration of dredging-induced sediment suspension are influenced by sediment composition at the dredge site, the type of dredge employed, and hydrodynamic conditions at the dredge site (Wilber et al. 2005). Prolonged sediment suspension and extensive turbidity plumes are primarily associated with the suspension of fine silt/clay particles that have relatively slow settling velocities, whereas sands and gravels that make up the coarse-grained sediment fraction resettle rapidly in the immediate vicinity of the dredge (Schroeder 2009). Construction of the proposed Wilmington Harbor navigation improvements would employ hydraulic pipeline (cutterhead), hopper, and mechanical (bucket) dredges. Associated disposal operations would include hydraulic (cutterhead) loading of barges for offshore transport to the ODMDS, mechanical (bucket dredge) scow loading for offshore transport to the ODMDS, direct transport to the ODMDS via self-propelled hopper dredges, and direct hydraulic (cutterhead) pipeline disposal to the beaches of Bald Head Island and Oak Island. Refer to Table 2 (previously shown) for a breakdown of dredging and disposal operations by equipment type, channel reach, and dates of operation (i.e., environmental work windows).

Sediment suspension by cutterhead dredges is generally confined to the near bottom water column in the immediate vicinity of the rotating cutterhead assembly (LaSalle et al. 1991). Based on sediment resuspension data collected during navigation dredging projects, Hayes et al. (2000) and Hayes and Wu (2001) reported average cutterhead dredge sediment resuspension rates ranging from 0.003 to 0.135% of the fine silt/clay fraction. Although cutterhead suspension rates at the sea floor are relatively low, hydraulic barge loading operations are typically associated with high suspension rates, primarily due to the surface discharge associated with overflow loading. Overflow loading is employed to achieve economically efficient loads for long-distance transport to offshore disposal sites. Similarly, hopper dredges are associated with high suspension rates due to the surface discharge associated with overflow loading of the hoppers. Mechanical dredges (bucket and clamshell) generally have the highest sediment suspension rates. Sediment suspension by mechanical dredges occurs through the impact of the bucket on the bottom, the washing of material out of the bucket as it is withdrawn from the bottom and moved through and above the water column, and losses of material during barge or scow loading via inadvertent spillage and/or intentional overflow loading to achieve economic loads (LaSalle 1990).

Dredging activities would directly affect marine and estuarine fishes through temporary sediment suspension and associated increases in turbidity. Dredging-induced increases in suspended sediment concentrations and turbidity can affect the behavior (e.g., feeding, predator avoidance, habitat selection) and physiological functions (e.g., gill-breathing) of marine and estuarine fishes. Additionally, the redeposition of suspended sediments can impact benthic invertebrate prey through direct burial and/or adverse effects on gill-breathing and filter-feeding functions (Michel et al. 2013). In response to fisheries concerns, a study was undertaken at Wilmington Harbor to monitor the sediment plumes produced by overflow barge loading in the Keg Island and Lower Big Island reaches of the navigation channel (Reine et al. 2002). The principal objective of the study was to determine the spatial extent of plumes and their potential to affect fish utilization of undisturbed nursery habitats that are adjacent to the maintained navigation channel. The study found that overflow plumes and elevated suspended sediment concentrations were narrowly confined to the navigation channel under both ebb and flood tidal conditions, with significant settling of the plumes to the lower portion of the water column occurring within ~300 meters of the barges. A maximum TSS concentration of 191 mg/L was recorded within the plume at the sampling point nearest the barge, whereas maximum TSS concentrations of 60 to 80 mg/L were recorded in the plume at a distance of 300 m. During active dredging, TSS concentrations over the adjacent flats remained similar to ambient conditions, with measured concentrations ranging from 19 to 33 mg/L. No evidence of plume migration or elevated TSS concentrations was detected over the adjacent flats during either the ebb or flood tide surveys.

Under the TSP, the intensity of dredging operations would temporarily increase during the initial three-year channel construction process; however, the results of the overflow plume study indicate that construction-related sediment suspension effects would primarily be confined to the navigation channel in the immediate vicinity of the barges. Dredging operations would adhere to the established fisheries environmental work window (1 August to 31 January), thus limiting the exposure of estuarine-dependent and anadromous species to potential sediment suspension effects. Pursuant to EPA's ocean dumping criteria established under the authority of the Marine Protection, Research, and Sanctuaries Act (MPRSA); water and dredged material would not be permitted to overflow or spill out of scows, barges, or hoppers during transport to the ODMDS. Post-construction channel maintenance would be accomplished through the continuation of current dredging practices. Relatively small increases in shoaling rates in the Anchorage Basin and lowermost inner harbor reaches would not require any modifications of the current maintenance dredging regime. Thus, the effects of maintenance dredging under the TSP would not differ significantly from the effects of maintenance dredging under the No Action alternative.

5.1.4 Entrainment

Hopper and cutterhead dredges have the potential to entrain fishes and invertebrates during all life cycle phases; including adults, juveniles, larvae, and eggs. Among adult and juvenile fishes, demersal species that inhabit the near-bottom water column environment are most likely to be entrained (Reine and Clarke 1998); however, studies have also reported the entrainment of pelagic fishes in small numbers (McGraw and Armstrong 1990). Entrainment studies indicate that dredging elicits an avoidance response by demersal and pelagic species and that most juvenile and adult fishes are successful at avoiding entrainment (Larson and Moehl 1990, McGraw and Armstrong 1990). The planktonic larvae of marine fishes and invertebrates lack effective swimming capabilities; and therefore, are vulnerable to entrainment by dredges operating in both offshore and inshore waters. Tidal inlets are a critical conduit for the larvae of ocean-spawning/estuarine-dependent fishes and invertebrates that spawn offshore on the continental shelf and use estuarine habitats for juvenile development. Successful larval recruitment to estuarine nursery areas is dependent on transport through a relatively small number of narrow tidal inlets. Larval ingress studies indicate that larvae accumulate in the nearshore ocean zone where they are picked up by along-shore currents and transported to the inlet (Churchill et al. 1999). The results of a long-term sampling program at Beaufort Inlet indicate that larval densities within the inlet are highest from late May to early June and lowest in November (Hettler and Chester 1990).

Larvae are concentrated in inlets during ingress periods, and thus are potentially more vulnerable to entrainment by dredges. However, model-projected larval entrainment studies at Beaufort Inlet indicate that entrainment rates are very low regardless of larval concentrations and the distribution of larvae within the water column (Settle 2003). Even under worst case conditions when the dredge is operating 24 hours/day and all larvae are assumed to be concentrated in the bottom of the navigation channel, the model-projected entrainment rate barely exceeds 0.1% of the daily (24-hour) larval flux through the inlet. Channel construction would temporarily increase the intensity of dredging operations in the Cape Fear River estuary; however, it is expected that the use of cutterhead dredges for all hydraulic dredging in the inlet and estuarine reaches would minimize the extent of larval entrainment, as the cutterhead mechanism is typically buried in the sediment during active dredging. Estuarine dredging operations under the

TSP would adhere to the established fisheries environmental work window (1 August – 31 January), thereby avoiding peak larval ingress periods. Based on the low projected entrainment rates and avoidance of peak ingress periods, it is anticipated that the loss of larvae due to entrainment would have negligible effects on marine and estuarine-dependent fish and invertebrate populations. The studies described above indicate that most juvenile and adult demersal and pelagic fishes would be successful at avoiding entrainment.

5.1.5 Confined Underwater Blasting

Confined blasting would be used as a pretreatment measure to break up hardened rock for subsequent removal by cutterhead and mechanical (bucket) dredges. Areas potentially requiring confined blasting encompass ~188 acres of rock surface area within the Keg Island, Lower Big Island, Upper Big Island, and Lower Brunswick channel reaches. These four reaches comprise a continuous ~4.4-mile section of the navigation channel from a point ~18 miles above the estuary mouth to a point approximately two miles below Eagle Island. Confined blasting involves the detonation of charges in drill holes that have been plugged with rock or other material (stemming) to prevent gas from escaping. A typical blast consists of an array of charges that are detonated on a delay to prevent cumulative blast pressure effects. Confined blasting greatly reduces blast pressure, which is the principal cause of injury to aquatic organisms.

The effects of confined blasting on fishes in the Cape Fear River estuary were investigated through a series of test blasts conducted during the fall and winter of 1998/1999 (Rickman 2000; Moser 1998, 1999). Test blasts consisting of 32 or 33 stemmed 52 to 62 pound charges on a 25 millisecond delay were conducted in a portion of the Big Island channel reach where blasting was to occur as part of the 96 Harbor Act Project. Hatchery reared shortnose sturgeon and striped bass along with locally captured white mullet and killifish were held in cages at distances of 35, 70, 140, 280, and 560 ft from the blast locations. Fish were evaluated and assigned an index of injury score immediately after the blasts and again after a holding period of 24 hours. Subsamples of the surviving sturgeon and striped bass that appeared to be uninjured based on external examination were subsequently necropsied to document internal injuries and assess the likelihood that fish would have recovered from any injuries that were identified. Additional subsamples of surviving fish were held in tanks for a period of two months to evaluate long-term survival. Blasts were also conducted with and without the use of air bubble curtains that were intended to reduce blast pressure impacts; however, bubble curtains were determined to have had little or no effect on fish survival, and were ultimately abandoned as a mitigative measure (Moser 1999, USACE 2000b).

Survival rates at distances of 140 ft and beyond were similar to survival rates at control stations located 0.5 mile from the blast locations, thus indicating that effects were confined to the area within a 140-ft radius of the blast location (Moser 1999). At the 35-ft and 70-ft locations, shortnose sturgeon mortality and injury rates were much lower than those for all other species. Immediate post-blast survival rates for sturgeon at distances of 35 ft and 70 ft ranged from 82.2% to 99.8%. Sturgeon survival rates did not change over the 24 hour post-blasting holding period, and the long-term (two months) survival rates of sturgeons from the 35 ft and 70 ft locations were similar to those from the control station. Necropsies indicated that 88% and 100% of the surviving fish from the 35-ft and 70-ft locations would have recovered and survived long-term. Immediate post-blast survival rates for striped bass were approximately 65% at 35 ft and 90% at 70 ft; while the average combined survival rates for white mullet and killifish were approximately 50% at 35 ft and 90% at 70 ft. Necropsies of surviving striped bass from the 35-ft location indicated that 34% would have recovered and survived long-term. Most of the injuries to striped bass consisted of swim bladder damage; including ruptures and hemorrhaging. In contrast, sturgeon injuries consisted primarily of distended intestines and hemorrhaging of the interior body wall, with very few swim bladder injuries. Moser (1999) attributed the low incidence of swim bladder injuries and relatively high survival rates of sturgeon to a direct connection between the swim bladder and the esophagus that allows gas to escape rapidly.

Under the proposed action, blasting methods and measures to mitigate blast pressure impacts on fisheries would be similar to those developed by the Wilmington District USACE for blasting in the northern Anchorage Basin as part of the last completed phase of the Wilmington Harbor 96 Act Project (USACE 2012). Although never employed, the effects of the planned blasting were evaluated in coordination with regulatory agencies through an Environmental Assessment (USACE 2012) and Section 7 formal consultation with the NMFS that resulted in a Biological Opinion (BO) for blasting effects on Atlantic and shortnose sturgeon (NMFS 2012). The development of a site specific blasting plan for the TSP would be coordinated with federal and state resource agencies to ensure that the potential effects of blasting on fisheries are mitigated to the maximum extent practicable. Although some impacts on fisheries in the form of mortality and injury would be unavoidable, the blast mitigation test results indicate that impacts would be limited to a relatively small area. Therefore, with the implementation of an effective mitigation plan, blasting would not be expected to have significant adverse effects on the productivity of fisheries in the Cape Fear River estuary.

5.2 Unconsolidated Bottom

5.2.1 Background

The effects of dredging on soft bottom benthic infaunal communities in the Wilmington Harbor navigation channel were investigated by Ray (1997) in a study conducted for the Wilmington Harbor 96 Act Deepening Project. Sampling of the navigation channel bottom, side slopes, adjacent undisturbed flats, and control sites was conducted during March and October along 14 transects representing channel reaches at 1, 2, and 3-year post-dredging durations. Species composition differed primarily along longitudinal sediment and salinity gradients, whereas the only significant compositional difference between vertical station positions (channel/slope/flat) was related to salinity intrusion along the channel bottom during the low flow October sampling period. Benthic community structure (taxa richness, abundance, and biomass) differed among the sampling sites according to sediment type, vertical station position, and post-dredging duration**.** In the sandy sediment reaches of the lower estuary; taxa richness, abundance, and biomass at stations in the channel were depressed for one to two years post-dredging, especially on the channel bottom and western channel slope. However, there were no differences among stations in the sandy reaches at 3-year post-dredging sites. In the silty sediment reaches of the middle to upper estuary, there were no differences in benthic community structure among stations. Taxa richness, abundance, and biomass at silty stations were always higher than corresponding control station values; regardless of station position (channel/slope/flat) and post-dredging duration. The absence of detected dredging effects at silty sites is consistent with short-term recovery periods of <6 months that have been reported in other silty sediment estuarine navigation channels (Van Dolah et al. 1984, Van Dolah et al. 1979, Stickney and Perlmutter 1975, and Stickney 1972). The benthic study results indicate that post-maintenance dredging infaunal recovery processes in the navigation channel eventually lead to the reestablishment of infaunal communities that are equivalent to those of adjacent undisturbed flats and control sites in terms of taxa richness, abundance, biomass, and species composition.

5.2.2 Estuarine Soft Bottom Effects

New dredging to construct the proposed inner harbor navigation channel improvements, inclusive of the channel slopes, would directly impact ~557 acres of previously undisturbed estuarine soft bottom habitat in the proposed channel widening and realignment areas (Table 8). Estuarine impacts would include 13 acres of shallow (<12 ft) soft bottom and 544 acres of deep (>12 ft) soft bottom. Construction and long-term maintenance of the improved channel would impact soft bottom habitat functions in the new dredging areas through permanent modification of the physical soft bottom environment and temporary recurring impacts on soft bottom habitats and associated benthic infaunal prey communities. The initial channel deepening process would permanently modify the vertical position of soft bottom habitats within the water column; lowering their positions along vertical water column gradients of light, DO, and salinity. Depth increases would generally be accompanied by reduced light availability and DO and increased salinity. Light availability at the bottom is an important component of shallow estuarine soft bottom habitats that supports significant primary productivity by benthic microalgae. Benthic microalgal productivity in turn supports high secondary productivity by soft bottom benthic infaunal invertebrate communities that comprise the prey base for most soft bottom foraging fishes. Channel construction would convert 12.9 acres of shallow (<12 ft) estuarine soft bottom habitat to deepwater (>12 ft) bottom habitat. Light is strongly attenuated in the CFR estuarine water column by both turbidity and dark organic stained waters from the major blackwater river tributaries (Mallin 2014). Consequently, bottom light availability and benthic microalgal primary productivity in the shallow to deepwater conversion areas would be lost or reduced to insignificant levels. Losses of primary productivity would in turn reduce secondary productivity by benthic infaunal invertebrate prey communities in the conversion areas. Given the strong light attenuating properties of the CFR estuarine water column, reduced bottom light availability would not be a factor affecting existing deepwater soft bottom communities that are currently positioned at depths >12 ft.

Table 6
Soft Bottom Dredging Impacts under the TSP

Channel Reach	**Existing Width[1]**	**Proposed Width[1]**	**Dredging Frequency (Yrs)**	**Dredging Area (acres)**	
				New[2]	**Existing Channel[3]**
Anchorage Basin	625	625-1509	1	2	95
Between Channel	550	625	1	8	37
Fourth East Jetty	500	550	2	30	111
Upper Brunswick	400	500	2	21	48
Lower Brunswick	400	500	2	40	87
Upper Big Island	660	660	2	11	59
Lower Big Island	400	500	2	16	43
Keg Island	400	500	2	37	81
Upper Lilliput	400	500	2	41	102
Lower Lilliput	600	600	2	15	160
Upper Midnight	600	600	2	19	205
Lower Midnight	600	600	2	9	122
Reaves Point	400	500	9	22	67
Horseshoe Shoal	400	500	3	23	59
Snows Marsh	400	500	3	59	143
Lower Swash	400	800-500	2	48	62
Battery Island	500	800-1300	2	111	80
Southport	500	800	4	13	10
Baldhead-Caswell	500	800	4	10	21
Smith Island	650	900	2	22	62
Total Inner Harbor				**557**	**1,656**
Baldhead Shoal Reach 1	700	900	2	24	73
Baldhead Shoal Reach 2	900	900	2	5	99
Baldhead Shoal Reach 3	500-900	600-900	1	132	398
Entrance Extension	N/A	600	10	207	0
Total Ocean Entrance				**368**	**570**
Total Ocean + Inner Harbor				**925**	**2,226**
Total Dredging < 12 ft				12.9	4.6
Total Dredging > 12 ft				912	2,221
Dredging PNA < 12 ft				5.9	0.0
Dredging PNA > 12 ft				27.0	0.0
Dredging AFSA				100	478

[1] Channel bottom width, excluding side slopes

[2] New dredging encompasses the area between the existing channel top-of-slope and the proposed channel top-of-slope, along with the bottom and slopes of the proposed entrance channel extension reach.

[3] Existing channel dredging encompasses the existing channel bottom and side slopes.

Construction and long-term maintenance of the channel improvements would increase the area of in-channel estuarine soft bottom habitat that is subject to recurring maintenance dredging disturbance by ~557 acres. Depending on reach-specific maintenance intervals, newly impacted estuarine soft bottom habitats would experience recurring maintenance dredging disturbance every one to four years for the duration of the 50-year project. Benthic infaunal invertebrate prey communities would experience corresponding cycles of removal and recovery every one to four years. Based on reported rates of benthic infaunal recovery in the Wilmington Harbor channel and other estuarine navigation channels (described above), the effects of individual dredging events on benthic infaunal communities in silty sediment channel reaches would be relatively short-term (<6 months), whereas infaunal communities in sandy channel reaches of the lower estuary would experience longer term effects lasting one to two years. Although the impacts of individual dredging events would be temporary, recurring periods of infaunal depression would cause a reduction in total benthic community productivity over the 50-year project life. The magnitude of productivity loss would vary among channel reaches according to reach-specific dredging frequencies and infaunal recovery rates.

As previously described, model-projected decreases in DO concentrations in the deepened channel are ≤0.3 mg/L and occur during the winter when DO concentrations are the highest of the year. Thus reduced DO is not expected to be a factor affecting soft bottom habitat functions under the proposed action. As previously described, modeling results indicate that channel deepening under the TSP would increase surface, mid-depth, and bottom salinities in relation to the No Action Alternative. Under typical flow conditions, the maximum relative increases in average annual salinity occur in the mid-depth (3.9 ppt) and bottom (4.1 ppt) layers in the vicinity of the Anchorage Basin and the Battleship channel reach. Projected increases at all depths are rapidly reduced in the reaches above and below Wilmington. Mesohaline and oligohaline benthic infaunal prey assemblages in the vicinity of Wilmington would be expected to shift upstream accordingly; however, as described by Ray (1997), the dominant salinity zone benthic assemblages are continually shifting their relative positions along the longitudinal estuarine axis in response to seasonal fluctuations in salinity. Thus it is expected that benthic assemblages would respond rapidly to the projected salinity changes under the proposed action. As described above, statistical analysis of infaunal community differences indicate that post-dredging infaunal recovery processes on the channel bottom and slopes eventually lead to the reestablishment of infaunal communities that are equivalent to those of adjacent undisturbed flats in terms of taxa richness, abundance, biomass, and species composition. The Wilmington Harbor benthic study provides no indication that a vertical shift in habitat position from adjacent flat to channel slope or bottom would lead to permanent benthic community changes.

5.2.3 Marine Soft Bottom Effects

New dredging to construct the proposed ocean entrance channel improvements, inclusive of the channel slopes, would directly impact ~368 acres of previously undisturbed marine soft bottom habitat in the proposed channel widening and offshore extension areas (Table 8). Construction and long-term maintenance of the ocean entrance channel improvements would increase the area of in-channel marine soft bottom habitat that is subject to recurring maintenance dredging disturbance by 368 acres. Existing bottom elevations in the proposed new extension reach and in proposed new dredging areas along the outermost section of the Baldhead Shoal 3 reach are within one to two feet of (and in some cases below) the proposed overdredge channel depth of -

51 ft. Thus, depth increases and associated modifications of the soft bottom physical environment in these areas, which comprise ~65 percent (240 acres) of the total marine soft bottom new dredging area, would be minimal. Existing bottom depths in the remainder of the new dredging areas (~128 acres) range from approximately -45 ft along the mid-point of the Baldhead Shoal 3 reach to approximately -20 ft along the Baldhead Shoal 1 reach near the estuary mouth. Accordingly, the magnitude of depth change and physical habitat modification in the remaining areas would vary along an offshore to onshore gradient.

Construction and long-term maintenance of the improved channel would have recurring impacts on marine soft bottom habitats and benthic infaunal communities in the new dredging areas. Reported rates of benthic infaunal recovery in the Wilmington Harbor channel indicate that infaunal communities in the sandy nearshore ocean channel reaches would experience effects lasting one to two years after each dredging event. The Wilmington Harbor benthic study did not investigate infaunal recovery beyond the ebb tidal delta in the offshore silty channel reaches. However, soft bottom habitats in deep offshore waters are relatively stable in relation to those of nearshore and estuarine environments. Consequently, the associated benthic infaunal communities are generally comprised of larger, longer-lived species that recover relatively slowly from disturbance. In the case of the entrance channel extension reach, infrequent dredging every 10 or more years would allow for full recovery during the interim periods between maintenance events. However, it is expected that dredging frequencies of one to two years in the Baldhead Shoal 3 and outer Baldhead Shoal 2 reaches would maintain the affected communities in a continual state of recovery, thereby permanently shifting composition towards that of a more opportunistic assemblage. Regardless of recovery rates, recurring periods of infaunal depression would reduce total benthic community productivity over the 50-year project life.

5.3 Primary Nursery Areas

The above described new dredging estuarine soft bottom impacts encompass ~32.9 acres of state-designated PNA habitat in the uppermost Anchorage Basin, Between Channel, and Fourth East Jetty project reaches; including 5.9 acres of shallow (<12 ft) PNA soft bottom and 27 acres of deep (>12 ft) PNA soft bottom. As described above, the effects of deepening on shallow soft bottom habitats would include the loss of shallow water refuge and benthic primary production habitat functions. The loss of refuge function would render the areas unsuitable as nursery habitat for the early juveniles of estuarine-dependent species. The 27 acres of existing deep (>12 ft) PNA habitat are currently lacking shallow water refuge and benthic primary production functions, thus the principal impact of the proposed action on these habitats would be a reduction in benthic infaunal prey productivity as described above for estuarine soft bottom.

5.4 Hard Bottom

Remote sensing surveys did not identify any naturally occurring hardbottom resources within the proposed channel modification areas. As indicated above, previous investigations indicate that the nearest naturally occurring hardbottoms are located approximately two to three miles west of the entrance channel and the new ODMDS. The proposed action would widen the authorized bottom width of the old ODMDS reach by 100 ft (50 ft either side); thus potentially impacting two large (relief 1.0-1.5 m) dredged material rubble mounds that are within ~50-100 ft of the existing west-side channel top of slope. However, the positions of the naturalized hardbottom rubble mounds are such that a slight shift in channel alignment would be sufficient to avoid the features. Efforts would be made to avoid or minimize impacts to the hardbottom features as part of the final channel design process during the Preliminary Engineering and Development (PED) phase of the project. Sediment suspension and redeposition effects during channel construction and maintenance would not differ significantly from those associated with existing maintenance dredging operations. Previous remote sensing surveys conducted by the USACE did not identify any hardbottom habitats within the new ODMDS or a surrounding 500-meter buffer zone. Therefore, proposed ocean disposal at the new ODMDS would not be expected to have any effect on hardbottom resources.

5.5 Shell Bottom

Analyses of remote sensing survey data did not identify any structural shell bottom habitats within the existing channel or the proposed channel expansion areas. Therefore, construction of the proposed channel improvements would not have any direct mechanical impacts on shell bottom. The distribution of oyster reefs in the estuary is limited by salinity to the lowermost ~10-mile reach of the CFR (Rodriguez 2009). Therefore, oyster reefs would not be affected by confined blasting at locations 18 miles or more above the estuary mouth. Heavy sediment redeposition can impact oysters by inhibiting larval attachment to hard substrates and reducing the respiration and feeding rates of juveniles and adults (Wilber and Clarke 2010). However, the results of sediment plume monitoring during hydraulic barge overflow loading at Wilmington Harbor indicate that suspended sediment plumes are narrow and confined to the navigation channel in the immediate vicinity of the barge (Reine et al. 2002). Monitoring detected no evidence of plume migration or elevated TSS concentrations over the adjacent flats during either the ebb or flood tide surveys. Furthermore, according to Colden and Lipcius (2015), eastern oysters that were subjected to experimental sediment deposition did not exhibit significant mortality or sublethal effects until at least 70% of the shell height was buried. The effects of dredging-induced sediment suspension and redeposition on oyster reefs outside of the navigation channel would be similar to the effects of maintenance dredging under the No Action alternative. As described above, the results of dredge plume monitoring at Wilmington Harbor indicate that significant sediment redeposition outside of the navigation channel would be unlikely. Therefore, it is expected that any sediment suspension and redeposition effects on shell bottom habitats would be temporary and minor.

5.6 Submerged Aquatic Vegetation

NCDMF has determined that mapped SAV occurrences in the lower estuary are aerial imagery-based misidentifications of marine macroalgae (Personal communication, Ann Deaton, NCDMF Habitat Protection and Enhancement Section, 19 Feb 2019). NCDMF has concluded that SAV beds are absent from the lower estuary. The only confirmed SAV beds in the Cape Fear River estuary, consisting of slender naiad (*Najas gracillima*), are located in the Brunswick River near the US HWY 74/76 Bridge. Therefore, construction of the proposed navigation channel improvements would not be expected to have any direct mechanical or sediment resuspension effects on SAV. Although SAV beds in the Brunswick River are removed from the proposed construction areas, slender naiad is a species of tidal freshwater to oligohaline habitats that is potentially vulnerable to indirect salinity intrusion effects. The identified occurrences are located on shallow subtidal flats adjacent to the shoreline, thus model-projected surface layer salinity data were used to evaluate potential salinity effects under the proposed action. Model-projected average annual surface salinity increases in the vicinity of the Brunswick River SAV beds are ~0.2 ppt under typical year flow conditions and ~1.0 ppt under dry year flow conditions. The effects of these relatively small projected increases in salinity on slender naiad are difficult to predict; however, ten years of continuous salinity monitoring data from the Cape Fear River at the upper end of Eagle Island show that the area experiences intrusions of relatively high salinity water on a regular basis (Leonard 2011). The apparent tolerance of slender naiad to periodic high salinity pulses suggests that significant adverse effects would be unlikely under the proposed action.

5.7 Estuarine Emergent Wetlands

Channel construction would not have any direct impacts on tidal wetlands. Salinity modeling results indicate that harbor deepening would cause relative upstream shifts in oligohaline-freshwater 0.5 ppt salinity isopleths ranging from ~0.18 to 0.83 mile. Wetlands potentially affected by the projected upstream shifts in the 0.5 ppt isopleths include ~242 acres of tidal freshwater swamp forest, ~98 acres of tidal freshwater marsh, and ~62 acres of brackish cattail marsh (Table 9). Projected shifts in the mesohaline-oligohaline 5.0 ppt isopleths under the proposed action are confined to the existing brackish marsh-dominated reaches of the estuary. Wetlands potentially affected by the various mesohaline-oligohaline isopleth shifts under the proposed action encompass ~470 acres of brackish cattail marsh, ~20 acres of Phragmites marsh, and approximately five acres of brackish marsh mix. Projected surface salinity changes within the mesohaline-oligohaline isopleth shift zones are limited to relatively small increases of ≤1.5 ppt. The potentially affected brackish wetlands consist almost entirely (96%) of cattail marsh, with the majority (~3.5%) of the remaining brackish wetlands consisting of marshes dominated by the non-native invasive species *Phragmites australis australis*. Cattail marshes dominate the estuarine tidal floodplain from approximately two miles below Eagle Island to the upper ends of the oligohaline reaches in the Cape Fear River and Northeast Cape Fear River, and thus are well adapted to a broad range of salinities. Therefore, the relatively small increases in salinity that are projected under the proposed action would not be expected to have any significant effect on cattail marshes. In the case of Phragmites marshes, any changes in community composition would be considered a beneficial effect.

The remaining tidal freshwater wetlands that were identified as potentially affected by oligohaline-freshwater isopleth shifts include 241.8 acres of tidal freshwater swamp forest and 98.7 acres of tidal freshwater marsh (Table 9). Although in many cases the projected oligohaline-freshwater isopleth shifts cover substantial distances, the projected surface salinity changes within the isopleth shift zones are limited to very small increases of ≤0.3 ppt. Although tidal freshwater swamp forest communities are capable of tolerating or recovering from occasional pulses of saline water, they are generally not able to tolerate regular flooding by saline waters. Based on studies conducted in the Cape Fear River estuary, Hackney and Avery (2015) indicate that the location along the river salinity gradient where 12% to 25% of the high tide events flood the adjacent tidal wetlands with >1 ppt saline water is the active zone of tidal swamp to tidal marsh conversion. Tidal freshwater marshes as defined by the baseline classification are slightly more tolerant of very low oligohaline salinities; however, the restriction of freshwater marshes to relatively short reaches of the estuary in the immediate vicinity of the oligohaline-freshwater boundary indicates that overall salinity tolerance is very limited. Thus, tidal swamp forest and tidal freshwater marsh communities are potentially vulnerable to relatively small increases in salinity. However, given the very small projected increases in salinity, the exact nature and extent of effects are difficult to predict. Generally, it is anticipated that the projected salinity increases would have some effects on community composition, and that shifts in freshwater community composition towards the brackish marsh spectrum would reduce community diversity. However, minor changes in tidal marsh plant community composition would not be expected to degrade the refuge, primary production, or forage EFH functions that are associated with these habitats.

Table 7
Freshwater Tidal Wetlands Potentially Affected under the Proposed Action

Water Body	Isopleth Shift	Model Scenario	Wetland Class (acres)		Total Freshwater Wetlands
			Tidal Swamp Forest	Tidal Freshwater Marsh	
Cape Fear Mainstem	Oligohaline-Freshwater	Dry Yr RSLR1	29.9	16.2	**46.1**
Cape Fear Mainstem	Mesohaline-Oligohaline	Dry Yr RSLR1	0.0	0.0	**0.0**
Northeast Cape Fear	Oligohaline-Freshwater	Dry Yr RSLR1	75.8	16.7	**92.5**
Northeast Cape Fear	Mesohaline-Oligohaline	Dry Yr RSLR1	0.0	0.0	**0.0**
Smith Creek	Oligohaline-Freshwater	Typical Yr RSLR1	27.4	0.0	**27.4**
Sturgeon Creek	Oligohaline-Freshwater	Typical Yr RSLR1	19.4	55.2	**74.6**
Jackeys Creek	Oligohaline-Freshwater	Typical Yr RSLR1	58.0	0.0	**58.0**
Barnards Creek	Mesohaline-Oligohaline	Typical Yr RSLR1	0.0	0.0	**0.0**
Town Creek	Oligohaline-Freshwater	Typical Yr RSLR1	13.9	0.0	**13.9**
Town Creek	Mesohaline-Oligohaline	Typical Yr RSLR1	0.0	0.0	**0.0**
Lilliput Creek	Oligohaline-Freshwater	Typical Yr RSLR1	17.4	9.7	**27.1**
Lilliput Creek	Mesohaline-Oligohaline	Typical Yr RSLR1	0.0	0.9	**0.9**
		Total (acres)	**241.8**	**98.7**	**340.5**

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