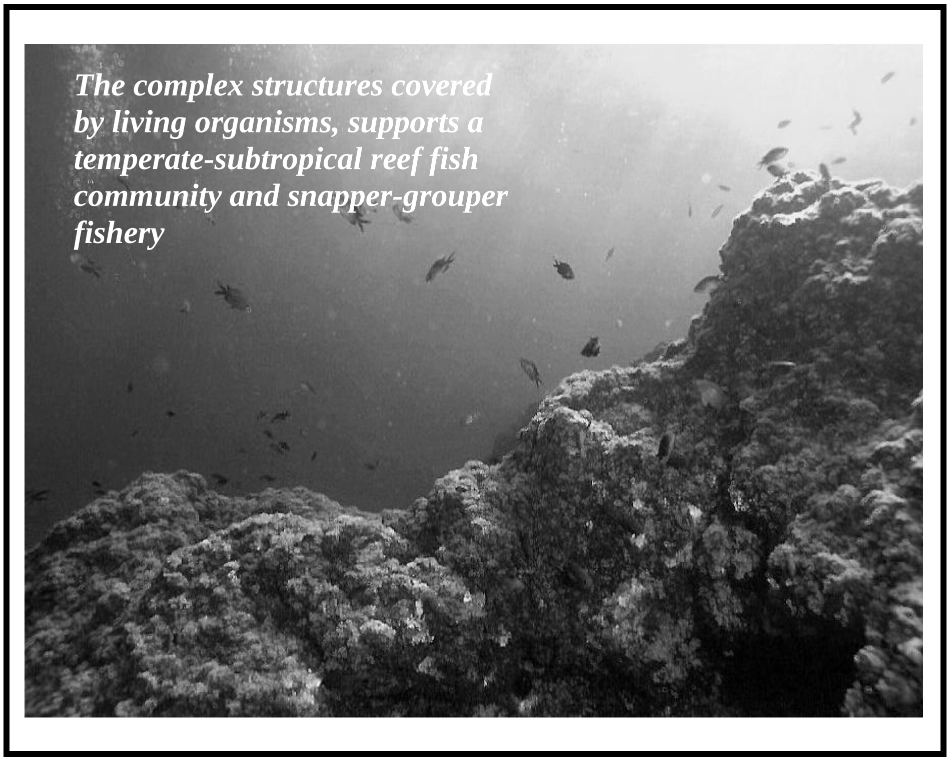
CHAPTER 7. HARD BOTTOM

7.1. Description and distribution

7.1.1. Definition

Hard bottom habitat is defined by Street et al. (2005) as "exposed areas of rock or consolidated sediments, distinguished from surrounding unconsolidated sediments, which may or may not be characterized by a thin veneer of live or dead biota, generally located in the ocean rather than in the estuarine system." In addition to areas of natural hard bottom, man-made structures, including artificial reefs, shipwrecks, and jetties, provide additional substrata for the development of hard bottom communities.



7.1.2. Description

Natural hard bottom, also referred to as "live rock" or "live bottom," consists of exposed rock outcrops or relic reef colonized to a varying extent by algae, sponges, soft coral, hard coral, and other sessile invertebrates (SAFMC 1998a; SAFMC 2008a). Hard bottom habitats vary in topographic relief from relatively flat outcrops with gentle slopes to a scarped ledge with up to 10 m of vertical, sloped, or stepped relief (Barans and Henry 1984; Riggs et al. 1996). Bioerosion of the hard substrate by encrusting organisms produces large-scale morphological features, including overhangs and undercut sloped scarps (Riggs et al. 1996; Riggs et al. 1998). Low-relief outcroppings may be subject to intermittent burial and exposure through the natural distribution of ephemeral sand bodies (SEAMAP-SA 2001). Areas of compacted or sheered mud sediments also function as hard bottom habitat (Riggs et al. 1996).

Artificial reefs are structures constructed or placed in waters for the purpose of enhancing fishery resources. Colonization of artificial reefs by algae, invertebrates, and other marine life results in establishment of additional hard bottom habitat. In North Carolina, artificial reefs have been constructed from surplus vessels, steel boxcars, concrete pipe, concrete rubble, rock, boat molds, tires, and surplus military aircraft. Concrete domes and igloos specifically designed to provide structurally complex habitat (i.e. Reef Balls ™) have also been used for artificial reef construction. The DMF Artificial Reef Program is responsible for deployment and maintenance of artificial reef sites in state and federal waters, following the guidelines of the DMF Artificial Reef Master Plan (DMF 1988). Shipwrecks off the North Carolina coast also provide added structure available as hard bottom habitat. Documented wrecks include World War II German U-boats, gunboats, tankers, freighters, barges, sailing ships, and wooden and iron-hulled steamers.

Jetties and groins are man-made rubble (e.g. large boulder) structures built perpendicular to the shoreline and designed to retard the littoral transport of sediments. Jetties are usually constructed at inlets for the primary purpose of stabilizing navigational channels. Because jetties emerge above the water line, they support both intertidal and subtidal hard bottom communities. Groins are similar but shorter than jetties, and their primary purpose is to trap sand, not maintain the channel. The degree of colonization of these hard structures by attached invertebrates and algae depends primarily on location, flow characteristics, and water quality conditions. Bridge and pier pilings, as well as other concrete structures in high salinity estuarine waters, also provide suitable substrate for hard bottom communities.

7.1.3. Habitat requirements

The primary requirement for the formation and stability of hard bottom habitat is exposed areas of hard substrate. Species composition and abundance of algae, invertebrates, and reef fishes at hard bottom habitats in the ocean off North Carolina vary with temperature and depth. Bottom water temperatures at these habitats range from approximately 11º to 27º C. Temperatures less than 12°C may result in the death of tropical species of invertebrates and fishes. Changes in water masses, seasonal fluctuations in water temperature, and light penetration physically stress the hard bottom community in North Carolina (Kirby-Smith 1989), limiting the abundance and diversity of hard coral and reef fish.

7.1.4. Distribution

Hard bottom occurs in both warm-temperate and subtropical areas of the South Atlantic Bight, although it is less extensive in the northern end of its range (North Carolina). This habitat extends from the shoreline and nearshore (within the state's three-nautical mile jurisdictional limit) to beyond the continental shelf edge (>200 m deep), generally occurring in clusters in specific areas (SEAMAP-SA 2001). Parker et al. (1983) estimated that hard bottom accounts for approximately 14% (504,095 acres) of the substratum between 27 and 101 m water depth from Cape Hatteras to Cape Fear, and 30% (1,829,321 acres) between Cape Fear and Cape Canaveral.

7.1.4.1. Hard bottom mapping

Several efforts have been undertaken to map hard bottom resources in coastal waters of the southeastern United States. In 1985, the Southeast Area Monitoring and Assessment Program—South Atlantic (SEAMAP-SA) began an initiative to identify the location and extent of hard bottom and coral reef habitats throughout the South Atlantic Bight to water depths of 200 m. Data used to identify hard bottom was based upon the presence of indicator species in traps or trawls, side scan sonar records, and video and diver observations. The amount of hard bottom habitat documented by this program was most likely an underestimate due to the ephemeral nature of low-relief hard bottoms and the difficulty of distinguishing bottom type using seismic data (SEAMAP-SA 2001).

Locations of natural hard bottom and artificial reef sites documented by SEAMAP-SA (2001) in both state and federal waters are shown in Map 7.1, along with some of the known shipwrecks. The majority of natural hard bottom outcrops identified are located in federal waters (> three nautical miles (nm) from shore) of Onslow and Long bays. Concentrations of hard bottoms in Long Bay occur between the Cape Fear River mouth and Shallotte Inlet. In Onslow Bay, hard bottom is most concentrated from Bogue Inlet east to Cape Lookout Shoals, from Brown's Inlet south to New Topsail Inlet, and from Masonboro Inlet to Frying Pan Shoals. Hard bottom in Raleigh Bay is most concentrated east of Cape Lookout Shoals and south of Diamond Shoals. Within state territorial waters, the SEAMAP-SA (2001) database identified 48 natural hard bottom sites and 75 possible hard bottom sites using point and line data, with the majority of sites occurring in Onslow Bay (Table 7.1).[47]

Table 7.1. Hard bottom and possible hard bottom locations in North Carolina state territorial waters by coastal bay. [Source: Point and line data identified by SEAMAP-SA (2001). Results from Moser and Taylor (1995) in parentheses.]

Bottom Type	Long Bay	Onslow Bay	Raleigh Bay	North of Hatteras	Total
Hard bottom (point)	2 (19)	14 (58)	1 (4)	2 (3)	19 (86)
Hard bottom (line)	3 (6)	25 (39)	1 (2)	0 (2)	29 (49)
Possible hard bottom (point)	1	8	3	4	16
Possible hard bottom (line)	5	37	12	5	59
Total	11 (25)	84 (97)	17 (6)	11 (5)	123 (135)

Recently, SEAMAP-SA expanded their efforts to synthesize existing data on bottom habitat distributions for water depths between 200 and 2000 m within the U.S. Exclusive Economic Zone (EEZ) of the South Atlantic Bight (SEAMAP-SA 2004; Udouj 2007). Similar to that done for shallower waters, data used to identify deepwater hard bottom included visual observations, presence of invertebrate indicator species in trawls, traps or dredges, and geological records (SEAMAP-SA 2004). The SEAMAP-SA Deepwater Bottom Mapping Project identified 34 natural hard bottom sites in the waters off North Carolina, many of which are concentrated in Onslow Bay (Udouj 2007). These sites include the proposed Cape Lookout and Cape Fear Deepwater Coral Habitat Areas of Particular Concern (CHAPC) (Ross 2006; Partyka et al. 2007; SAFMC 2008b).

In addition to the large-scale SEAMAP-SA mapping efforts, Moser and Taylor (1995) compiled information on the distribution of hard bottom in the nearshore ocean waters of North Carolina using surveys of local researchers, dive professionals, and fishermen. A total of 198 hard bottom positions were identified with several sites not included in the SEAMAP-SA (2001) database (Map 7.1, Table 7.1). Over 92% of the identified nearshore hard bottom is south of Cape Lookout, predominantly in the southern half of Onslow Bay and in northern Long Bay. Concentrations of nearshore hard bottoms occur seaward of inlets, including Bogue, New River, New Topsail, Masonboro, Carolina Beach, Lockwood's Folly and Shallotte inlets. Twenty of the identified nearshore hard bottom sites were reported as high-profile relief, defined by Moser and Taylor (1995) as vertical relief greater than two meters, with several sites, specifically those off Carolina Beach and New River, extensive in both area and topographic relief. Outcroppings of moderate-to-high relief occur in shallow waters near the shoals of Cape Fear and Cape Lookout. Vast areas of low-relief hard bottom, intermittently covered with a thin layer of sand, occur extensively from 1) mid-Onslow Beach to south of New River Inlet and 2) Yaupon Beach west to Tubbs Inlet (Moser and Taylor 1995). At Fort Fisher, a unique intertidal and subtidal coquina rock outcrop extends from the beach into the surf zone.

Several localized mapping efforts have provided detailed information with regards to the extent of hard bottom habitats in specific areas of the North Carolina coast (Crowson 1980; Lombardero et al. 2008). These mapping efforts have primarily focused on nearshore resources in the vicinity of Surf City and New River Inlet. Extensive low to high-relief hard bottom outcrops have been identified in these areas.

[47] Line data represents information from trawls. The lengths of the trawl lines vary, and some lines may actually represent several transects of one area. Similarly, some hard bottom lines may overlap with hard bottom points.

Crowson (1980) found that much of the nearshore low-relief hard bottom in the proximity of New River Inlet was partially covered by a thin layer of sand. In boring for compatible sand sources for Brunswick County beach nourishment, the US Army Corps of Engineers (USACE) has identified several areas of low-relief hard bottom seaward of Oak Island, Holden Beach, and Ocean Isle (USACE, unpub. data).

7.1.4.2. Distribution of man-made hard bottom

There are 47 DMF-managed artificial reefs of varying construction in North Carolina, of which 29 are located in federal ocean waters, 11 in state ocean waters (Map 7.1), and seven in estuarine waters.[48] The DMF Artificial Reef Program generally adds material to the 40 existing ocean sites, rather than creating new reefs, although new reefs are created on occasion. In addition to the DMF-managed artificial reefs, the USACE constructed an artificial reef off the Cape Fear River using rock dredged during deepening of the shipping channel. The North Carolina Department of Cultural Resources, Underwater Archaeology Branch, estimates there are over 1,000 sunken vessels off the North Carolina coast dating back to the earliest period of European exploration (http://www.archaeology.ncdcr.gov/ncarch/underwater/underwater.htm, 2008). The majority of shipwrecks are in federal waters, with concentrations around the three cape shoals. Gentile (1992) listed 46 documented wrecks in waters south of Hatteras Inlet, with most located northeast and west of the mouth of the Cape Fear River (Map 7.1). There are also two jetty systems and three groin systems along the North Carolina ocean shoreline. A single jetty is situated on the west side of Cape Lookout, while Masonboro Inlet has jetties on both sides–one attached to Wrightsville Beach, and the other attached to Masonboro Island. The groins are located on the south side of Oregon Inlet, off the former site of the Cape Hatteras Lighthouse, and on the west side of Beaufort Inlet. Numerous small groins and jetty systems are in estuarine waters as well, but these features have not been mapped.

7.2. Ecological role and functions

7.2.1. Ecosystem enhancement

Hard bottoms, through bioerosion, contribute significant volumes of new sand to sediment-starved sections of the North Carolina continental margin, such as Onslow and Long bays (Riggs et al. 1996; Riggs et al. 1998). Three primary groups of bioeroders, including rock boring bivalves, burrowing shrimp, and macroalgae, physically and/or chemically degrade hard bottom of different hardnesses and slopes (Riggs et al. 1998). Larvae of rock boring bivalves erode mostly muddy sandstones by chemically (i.e. secretion of acid) or mechanically (i.e. abrasion from their hard shell) burrowing through sections of rock. Over time, multiple tunnels weaken the rock until chunks break off, leaving a fresh surface for more bivalve larvae to settle on and bore into. Macroalgae erode rock (primarily Pleistocene limestone) when storms and strong water currents dislodge their holdfasts from the rock surface, removing small pieces of rock along with the plant itself. Rates of sediment production from bioerosion vary with respect to substrate type, ranging from 5.5 $kg/m^2/yr$ on vertical and sloped Miocene mudstone to 0.03 $kg/m^2/yr$ on flat, highly lithified Plio-Pleistocene limestone (Riggs et al. 1998). These processes also enhance the structural complexity of the hard bottom outcrops, which promotes diversity of fish habitat within the reef (Riggs et al. 1996; Riggs et al. 1998).

7.2.2. Productivity

Exposed hard substrate provides stable attachment surfaces for colonization by sessile marine invertebrates and algae. The vertical relief and irregularity of hard bottom structure affords greater habitat complexity, allowing more species to coexist (Wenner et al. 1984; Fraser and Sedberry 2008). Areas of exposed hard bottom may be quite small and isolated, and have been considered oases of productivity surrounded by less productive unconsolidated ocean bottom (SAFMC 1998a; SAFMC

[48] The Shell Bottom chapter (3.0) covers estuarine reefs located in salinities suitable for oysters.

2008a). Species diversity and extent of colonization on temperate hard bottom vary with topography, environmental conditions, and distance from shore. Much of the research on hard bottom communities in North Carolina has been focused on locations beyond the three-mile state boundary (MacIntyre and Pilkey 1969; Schneider 1976; Peckol and Searles 1984; Kirby-Smith 1989).

Macroalgae are the dominant colonizing organisms on North Carolina hard bottoms, ranging from 10% to 70% of the biotic cover (Peckol and Searles 1984). Roughly 150 species of encrusting macroalgae have been identified, with the greatest diversity occurring in Onslow Bay (Schneider 1976). Perennial and crustose brown and red algae, including *Sargassum filipendula*, *Dictyopteris membranacea*, *Lobophora variegata*, *Lithophyllum subtenellum*, *Zonaria tournefortii*, and *Gracilaria mammillaris* are dominant algal forms (Schneider 1976; Peckol and Searles 1984; Renaud et al. 1997; Mallin et al. 2000a; DMF 2001d). The shallow inshore flora consists largely of temperate species, while offshore areas support more tropical flora (Searles 1984). The greatest abundance of macroalgae occurs at offshore habitats due to the high proportion of suitable substrate, greater relief on the shelf break, and mild water temperatures. Of the offshore species, 66% are at their northern limit of distribution in Onslow Bay, and 2% are at their known southern distributional limit (Schneider 1976).

7.2.3. Benthic community structure

Attached, sessile invertebrates account for 10% or less of the biotic cover on hard bottom in North Carolina (Peckol and Searles 1984). Peckol and Searles (1984) reported that the soft corals *Titandeum frauenfeldii* and *Telesto fructiculosa*, and the hard coral *Oculina arbuscula* were the most abundant non-mobile invertebrates, while sea urchins (*Arbacia punctulata* and *Lytechinus variegatus*) were the most common mobile invertebrates. In a study of hard bottom communities at nearshore and offshore reefs, Kirby-Smith (1989) found that benthic community structure varied with season, depth, and distance from the shelf edge. Inner shelf sites, in approximately 16–27 m water depths, had somewhat lower diversity than mid- or outer shelf sites. Regardless of location, mollusks, polychaetes, and amphipods were dominant in the number of species observed.

Wenner et al. (1984) reported that sponges, bryozoans, corals, and anemones[49] dominated the large macroinvertebrate community in terms of numbers and species diversity during all seasons at hard bottom sites in South Carolina and Georgia. Sponges comprised 59–78% of the total invertebrate biomass on the inner shelf, although tunicates, anthozoans, and mollusks also contributed substantially. Species which typified inner shelf sites included the sponges *Homaxinella waltonsmithi, Spheciospongia vesparium, Cliona caribbaea*, and *Halichondria bowerbanki*; the echinoderms *Lytechinus variegatus, Arbacia punctuata*, *Encope michelini*, and *Ocnus pygmaeus*; the bryozoan *Membranipora tenuis*; and the decapod crustacean *Synalpheus minus*. Polychaetes were the most diverse and abundant group of small invertebrates, followed by mollusks, and amphipods.[50]

Species composition of hard bottom communities in the nearshore waters of North Carolina is less tropical in nature compared to that farther offshore or to the south due to cooler water temperatures and greater temperature fluctuations (Kirby-Smith 1989; Fraser and Sedberry 2008). Furthermore, macroalgae outcompetes the hard coral *Oculina arbuscula* at nearshore reefs in Onslow Bay, limiting its growth and recruitment, as well as restricting its distribution to deeper, poorly lit habitats via competitive exclusion (Miller and Hay 1996). Because of these conditions, hard bottom in state territorial waters is colonized to a lesser extent by hard and soft corals than offshore or more southern areas. Offshore hard bottom, however, appears to offer suitable habitat for two species of tropical reef building corals: *Solenastrea hyades* and *Siderastrea siderea*. These species grow on flat rock outcrops in Onslow Bay at

[49] sponges (89 Porifera taxa); bryozoans (91 Bryozoa taxa); and corals and anemones (70 Cnidaria taxa)

[50] polychaetes (285 species, 72% of total individuals); mollusks (251 species, 4.3% of total individuals); and amphipods (100 species, 13% of total individuals)

depths of 20 to 40 m approximately 32 km offshore (MacIntyre and Pilkey 1969; MacIntyre 2003). Other species of coral reported in North and South Carolina include the hard corals *Oculina arbuscula*, *Oculina varicosa*, *Astrangia danae*, *Phyllangia americana*, *Balanophyllia floridana*, and the soft corals *Leptogorgia virgulata*, *Telesto* spp., *Lophogorgia* spp., *Titanideum frauenfeldii*, and *Muricea pendula* (Wenner et al. 1984; Hay and Sutherland 1988).

Unique and productive hard bottom communities are also found on the slope off North Carolina (> 250 m water depth) (Ross 2006; Partyka et al. 2007; Ross and Nizinski 2007). Because these habitats seem to be at their northern limit of distribution in Onslow Bay, they may be distinct in biotic resources as well as habitat expression. The hard coral *Lophelia pertusa* is the dominant macroinvertebrate, although the colonial corals *Madrepora oculata* and *Enallopsammia profunda* as well as a variety of solitary corals, sponges, and anemones are also abundant. Overall, species diversity of these deep water habitats increases south of Cape Fear (Partyka et al. 2007; Ross and Nizinski 2007). The Galatheid crab *Eumunida picta*, brisingid basket star *Novodinia antillensis*, and the brittle star *Ophiacantha bidentata* typify the mobile invertebrate community in the deep water reefs off North Carolina (Ross 2006).

7.2.4. Fish utilization of natural hard bottom

Fish comprise a significant proportion of the faunal biomass on hard bottom and are an important component of the overall trophic structure (Jaap 1984; Thomas and Cahoon 1993; Steimle and Zetlin 2000). Habitat utilization patterns by hard bottom fishes are primarily determined by water temperature and topography (Wenner et al. 1984; SAFMC 1998a; SAFMC 2008a). Temperatures less than 12º C may result in the death of some tropical species, while hard bottoms with relatively high relief support a greater abundance and diversity of fishes because of their structural complexity and more permanent nature (Huntsman and Manooch 1978). Studies that have examined fish assemblages on hard bottom habitats in North Carolina include Huntsman and Manooch (1978), Miller and Richards (1980), Grimes et al. (1989), Clavijo et al. (1989), Lindquist et al. (1989), Potts and Hulbert (1994), Parker and Dixon (1998), Quattrini et al. (2004), Quattrini and Ross (2006), Ross and Quattrini (2007), and Shertzer and Williams (2008). All of these studies, however, were conducted seaward of state territorial waters, including those at sites on the inner shelf. *Research specific to nearshore hard bottom (i.e. within state territorial waters) is needed to better understand the dependence of fishes on this habitat.*

Natural hard bottoms off the North Carolina coast support large populations of tropical, subtropical, and warm-temperate reef fish, as well as numerous coastal pelagic species. Along the coasts of North and South Carolina, well over 150 species of reef fish have been documented on inshore, offshore, and shelf-edge hard bottoms, with species richness and diversity increasing with distance from shore (Huntsman and Manooch 1978; Grimes et al. 1989; Clavijo et al. 1989; Lindquist et al. 1989; Parker and Dixon 1998, Quattrini et al. 2004; Quattrini and Ross 2006; Ross and Quattrini 2007). Documented species include wrasses, damselfish, snappers, grunts, porgies, and sea basses. Generally, inshore hard bottoms support a higher proportion of temperate fishes, such as black sea bass (*Centropristis striata*), spottail pinfish (*Diplodus holbrookii*), and estuary-dependent migratory species (Huntsman and Manooch 1978; Grimes et al. 1989). A list of species reported at nearshore hard bottom in North and South Carolina is provided in Table 7.2.

Table 7.2. Fishes occurring at nearshore hard bottom in North Carolina and South Carolina coastal waters. (Sources: Grimes et al. 1989; Powell and Robins 1998; DMF, unpub. data)

Family	**Scientific name**	**Common name**
Carcharhinidae	*Carcharhinus falciformis*	Silky shark
Muraenidae	*Gymnothorax nigromarginatus*	Blackedge moray
Ophichthidae	*Ophichthus ocellatus*	Palespotted eel
Engraulidae	*Anchoa* spp.	Anchovies
Synodontidae	*Synodus foetens*	Inshore lizardfish
	Trachinocephalus myops	Snakefish
Batrachoididae	*Opsanus pardus*	Leopard toadfish
Antennariidae	*Antennarius ocellatus*	Ocellated frogfish
Gadidae	*Urophycis earllii*	Carolina hake
Ophidiidae	*Ophidion marginatum*	Striped cusk-eel
Syngnathidae	*Hippocampus erectus*	Lined seahorse
	Syngnathus spp.	Pipefishes
Serranidae	*Centropristis ocyurus*	Bank sea bass
	Centropristis striata	Black sea bass
	Dermatolepis inermis	Marbled grouper
	Diplectrum formosum	Sand perch
	Epinephelus adscensionis	Rock hind
	Epinephelus drummondhayi	Speckled hind
	Epinephelus morio	Red grouper
	Cephalopholis fulva	Coney
	Epinephelus guttatus	Red hind
	Mycteroperca microlepis	Gag
	Mycteroperca phenax	Scamp
	Mycteroperca venenosa	Yellowfin grouper
	Cephalopholis cruentata	Graysby
	Serranus subligarius	Belted sandfish
Priacanthidae	*Pristigenys alta*	Short bigeye
	Heteropriacanthus cruentatus	Glasseye snapper
Apogonidae	*Apogon pseudomaculatus*	Twospot cardinalfish
Pomatomidae	*Pomatomus saltatrix*	Bluefish
Carangidae	*Alectis crinitus*	African pompano
	Caranx ruber	Bar jack
	Decapterus punctatus	Round scad
Lutjanidae	*Lutjanus analis*	Mutton snapper
	Lutjanus campechanus	Red snapper
	Lutjanus griseus	Gray snapper
Haemulidae	*Haemulon aurolineatum*	Tomtate
	Haemulon plumieri	White grunt
	Orthopristis chrysoptera	Pigfish
Sparidae	*Diplodus holbrookii*	Spottail pinfish
	Archosargus probatocephalus	Sheepshead
	Calamus leucosteus	Whitebone porgy
	Stenotomus chrysops	Scup
Sciaenidae	*Equetus umbrosus*	Cubbyu
	Cynoscion regalis	Weakfish
Labridae	*Halichoeres bivittatus*	Slippery dick
	Tautoga onitis	Tautog
Ephippidae	*Chaetodipterus faber*	Atlantic spadefish
Blenniidae	*Parablennius* sp.	Blennies
Gobiidae	*Ioglossus calliurus*	Blue goby
Paralichthyidae	*Paralichthys dentatus*	Summer flounder
	Paralichthys lethostigma	Southern flounder

Lindquist et al. (1989) reported 30 species in 14 families at a natural inner shelf (~5 miles from shore) hard bottom site in Onslow Bay, North Carolina. Commonly occurring and numerically abundant species were, in order of decreasing abundance, are juvenile grunts, round scad, tomtate, spottail pinfish, and black sea bass.

Other common species included slippery dick (*Halichoeres bivittatus*), scup (*Stenotomus chrysops*), pigfish (*Orthopristis chrysoptera*), cubbyu (*Equetus umbrosus*), belted sandfish (*Serranus subligarius*), and sand perch (*Diplectrum formosum*). Species composition at this reef varied due to seasonal inshore migrations of tropical and subtropical fishes. A partial list of the most important fish species that utilize hard bottom in North Carolina’s state territorial waters and the function the habitat provides is given in Table 7.3.

Table 7.3. Habitat utilization, stock status, and use of important fish species that occupy hard bottom areas in North Carolina's nearshore (≤ 3 nm from shore) ocean waters.

	Hard bottom Functions [1]						
Species	**Refuge**	**Spawning**	**N rsery**	**Foraging**	**Corrido**	**Fishery [2]**	**2010 Stock status [3]**
MARINE SP WNI G, HIGH SALINITY NURSERY							
Black sea bass [4]	**X**	**X**	**X**	**X**	**X**		**D- S of Cape Hatteras, C- N of Cape Hat eras**
Bluefish	X			X		X	V
D mselfish (mult. spp.)	**X**	**X**	**X**	**X**			
Gag [4]	**X**		**X**	**X**	**X**	**X**	**C**
Gobies (multiple spp.)	**X**	**X**	**X**	**X**			
King mackerel	X			X		X	C
Pigfish	**X**	**X**	**X**	**X**		**X**	
Planehead filefish	**X**	**X**	**X**	**X**			
Scup [4]	**X**	**X**	**X**	**X**		**X**	**V**
Spottail pinfish	**X**	**X**	**X**	**X**		**X**	
Summer flounder	X	X		X		X	R
Tautog	**X**		**X**	**X**	**X**	**X**	
Wrasses (mult. spp.)	**X**	**X**	**X**	**X**			
MARINE REEF FISH COMPLEX							
Atlantic spadefish	**X**	**X**	**X**	**X**		**X**	C- reef fish complex as a whole in NC. Individual species have not been evaluated in NC.
Greater amberjack	**X**			**X**		**X**	
Round scad	**X**		**X**	**X**			
Sheepshead	**X**	**X**	**X**	**X**		**X**	
Tomtate	**X**	**X**	**X**	**X**		**X**	
White grunt	**X**	**X**	**X**	**X**		**X**	
Whitebone porgy	**X**		**X**	**X**		**X**	

* Scientific names listed in Appendix D. Names in **bold** font are species whose relative abundances have been reported in the literature as being generally higher in hard bottom than in other habitats. Note that lack of bolding does not imply non-selective use of the habitat, just a lack of information.

[1] Powell and Robins 1998; Grimes et al. 1982; F. Rohde/DMF pers. com. 2003

[2] Commercially or recreationally caught species. Other species are important to the ecosystem as prey
[3] V = Viable, R = Recovering, C = Concern, D = Depleted, U = Unknown (http://www.ncdmf.net/stocks/2010NCDMF%20StockStatusReport.pdf).

[4] Part of the reef fish complex but evaluated separately by DMF for stock status

7.2.5. Fish utilization of man-made structures

When occurring in similar environmental conditions, the composition and density of fish at artificial reefs tend to be similar to those at natural hard bottoms (Huntsman and Manooch 1978; Miller and Richards 1980; Ambrose and Swarbrick 1989; Lindquist et al. 1989; Bohnsack et al. 1994; Potts and Hulbert 1994). Species composition, relative abundance, and catch-per-unit-effort (CPUE) at artificial reef sites in North Carolina are documented periodically by DMF (DMF 1998; DMF 2002). An evaluation of the effectiveness of different artificial reef materials found species assemblages to be similar on reefs constructed with concrete pipes or domes. However, the evaluation also found that CPUE was 71 – 85% greater on natural reefs than nearby artificial reefs (DMF 1998). A more recent assessment conducted between 2001 and 2005 found that CPUE by number and weight of recreationally important demersal target species, including grouper (*Epinephelus* and *Mycteroperca*), black sea bass, snapper (*Lutjanus* spp.), vermilion snapper (*Rhomboplites aurorubens*), gray triggerfish (*Balistes capriscus*), porgies (*Calamus and Pagrus*), and flounder (*Paralichthys* spp.), were similar, if not higher at artificial reef sites compared to adjacent natural reefs (DMF, unpub. data), possibly reflecting the naturalization of artificial substrata over time. Several studies have reported that multiple artificial patch reefs surrounded by sand habitat support greater fish abundance and diversity than one large area of equal material, suggesting the importance of habitat variety to overall ecosystem quality (Bohnsack et al. 1994; Auster and Langton 1999; Jordan et al. 2005).

Jetties provide some of the same habitat functions for fishery resources as natural hard bottoms and artificial reefs. The fish community found at jetties in North Carolina is a subset of that found on offshore hard bottoms and estuarine oyster reefs (Lindquist et al. 1985; Hay and Sutherland 1988). Most fishes are absent from inshore jetty habitats in the winter, gradually returning as waters warm in spring. Hay and Sutherland (1988) grouped fishes documented on jetties in North and South Carolina into five general categories based on their mobility, association with structure, and seasonality of jetty occupancy:

- Small cryptic resident fishes, such as blennies and gobies;
- Numerically dominant fishes that migrate offshore in winter, such as pinfish, spottail pinfish, black sea bass, and pigfish;
- Predatory pelagic fishes, such as bluefish, Spanish mackerel, and king mackerel;
- Fishes attracted to jetties during their seasonal migrations, such as smooth dogfish (*Mustelus canis*); and
- Tropical fishes that occur as strays during summer, such as butterflyfishes and surgeonfishes.

Although jetties provide suitable habitat for some structure-oriented fish, the species that utilize them do not require jetties for survival since they are attracted from existing natural hard bottom and estuarine oyster reefs.

7.2.6. Specific biological functions

7.2.6.1. Refuge and foraging

The complex three-dimensional structure of hard bottom provides protective cover for numerous organisms (Huntsman and Manooch 1978; Potts and Hulbert 1994; Mallin et al. 2000a; Quattrini and Ross 2006; Fraser and Sedberry 2008; Kendall et al. 2008). Hard bottom habitats are often the only source of structural refugia in open shelf waters. The abundance of fish on hard bottom is related to the amount and type of structure of the reef habitat (Huntsman and Manooch 1978; Potts and Hulbert 1994; Kendall et al. 2008). Rocky faces with more complexity consistently support a greater abundance and diversity of resident reef fish than less complex habitats.

The structure provided by hard bottom also concentrates prey resources and attracts predators. In general, most reef fish are carnivores (Jaap 1984; Sedberry and Cuellar 1993; Lindquist et al. 1994; Goldman and

Sedberry 2006). Benthic invertebrates are therefore very important as energy assimilators and food sources for reef fish (Jaap 1984). Lindquist et al. (1994) found that black sea bass, scup, and cubbyu forage extensively on both reef and adjacent soft bottom invertebrates at a nearshore hard bottom site off the North Carolina coast. Posey and Ambrose (1994) documented significant reductions in soft bottom macroinvertebrate densities within 10 m of an inner shelf reef due to the foraging activity of several reef fishes. These finding suggest that, in addition to reef-associated invertebrates, sand substrata organisms around reefs function as valuable prey for reef fishes.

The abundance of prey and extent of structural refugia afforded by hard bottom in turn supports high fish productivity. Nearshore hard bottom can support over thirty times as many individuals per transect as adjacent sand habitats (Lindeman 1997). Accordingly, natural reefs sustain greater fish stocks (270 to 5,279 kg/ha) compared to non-reef open shelf bottom (6.3 to 46.3 kg/ha) (Huntsman 1979).

7.2.6.2. Spawning

Hard bottom also functions as crucial spawning areas for numerous species of fish and invertebrates. Most reef fish spawn in aggregations in the water column above the reef surface (Jaap 1984). The timing of egg release is often triggered by nightfall or tide stage, probably to reduce the risk of predation. While offshore and shelf-edge reefs have been documented as important spawning habitat for species of the snapper-grouper complex (Wyanski et al. 2000; White and Palmer 2004; Burton et al. 2005; Burgos et al. 2007), nearshore hard bottom provides valuable spawning sites for smaller and more temperate reef species. Species known to spawn on nearshore hard bottom include black sea bass and sand perch (Powell and Robins 1998). Sheepshead (*Archosargus probatocephalus*), Atlantic spadefish (*Chaetodipterus faber*), seaweed blenny (*Parablennius marmoreus*), inshore lizardfish (*Synodus foetens*), and several species of damselfish, wrasses, and gobies (*Ioglossus calliurus* and others) are also thought to spawn on nearshore hard bottom (F. Rohde/DMF, pers. com., 2001). *More research is needed concerning spawning activity on, and recruitment to, nearshore hard bottom to understand the importance of this habitat and document trends in fish utilization*.

7.2.6.3. Nursery

Nearshore and inner shelf hard bottom serves as important settlement and nursery habitat for the larvae and early juveniles of many reef fishes. In a study of the abundance and distribution of ichthyoplankton adjacent to hard bottom in open shelf waters (< 55 m water depth) in Onslow Bay, Powell and Robbins (1998) collected the larvae of 22 reef-associated families. Planehead filefish (*Monacanthus hispidus*), the blenny *Parablennius marmoreus*, the goby *Ioglossus calliurus*, black sea bass, sand perch, and several species of grunts, snappers, and wrasses were commonly collected. These taxa are thought to spawn in somewhat deeper waters of Onslow Bay and recruit locally to nearshore hard bottom (Powell and Robins 1998). Although the mechanisms of recruitment to hard bottom habitats are generally unclear, it is apparent that successful recruitment depends on water circulation patterns transporting larvae to suitable habitat (Jaap 1984).

7.2.6.4. Corridor and connectivity

Nearshore hard bottom also serves as a migratory corridor for the late juveniles of estuary-dependent reef fishes (Lindeman and Snyder 1999; Baron et al. 2004). In North Carolina, these species include black sea bass, gag, red grouper, sheepshead, Atlantic spadefish, bank sea bass, and gray snapper, which use estuarine habitats as early juveniles and move to offshore hard bottom with growth. Red snapper and mutton snapper juveniles have also been documented in North Carolina's estuaries to a lesser extent (DMF, unpub. data). Juveniles migrating offshore benefit from the structural refugia and high abundance of prey organisms provided by nearshore hard bottoms. Several studies on the southeast coast of Florida have reported that early life stages represent over 80% of the individuals at nearshore hard bottom sites

(Lindeman and Snyder 1999; Baron et al. 2004). These assemblages were primarily dominated by juvenile grunts, wrasses, and damselfish. In North Carolina, the patchy distribution and limited extent of nearshore hard bottom suggest that habitat availability may limit survival of early stages of reef fish, giving available hard bottom habitat particularly high value (P. Parker/NMFS, pers. com., 2002).

7.3. Status and trends

7.3.1. Status of hard bottom habitat

The condition of shallow hard bottom in North Carolina state territorial waters is of particular importance to the health and stability of estuary-dependent snapper-grouper species that utilize this habitat as "way stations" or protective stopping points as they emigrate offshore. Because of the high market value, number of recreational participants, and associated businesses, the offshore snapper-grouper complex supports productive commercial and recreational fisheries. Between 2005 and 2007, the North Carolina commercial snapper-grouper fishery harvested an average of 1,148,152 lbs of fish at an annual market value of over $3.1 million (DMF 2008c). During those same years, recreational fisherman (including private boats, charter boats and head boats) harvested an average of 687,216 lbs of fish in the snapper-grouper complex.

Nearshore hard bottoms are generally considered to be in good condition overall (SAFMC 1998b). Although adequate information exists on the distribution of hard bottom off the North Carolina coast (Moser and Taylor 1995; SEAMAP-SA 2001; Udouj 2007), little information is available to evaluate the status and trends of hard bottom habitat in state territorial waters. Anecdotal information from fishermen and local residents in coastal North Carolina suggests that many known nearshore hard bottom sites in the mid-twentieth century are now completely covered by sand, and that the abundance of fish in these areas is much reduced. *An extensive and regular survey of nearshore hard bottom distribution and quality is needed to better evaluate status and trends of both habitat and biological communities.*

7.3.2. Status of associated fishery stocks

Commercially or recreationally harvested reef fish are managed collectively as the reef fish complex or Snapper-Grouper management unit, which includes 73 species of snappers, sea basses and groupers, porgies, tilefishes, grunts, triggerfishes, wrasses, spadefish, wreckfish, and jacks. Management authority is shared by NMFS, SAFMC, and DMF/MFC. Of these species, only some are found on hard bottoms in North Carolina state territorial waters. Information is available on the status of many reef fishes through state, interstate, and federal stock assessments. Fishery-dependent data on reef fish are collected by the DMF Offshore Live Bottom Fishery Program (DMF biological database program 438/448). Fishery-independent data on reef fish abundance and community structure are also available for a portion of North Carolina from the Marine Resources Monitoring, Assessment, and Prediction Program (MARMAP), a cooperative fisheries project of the Marine Resources Research Institute (MRRI) of the South Carolina Department of Natural Resources (SCDNR). This program has conducted standardized groundfish (bottom fish) surveys from Cape Lookout, North Carolina south to Ft. Pierce, Florida since 1972 using a variety of fishing gears. Sampling occurs on mid-shelf and shelf-edge reef habitats in water depths of 16 m to more than 92 m. Although sampling is focused seaward of state waters, this program provides valuable information for stock assessments of reef fishes, including species that utilize nearshore hard bottom in North Carolina.

Most major South Atlantic reef fish stocks are considered fully utilized or over-utilized (NMFS 2008). Of 73 managed species in the South Atlantic Snapper-Grouper management unit, three species were classified as "Overfished" in 2007 by the NMFS, four were "Not Overfished", and 66 were "Unknown"

(NMFS 2008).[51] Overfished species included snowy grouper, black sea bass, and red porgy. In addition, 10 species were reported to be subject to Overfishing, 13 were not subject to Overfishing, and the status of 50 species was Unknown (NMFS 2008). *More data are needed for evaluating the stock status of species in the reef fish complex off North Carolina.*

In North Carolina, the reef fish complex as a whole was classified as Concern by DMF in 2009 (DMF 2009a). The reef fish complex includes numerous species, of which at least ten are common in North Carolina state territorial waters. For stock status of individual reef fishes, DMF defers to SAFMC Southeast Data, Assessment, and Review (SEDAR) stock assessments. Of the species listed in Table 7.3 that are highly associated with nearshore hard bottom in North Carolina, five stocks have been evaluated by DMF. One stock was reported as "Depleted" (black sea bass south of Cape Hatteras) in 2010 and three were reported as Concern (black sea bass north of Cape Hatteras, gag, and reef fish complex) (http://www.ncdmf.net/stocks/2010NCDMF%20StockStatusReport.pdf). Scup were considered Viable in 2010.

Although most exploited reef fish species are caught primarily in federal waters, several, such as gag and black sea bass, are highly dependent on nearshore hard bottom as primary and secondary nursery areas, and for providing migratory corridors as individuals move offshore with age. The apparent vulnerability of reef fishes to overfishing is attributed to their long lives, slow growth, large size, delayed sexual maturity, ease of capture, and preference for patchy hard bottom habitats. *Nearshore hard bottoms (within state territorial waters) should be considered for nomination as Strategic Habitat Areas because of their importance as secondary nursery habitats and migratory corridors for black sea bass, gag, and other reef fish species, as well as valuable foraging habitat for flounder, mackerel, and weakfish.*

The status and health of reef fish stocks in North Carolina may be particularly subject to changes in the quantity or quality of habitat. Although some research in Florida has indicated that habitat is not limiting and reef fish populations are controlled primarily by recruitment success (Bohnsack 1996; Grossman et al. 1997), these studies may not be applicable to North Carolina where hard bottom is much less extensive. In North Carolina, there appears to be a direct relationship between the amount of hard bottom and the number of reef fish. Of the three Carolina Bays, Onslow Bay has more hard bottom than Long Bay or Raleigh Bay, and also has the greatest amount of reef fish (P. Parker/NMFS, pers. com., 2002). This relationship implies that increased habitat quantity would result in larger populations of reef fish.

7.3.3. Hard bottom enhancement

Artificial reefs may enhance fish production by providing additional foraging, spawning, and refuge habitat, increasing an area's carrying capacity (Bohnsack 1989; Grossman et al. 1997; Lindberg 1997; Brickhill et al. 2005). They are most effective at bolstering production where reef habitat is limiting, when a large stock reservoir exists, and when fishing effort is low (Bohnsack 1996; Grossman et al. 1997; Powers et al. 2003). Powers et al. (2003) estimated that annual fish productivity was 32% greater at artificial reefs protected from fishing as compared to those subject to fishing pressure. This suggests that artificial refugia would be beneficial for enhancement of fish productivity and ecosystem value. An artificial refugia site is an artificial reef that is designated as a no-take area to provide an unfished habitat to aid in stock recovery, conduct research, and test effectiveness of enforcement. *Construction of artificial refugia (no-take artificial reefs) or designation of existing artificial reefs as refugia (no-take, Marine Protected Areas) should be considered to enhance fisheries productivity.*

High numerical abundance of fish, however, may not necessarily be associated with increased production. There is some concern among fishery scientists that artificial reefs only concentrate available biomass

[51] Overfished is defined as a stock size below an established biomass threshold and Unknown is defined as a stock for which no recent assessment was conducted or insufficient information about the stock exists to make a determination (NMFS 2008).

rather than increase regional productivity. This attraction-production debate is yet to be resolved (Bohnsack 1989; Bohnsack et al. 1994; Pickering and Whitmarsh 1996; Carr and Hixon 1997; Grossman et al. 1997; Lindberg 1997; Rilov and Benayahu 2000). *Additional research is needed to determine if, and to what extent, artificial reefs in North Carolina simply concentrate available fish or effectively increase fish biomass.*

Artificial reefs must be properly designed, sited, and managed to successfully increase production of benthic organisms and fish populations (DMF 1988; Gregg 1995; Brickhill et al. 2005; Strelcheck et al. 2005). Small, complex structures that mimic natural hard bottom may be better for recruitment and enhance juvenile survival, while larger structures may be better for attracting large predators and enhance fishing opportunities (Bohnsack et al. 1994; Jordan et al. 2005; Lindberg et al. 2006). One ongoing problem that the DMF has experienced with artificial reefs is the failure of some designs, such as those composed of tires, to remain assembled and in position. More recent artificial reefs constructed of concrete pipes and domes appear to be sufficiently stable and durable when deployed (DMF 1995; Gregg 1995). The DMF Artificial Reef Master Plan provides siting guidelines and construction standards for artificial reefs in North Carolina (DMF 1988). Some of the recommendations that pertain to habitat enhancement include:

- North Carolina's artificial reef program should NOT use materials that:
  - Are toxic to the environment.
  - Are not stable and may move off-site.
  - Are not durable and will have a short lifespan in the ocean.
- Materials used should provide the degree of habitat complexity and profile appropriate for the targeted reef species.
- Artificial reefs should be designed to increase surface area and interstitial space by addition of rock, concrete, or other suitable materials to barges and stripped vessels that lack structural complexity.
- Trolling alleys, reef clusters, and reef sanctuaries should be incorporated into reef complex designs.
- Artificial reefs should NOT be sited where:
  - Natural hard bottom exists.
  - The seafloor would not support proposed reef structures.
  - High-energy environments exist.
  - Traditional commercial fishing activities occur.
  - They would be a navigation or liability hazard.
- Enhancement of existing artificial reef sites should be a higher priority than construction of new artificial reef sites.
- If artificial reefs are used to replace natural reef habitat that has been damaged or destroyed, they should be designed and constructed to provide proven biologically productive habitat (DMF 1988).

In 2009, the DMF Artificial Reef Program shifted its focus toward development of estuarine artificial reefs. The Artificial Reef Program, in association with the Oyster Sanctuary Program[52], will develop nursery habitat evaluation and enhancement projects for estuary-dependent reef fishes, including gag and black sea bass. Addition and enhancement of estuarine artificial reefs may increase fish production on nearshore and offshore hard bottoms by providing additional estuarine nursery habitats, potentially increasing the number of recruits.

7.3.4. Designated areas

Natural hard bottom is protected through both state and federal designations. The N.C. Natural Heritage Program inventories, catalogues, and supports conservation of the rarest and most outstanding elements of natural diversity in the state. The program designates rare or significant plants, animals, or natural

[52] See Shell Bottom chapter (2.0) for more information on the Oyster Sanctuary Program.

communities that merit special consideration when making land use and conservation decisions. Four hard bottom sites within state territorial waters (Map 2.3) have been designated by this program as Significant Natural Heritage Areas (SNHA) (Natural Heritage Program, unpub. data). These include rock outcrops off Bogue Banks (two acres), New River Inlet (1300 acres), South Topsail Island (38 acres), and Masonboro Island (50 acres). In addition, the intertidal Fort Fisher Coquina Rock outcrops (47 acres) were also designated as SNHA. *These and other nearshore hard bottoms should be considered for nomination as Strategic Habitat Areas because of their natural significance and vulnerability to impacts from on-shore land development activities*.

Certain natural hard bottoms have been designated as federal Essential Fish Habitat-Habitat Areas of Particular Concern (EFH-HAPC) based on four criteria: 1) importance of ecological functions; 2) sensitivity to human degradation; 3) probability and extent of effects from development; and 4) rarity of the habitat. In North Carolina, all of the nearshore hard bottom, The Point, Ten Fathom Ledge (Onslow Bay), Big Rock (Onslow Bay), and the entire shelf break have been given this designation for the snapper-grouper complex (SAFMC 1998a; SAFMC 2008b). In addition, the SAFMC has proposed the establishment of deepwater Coral Habitat Areas of Particular Concern (CHAPCs) to protect what is currently thought to be the largest contiguous distribution (>23,000 square miles) of deepwater coral ecosystems in the world (SAFMC 2008b). The proposed CHAPCs include two locations in Onslow Bay, North Carolina: the Cape Lookout *Lophelia* Bank (122 square miles) and the Cape Fear *Lophelia* Bank (52 square miles). The Cape Lookout *Lophelia* Bank encompasses two large *Lophelia* coral mounds, with the main mound rising 80 meters (262 ft.). More than 54 species of deepwater reef fishes have been documented along this bank. The Cape Fear *Lophelia* Bank also includes mounds rising nearly 80 meters (262 ft.) and exhibits some of the most vertically rugged habitat of any deep water reef in North Carolina. Over 12 fish species have been documented along this bank, including many larger deepwater reef fishes. In addition, the Cape Fear *Lophelia* Bank is the only location in North Carolina where wreckfish have been observed (Ross 2006; SAFMC 2008b).

In 2000, federal Executive Order 13158 directed federal agencies to strengthen the management, protection, and conservation of existing Marine Protected Areas (MPAs), and establish new or expanded MPAs through the creation of a scientifically-based comprehensive national system of MPAs representing diverse marine ecosystems (65 FR 34909). In response to this directive and because of concern for major stocks of the snapper-grouper complex that are undergoing overfishing and/or overfished, and failure of those stocks to adequately recover despite extensive changes in fishing regulations, the SAFMC established several Marine Protected Areas (MPAs) in the South Atlantic Bight through Amendment 14 to the South Atlantic Snapper Grouper Fishery Management Plan (SAFMC 2007). The NMFS issued a final rule to implement Amendment 14 effective February 2009 (74 FR 1621-1631), officially creating eight Type II MPAs in which fishing for or possession of South Atlantic snapper-grouper species are prohibited, but other types of fishing, such as trolling, are allowed. Use of MPAs has proven effective in habitat protection and fishery enhancement, particularly for species with restricted geographical movements typical of most reef fishes (Bohnsack 1993). A study of 89 marine reserves world-wide showed that fish and other marine life quickly recovered when protected by establishment of marine reserves (Halpern 2003), and organisms within the protected areas repopulated adjacent waters (AAAS 2001; Roberts et al. 2001). The primary purpose for MPA designation by the SAFMC is to protect a portion of the population and habitat of long-lived, slow growing, deepwater snapper-grouper species from directed fishing pressure to achieve a more natural sex ratio and age and size structure within the proposed MPAs, while minimizing adverse social and economic effects (SAFMC 2007). In North Carolina, the Snowy Grouper Wreck MPA (150 square miles) was established in federal waters of Onslow Bay, east of Cape Fear. This location was once the site of a known spawning aggregation of snowy grouper, and supports numerous speckled hind, gag, red porgy, red grouper, graysby, and hogfish, as well as tuna, dolphinfish, wahoo, and marlin.

Although the MFC has the authority to establish no-take areas within state jurisdictional waters, there has been little discussion concerning establishment of nearshore hard bottom reserves through state management. The Fisheries Director may prohibit or restrict taking of fish and use of any equipment in and around any artificial reef or research sanctuary subject to some conditions [MFC Rule 15A NCAC 3I .0109]. Many areas within state waters, such as primary nursery areas, are already protected from certain fishing activities through MFC rules. *Nearshore hard bottom nominated as Strategic Habitat Areas should be considered for designation as MPAs, either through state or federal avenues, to provide some protection from fishing gear impacts and enhance fish production.*

Man-made structures functioning as hard bottom have also been given varying levels of designation and protection. In 1975, the wreck of the USS Monitor, a Civil War ironclad located in federal waters off Cape Hatteras, was designated as the first national marine sanctuary. Within North Carolina state territorial waters, the USS Huron, a popular wreck located 250 yards off the beach in Dare County, was designated by the state as a historic shipwreck preserve (Map 7.1). Furthermore, all artificial reefs, along with all natural hard bottoms have been designated by the NMFS as Essential Fish Habitat (EFH).

7.4. Threats and management needs

7.4.1. Water-dependent development

7.4.1.1. Dredging (navigation channels and boat basins)

Dredging near or on hard bottom is potentially the most damaging physical human activity to this habitat (SAFMC 1998b). Navigational dredging is associated with the creation of, or modification to, shipping channels. Dredge gear impacts hard bottom directly by dislodging corals or colonized rock (live rock), as well as injuring live tissue, which may lead to infection or mortality (SAFMC 1998b). The disposal of dredged sediments on Ocean Dredged Material Disposal Sites (ODMDS) may, through sediment dispersal from the ODMDS, bury adjacent hard bottom habitat, resulting in long-term loss of sessile biota and associated finfishes (Crowe et al. 2006). Even if hard bottom is not buried, increased sedimentation stresses corals and other sessile invertebrates, and may result in decreased productivity or death if the organisms cannot purge the sediments deposited on them (SAFMC 1998b; Crowe et al. 2006). Silt generated by dredging may remain in the area for long periods and continue to impact hard bottom when resuspended during storms.

Dredging of large navigation channels through oceanic bottoms in North Carolina is limited to the entrance channels leading to the state ports in Wilmington and Morehead City via Cape Fear and Beaufort inlets, respectively. Although hard bottom is found in the general vicinity of both port entrance channels, it is particularly abundant in the ocean adjacent to the Port of Wilmington. In 2002, the Wilmington channel was rerouted as part of a project to deepen the river channel and port, and create a new ODMDS. The proposed route was, however, altered to avoid dredging through hard bottom (F. Rohde/DMF, pers. com., 2002). Dredging and stabilization of other inlets, such as New River, Masonboro and Shallotte inlets, can also potentially impact hard bottom through direct removal of hard bottom resources, as well as increased turbidity and sedimentation in the vicinity of dredge sites.

7.4.1.2. Shoreline stabilization

Due to the economic and recreational value of beaches, several different erosion control measures have been used to protect coastal property and structures from continued erosional loss of protective shorelines and dunes (ASMFC 2002a). The most common method of combating ocean shoreline retreat is beach nourishment, in which sediments from a dredge site (e.g. nearshore ocean or inlet) or land-based source are placed on the shoreface in order to build the beach profile and extend it seaward (ASMFC 2002a; Peterson and Bishop 2005). However, these dredge-and-fill projects can have deleterious effects on nearshore hard bottom if sited inappropriately (Blair et al. 1990). Similar to that for navigational dredging, dredging of ocean borrow areas can directly impact hard bottom via mechanical removal of hard corals, soft corals, sponges, algae, and other benthic organisms. In addition, these organisms may be fractured (e.g. hard corals), injured (e.g. soft corals and sponges), or silted over, reducing the health and productivity of hard bottom resources. Current CRC rules prevent dredging activities within a 500 m buffer of significant biological communities, such as high relief hard bottom areas [CRC Rule 15A NCAC 07H .0208(b)(12)(A)(iv)]. Under this rule, "high relief" is defined as relief greater than or equal to one-half meter per five meters of horizontal distance. However, research by Lindquist et al. (1994) suggests that reef fishes derive a significant portion of their nutritional requirements within a 500 m "halo" of any exposed hard bottom. Because of this finding, the Ocean Policy Steering Committee (OPSC), a group established by DCM to examine North Carolina's emerging ocean policy issues, has recommended in their draft report that a 500 m dredging buffer should be established around all hard bottom areas, including those periodically buried with thin, ephemeral sand layers (DCM 2009). In the past few years beach nourishment planning efforts have attempted to mine closer than this distance due to the difficulty of finding an area of sand not within the hard bottom buffer. *Using the recommendations from the OPSC, the CRC should modify existing rules pertaining to mining of submerged lands to require a 500 m dredging buffer around any exposed hard bottom, thus minimizing potential impacts to fish habitat functions. Furthermore, these buffers should be enforced.*

The subsequent addition of sand to the shoreface can also negatively affect nearshore hard bottom through direct burial and sediment redistribution. At a beach nourishment project site in Florida, Lindeman and Snyder (1999) observed dramatic decreases in fish species and numerical abundance of individuals following the burial of nearshore hard bottom. The number of species detected 12 months prior to and 15 months after burial decreased by nearly one order of magnitude, from 54 to eight species (Lindeman and Snyder 1999). The average number of individual fish recorded per transect also declined from 38 pre-burial to less than one post-burial (Lindeman and Snyder 1999). At several other beach nourishment projects in Florida, added sand was documented to redistribute offshore from the beach via cross-shelf currents, covering hard bottom habitat (Marsh and Turbeville 1981; Continental Shelf Associates 2002). Studies off Wrightsville Beach and Atlantic Beach, North Carolina documented movement of sands from the nourished beaches across the shoreface (Thieler et al. 1995; Thieler et al. 1998; Reed and Wells 2000), with hard bottom becoming buried by nourishment sands in the vicinity of Wrightsville Beach (R. Thieler/USGS, pers. com., 2001). Commercial fishermen in the Wrightsville Beach area, where nourishment has been conducted regularly since the 1960s, reported that nearshore hard bottoms that were once productive fishing areas are now covered in sand and are no longer fished due to poor yield (W. Cleary/UNC-W, pers. com., 2001). Ojeda et al. (2001) found little to moderate change in percent of seafloor with exposed hard bottom or rocky substrate within two years of a nourishment project off Myrtle Beach, South Carolina. Available data from the study indicated that the nearshore loss of hard bottom seaward of the project was due to localized introduction of new sand from beach fill, but was only somewhat greater than the natural variability occurring from shifting sands (Ojeda et al. 2001).

In North Carolina, the frequency and magnitude of beach nourishment activities (including dredged material from navigational channels placed on beaches) have increased over time.[53] The cumulative length of shoreline affected by ocean beach management projects is approximately 176 miles or about 55% of the North Carolina ocean coastline (ASMFC 2002a). The majority of nourishment projects (existing, authorized, and requested) are located south of Cape Lookout where hard bottom is most abundant, especially in the nearshore. *The transport of sand from nourished beaches over time should be monitored. Future research should attempt to determine if the probability or extent of burial are affected by sand volume, type, or grain size, by the time-of-year of project initiation, and/or by the distance between nourished beach and hard bottom.*

[53] Refer to the Soft Bottom chapter threats section for status, trends, and location of beach nourishment activity.

7.4.1.3. Energy infrastructure

A newly developing threat to hard bottom comes from the opportunity for oil and natural gas exploration on the outer continental shelf (OCS). During 2008, a federal moratorium on offshore drilling for oil and natural gas, which covered much of the OCS in the Atlantic and Pacific oceans, was lifted. This opened the majority of federal waters, including those off the coast of North Carolina, to future oil and natural gas exploration, development, and production. Such activities can have detrimental effects to hard bottom habitat. The direct impact of oil and natural gas development on hard bottom is physical in nature, in which organisms and hard substrate are damaged or dislodged from the platform anchor site, or smothered by sediments from the disposal of drilling muds (Lissner et al. 1991; Boehm et al. 2001). The disturbance from drilling reduces, at least temporarily, natural habitat complexity, and species richness and diversity. Site-specific recovery from such disturbances may take years to decades and is dependent on the vertical relief of the hard substrate and growth characteristics of the local organisms (Lissner et al. 1991). In addition to physical impacts, disposal of drilling muds, as well as produced formation water (oily water produced after separation from oil) can cause acute or chronic toxic effects to hard bottom organisms and reef fishes (Lissner et al. 1991; Hyland et al. 1994; Holdway 2002). Exposure to toxins associated with drilling activities have been found to cause adult mortality, tissue loss, and reduced relative viability of corals, and altered liver enzyme activities in reef fish living in close proximity to oil producing platforms (Holdway 2002). *Drilling on or in the vicinity of hard bottom resources on the OCS of North Carolina should be prohibited to minimize potential impacts to ecologically productive hard bottoms and there dependent biological communities*.

The last active offshore oil and natural gas leases in the federal waters off North Carolina were relinquished in November 2000 (http://www.gomr.mms.gov/homepg/offshore/atlocs/atocsfax.html, 2008). Several companies, including Amerada Hess, Chevron, Conoco, Marathon, Mobil, Occidental Petroleum Corporation (OXY), and Shell held interests, singly or jointly, in the Manteo Exploration Unit, a submerged area comprised of 21 lease blocks located approximately 44.8 statute miles northeast of Cape Hatteras (Vigil 1998). The current federal Minerals Management Service (MMS) 5-year Lease Program, which consists of the schedule for lease sales, as well as the size and location of blocks offered, took effect July 2007 and runs through June 2012. The Program includes a special interest sale scheduled for 2011 of about 2.9 million acres in the Mid-Atlantic Planning Area, 50 miles offshore the coast of Virginia and approximately 25 miles north of the North Carolina-Virginia border. Under the authority of the Outer Continental Shelf Lands Act, CAMA consistency process, and CRC administrative rule on coastal energy policies (15A NCAC 7M .0400), North Carolina submitted comments on the proposed Program in which concerns were raised regarding the effects on fisheries, fisheries habitat, tourism, and continued dependency on fossil fuels, and that by virtue of proximity, North Carolina would be subject to direct adverse impacts of such a sale, with no commensurate benefit. The MMS, at the request of the federal government, developed a new draft 5-year Lease Program in January 2009 that could replace or supersede the remaining portion of the current Program if implemented. *North Carolina should continue to be engaged in the MMS 5-year Lease Program and any proposed OCS energy development project.*

In addition to oil and natural gas exploration, there is an increasing interest in the development of offshore wind farms off the coast of Cape Hatteras and Cape Lookout, as well as in Albemarle and Pamlico sounds, as these areas have some of the most abundant wind resources in the state (http://www.ncsc.ncsu.edu/, 2009). Although offshore wind farms are generally considered a source of "green" energy, the construction of foundations for turbine towers can impact immediate and adjacent marine habitats (Byrne Ó Cléirigh et al. 2000). Changes to the natural seabed structure can alter the composition and biomass of macroalgae, sessile invertebrates, and fish (Byrne Ó Cléirigh et al. 2000; Wilhelmsson and Malm 2008). A study in the Baltic Sea found that the presence of turbine foundations affected the assemblage of invertebrates and algae colonizing adjacent natural hard bottom areas, resulting in an increased abundance of blue mussels and decreased abundance of algae (Wilhelmsson and

Malm 2008). These structures may also pose a conflict for commercial fishing activities, as well as beach nourishment borrow areas. CRC is in the process of modifying their rules to include wind turbines as water-dependent structures [15A NCAC 07H. 0208]. *Should the State consider siting a wind facility in state or federal waters, proper placement of turbine foundations is necessary to minimize potential impacts to hard bottom habitat and minimize conflicts with existing activities*.

In 2009 the North Carolina General Assembly formed a Legislative Research commission Advisory Subcommittee on Offshore Energy Exploration. The Advisory Subcommittee is studying:

1) The implications of leasing federal waters off North Carolina's coast in the Atlantic Outer Continental Shelf to energy companies for oil and natural gas exploration.
2) Relevant federal law and the legal authority of the State of North Carolina with regard to offshore drilling.
3) The potential impacts on the nation's energy supply, including documenting the best unbiased estimates available for what oil and natural gas might exist.
4) The potential financial impact of proposed exploration on the State of North Carolina, including effects on the economy, tourism, the commercial fishing industry, the impacts of a more industrial coastline, and ensuring a share of State profits.
5) The environmental impacts of exploration on North Carolina's coastline, including possibilities of spills, effects on water quality, air quality, marine life, and contributions to global climate change.
6) The environmental impacts of the infrastructure that would be associated with exploration and drilling for oil and natural gas.

The committee is working on developing final recommendations to the state, which will likely include the need to work with MMS to achieve the best overall outcome for the state of North Carolina and the need for additional information.

Associated with offshore energy development, as well as the expansion of high-speed transoceanic telecommunications, comes the need for installation or maintenance of cables and pipelines placed across oceans and waterways. Cables and pipelines are generally laid directly on the seafloor, and routed into a dredged or bored trench, conduit, or access hole where they come onshore (landing site). Once the access hole or conduit is in place and buried, maintenance or placement of new cables or pipelines involves dredging these holes back open. Current CRC rules prohibit structures, such as cables and pipelines, from coming onshore on oceanfront beaches [15A NCAC 07H. 0300].

Environmental concerns to hard bottom associated with laying cables or pipelines identified by Nero (2001) and Blue Atlantic Transmission System (2003) include:

- Cable "sweeping" and crushing of hard bottom communities during installation or repairs.
- Escape of pressurized fluid mud used to lubricate the drill hole for directional drilling (drilling a tunnel under the seafloor) may cause turbidity plumes and subsequent burial or smothering of sensitive hard bottom resources.
- Restriction or alteration of macrofaunal movement due to physical barriers, noise, vibrations, or magnetic fields.

North Carolina should coordinate with federal agencies, other states, and private companies with offshore infrastructure interests to manage the placement of cables and pipelines in North Carolina offshore waters in a manner that minimizes impact to hard bottom and minimizes conflicts with recreational and commercial fishing.

7.4.2. Boating activity

7.4.2.1. Anchoring and diving

Boating related activities, such as anchoring or diving on hard bottom, can also damage this habitat. Anchors and chains from recreational or commercial boats can damage corals and other benthic organisms, creating lesions and leading to infection (SAFMC 1998b). Divers can kick or overturn corals and live rock, which results in habitat damage. Recreational spearfishing with power heads also can damage corals where diving activity is concentrated (SAFMC 1998b). In North Carolina, however, damage from recreational diving is probably minimal due to the relatively low numbers of divers in the nearshore areas.

Diver harvest of live rock for the aquarium trade was found to cause extensive destruction and loss of hard bottom, with additional damage occurring when chemicals were used (SAFMC 1998b). Several state and federal regulations provide protection for hard bottom habitat from such destructive harvest techniques. Since 1995, North Carolina has prohibited directed harvest of all coral or any live rock in state waters [MFC rule 15A NCAC 3I .0116]. In addition, any live rock or coral incidentally harvested with any gear must be returned immediately to the waters where it was taken. Similar NMFS regulations exist for federal waters, which prohibit the collection of live rock, stony corals and black corals, fire coral and hydrocorals, and two species of seafans (SAFMC 1982; SAFMC 1994). However, NMFS may issue permits to take prohibited coral for scientific, research, and educational purposes, and for use of allowable chemicals and harvest of octocorals.

7.4.3. Fishing gear impacts

7.4.3.1. Mobile bottom disturbing gear

Bottom trawls, dredges, and other mobile gears can cause rapid and extensive physical damage to living and non-living components of hard bottom (SAFMC 1998b; Auster and Langton 1999; Freese 2001; NRC 2002; Reed et al. 2007; Wells et al. 2008). Dragged fishing gear directly removes or damages attached benthic organisms, such as sponges, corals, and macroalgae, often leading to mortality. These gear types also displace outcrop structures from the seafloor. Damage from mobile gear is especially extensive where the bottom is uneven and there is a concentration of epiflora and/or epifauna. The removal of structure and attached biota decreases species richness and diversity, and reduces habitat complexity (Watling and Norse 1998; Auster and Langton 1999; NRC 2002). In addition, indirect damages to hard bottom habitat occur through altered trophic linkages and nutrient cycles, as well as an increased vulnerability of injured organisms to subsequent diseases and predation (Auster and Langton 1999; NRC 2002). Trawling, in particular, also results in an immediate reduction of mobile benthic invertebrates (e.g., crabs and polychaete worms) on and adjacent to hard bottom, reducing food resources available to other reef organisms.[54]

Although most trawls and dredges are generally not towed over hard bottom, one type of trawl was designed specifically for use in this habitat. Roller-rigged trawls are equipped with large rubber discs to roll over hard bottom without becoming entangled. Several studies have noted significant damage to sponges, hard corals, and soft corals at hard bottom locations where roller-rigged trawls had been used (Tilmant 1979; Van Dolah et al. 1987). While many sponges and corals can recover, at least partially, within one year following trawling, it may require several years for some species to completely regenerate to their initial, pre-disturbance sizes due to slow growth rates (Van Dolah et al. 1987). To address the potential for extensive hard bottom degradation, roller-rigged trawls have been prohibited by federal regulations for the harvest of snapper-grouper south of Cape Hatteras since 1989 (SAFMC 1998b).

[54] Refer to Appendix O for a list of the fishing gears used in North Carolina waters and their probable habitat impacts.

Bottom trawling is conducted extensively in North Carolina state ocean waters, in particular for shrimp and, to a lesser extent, for flounder. Shrimp trawl effort in the ocean is most concentrated in the southern region of North Carolina (Onslow, Pender, New Hanover, and Brunswick counties), where hard bottom is most abundant (Fig. 7.1a). Flounder trawling in the ocean occurs in the northern (Currituck, Dare, and Hyde counties) and central (Carteret County) regions, but is most concentrated north of Cape Hatteras (Fig. 7.1b). The number of ocean flounder trawl trips during 1994–2007 has ranged from 11 to 202 trips/year, while the number of ocean shrimp trawl trips has ranged from approximately 1,500 to almost 4,000 trips/year (DMF, unpub. data).[55] Several state rules provide protection for nearshore hard bottom habitat from the potential impacts of ocean trawling. Current MFC rules prohibit trawling within one-half mile of the ocean shoreline from the Virginia border south to Oregon Inlet [15A NCAC 3J.0202], as well as within the military danger zone and restricted area, and sea turtle sanctuary, both located seaward of Onslow Beach [15A NCAC 3I .0110, 15A NCAC 3I .0107]. However, trawling is not restricted at most locations in the nearshore ocean waters of Onslow and Long bays, where the majority of nearshore hard bottom is concentrated. The extent that trawls contact and damage hard bottom in North Carolina is not known. Because the irregular hard surfaces of hard bottom can tear nets and damage expensive gear, fishermen generally try to avoid those areas. *While there is potential for damage, research is needed to determine if and to what extent hard bottom is being damaged by trawling activity in North Carolina, particularly shrimp trawls in the southern portion of the coast. The specific locations of trawl trips should be mapped. In addition, nearshore ocean hard bottoms should be considered for nomination as Strategic Habitat Areas due to their importance as secondary nursery habitats and corridors for gag, black sea bass, and other fisheries resources.*

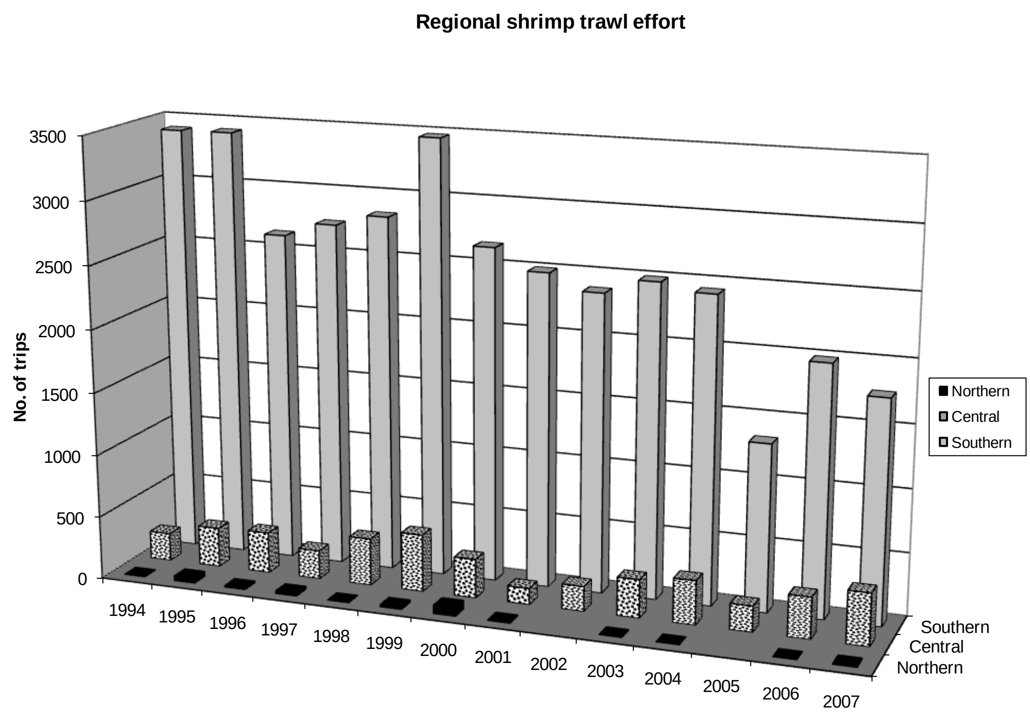


Figure 7.1a. Shrimp trawl fishing effort (number of trips) in North Carolina's nearshore ocean waters (0-3 miles from shore), 1994–2007, by coastal region. (Source: DMF, unpub. data)

[55] Number of trips calculated as those landed in Currituck, Dare, Hyde, Carteret, Onslow, Pender, New Hanover, and Brunswick counties only. Trips in the ocean (0-3 miles) landed in other counties are not included in the present analysis.

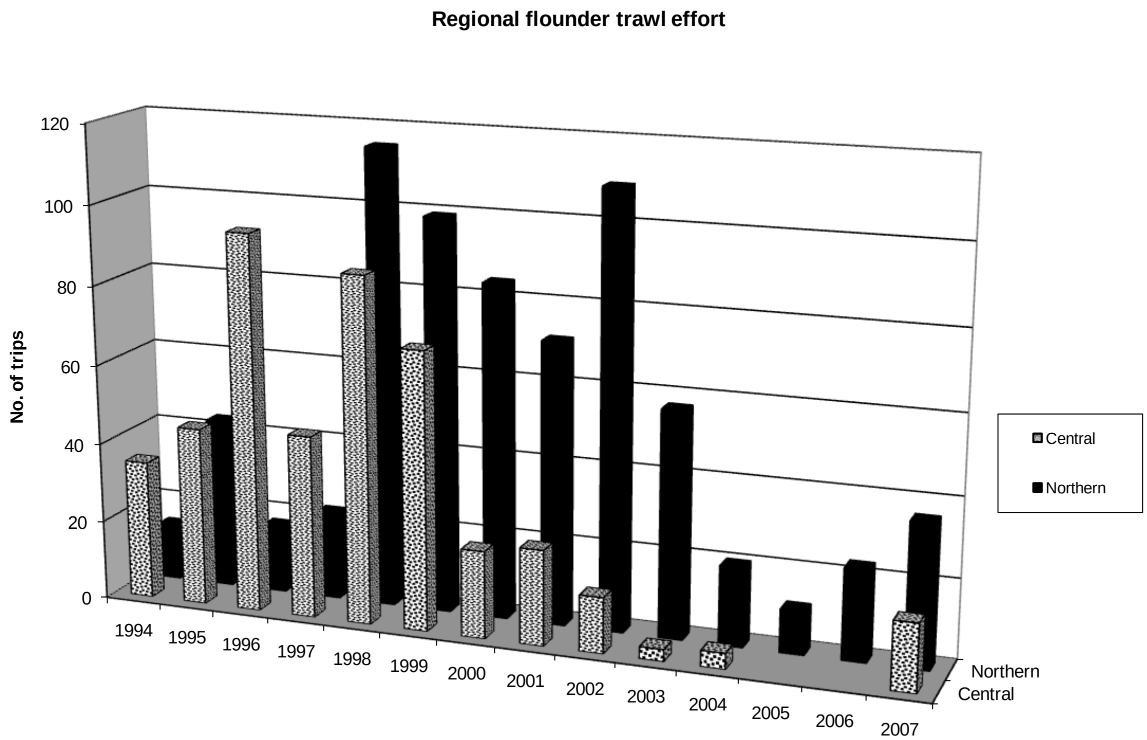


Figure 7.1b. Flounder trawl fishing effort (number of trips) in North Carolina's nearshore ocean waters (0-3 miles from shore), 1994–2007, by coastal region. (Source: DMF, unpub. data)

7.4.3.2. Passive capture techniques

Bottom longlines and fish traps can also physically damage the structure of hard bottom, as well as injure or kill the associated sessile biota (SAFMC 1998b). However, these passive fishing gears are of minimal concern because they are not used extensively or at all in North Carolina state waters. Use of bottom longlines was prohibited by federal regulations in depths of less than 50 fathoms (300 ft) throughout the South Atlantic area as part of Amendment 4 of the Snapper Grouper Fishery Management Plan in 1991 to reduce fishing mortality and habitat damage. Fish traps were also prohibited in all federal waters through Amendment 4, with the exception of smaller black sea bass pots, which are allowed if equipped with escape vents and biodegradable panels to release undersize fish and eliminate waste from lost pots ("ghost fishing"). In North Carolina state territorial waters, fish traps cannot be used to target snapper-grouper [15A NCAC 3M .0506(s)(1)], but are allowed for black sea bass. Nevertheless, black sea bass pots are more commonly used in federal waters and may have a greater impact to hard bottom in those areas.

7.4.3.3. Rod and reel

Although direct impacts of rod and reel gear on hard bottom habitat are considered low, recreational fishing was identified at a NMFS conference as a major concern because of the large number of participants in the fishery (Hamilton 2000). Reef fishes are targeted by many recreational fishermen and their habitat may receive concentrated use, leading to unknown cumulative impacts. Lost fishing gear (e.g., line, wire leaders, hooks, sinkers) and discarded rubbish (especially plastics) can entangle or be ingested by marine life (Sheavly 2007), as well as cause tissue abrasions and partial colony mortality of sessile invertebrates (Chiappone et al. 2005). Roughly 18% of marine debris identified in U.S. waters is comprised of ocean-based items, including clumps of fishing line, and floats and buoys (Sheavly 2007). Bauer et al. (2008) found that at Gray's Reef National Marine Sanctuary, the presence and abundance of marine debris, particularly hook and line fishing gear, was directly related to observed recreational boating and fishing activity. In the Florida Keys National Marine Sanctuary, hook and line fishing gear represented 87% of the marine debris removed from about 6.2 acres of hard bottom habitat, although less than 0.2% of the available milleporid hydrocorals, stony corals, and gorgonians were adversely affected (Chiappone et al. 2004; Chiappone et al. 2005). In addition to the potential physical effects of discarded fishing gear, chemical contamination from lost lead sinkers is also a concern. *Monitoring of hard bottom is needed to assess the level of impact from rod and reel fishing. Educating anglers on the impacts of lost fishing gear and discarded litter to hard bottom and associated species would be helpful in reducing those impacts.*

7.4.4. Water quality degradation

Since snapper-grouper species are most sensitive to toxins and other pollutants during early life stages (SAFMC 1998b), it is essential to maintain good water quality at critical nursery habitats, including nearshore hard bottoms. The effect of degraded water quality on a given species depends primarily on its life history (Schaaf et al. 1987; Schaaf et al. 1993), as well as feeding behavior and diet at all life stages. With the exception of oil and gas development,[56] the primary threats to water quality at hard bottom sites are ocean dumping and coastal pollution from discharge of sewage, stormwater runoff, herbicides, and pesticides (SAFMC 1998b).

Offshore dumping of dredged material occurs at designated sites in federal waters and must be conducted pursuant to the Water Resources Development Act Amendments of 1992 to the Marine Protection, Research, and Sanctuaries Act of 1972 for the management and monitoring of ocean disposal activities. This law requires that ocean dredged material disposal will not unreasonably degrade the marine environment. In North Carolina, three ODMDS exist: one seaward of the Port of Morehead City and two seaward of the Port of Wilmington (COE and EPA 1996; COE and EPA 1997; COE and EPA 2002). While no hard bottoms have been identified in the vicinity of the Morehead City ODMDS (COE and EPA 1997), extensive hard bottom resources have been found within one nautical mile of both Wilmington ODMDS (COE and EPA 1996; COE and EPA 2002), suggesting the potential for water quality impacts on natural hard bottoms neighboring these sites. However, prior to disposal, any fine-grained sediments that are dredged are chemically and biologically tested to ensure the environmental integrity of an ODMDS. *The COE should continue environmental monitoring during use of the two Wilmington ODMDS to determine their effect on adjacent hard bottom habitat and report monitoring results.*

Point discharges of wastewater and sewage can also negatively impact the health and stability of hard bottom. Several studies of hard bottom communities in the Mediterranean found that species richness, abundance, and diversity of corals and echinoderms declined with increasing proximity to sources of pollution (Hong 1983; Hermelin et al. 1981). Terlizzi et al. (2002) reported that a sewage outfall on the southern Apulian coast of Italy negatively influenced the natural distribution pattern of filamentous green algae. At the same location, reef fish assemblages differed between the sewage-impacted site and adjacent controls, with more planktivorous and detritivorous fishes at the sewage outfall (Guidetti et al. 2003). Current North Carolina state (EMC) policies prevent wastewater discharge into the Atlantic Ocean, with one exception: the discharge off Oak Island of heated flow-through, non-contact cooling water from the Brunswick Steam Electric Plant. *Because nearshore hard bottoms are so vulnerable to damage from changes in water quality, this "non-discharge" policy should be maintained.*

Hard bottom can be degraded not only by point discharges, but also by outflowing pollutants from estuarine and river waters. The effect of these non-point outflows on hard bottom off the coast of North Carolina is largely unknown since little monitoring has been conducted. In 1999, UNC-W began the

[56] Refer to the Energy Development section for more information on the effects of oil and gas development.

Coastal Ocean Monitoring Program (COMP), currently known as the Coastal Ocean Research and Monitoring Program (CORMP), which focused on ocean processes in the coastal ocean off southeastern North Carolina. Among other things, this project investigated the chemical and biological effects of the Cape Fear River's plume on the nearshore ocean, as well as responses of the plume to major storm events. Results following Hurricane Floyd found that approximately 200 mi^2 of coastal ocean waters were affected by elevated turbidity and nutrient levels for approximately one month (Cahoon et al. 2001). In comparing water quality of nearshore ocean waters in Long Bay, which is heavily influenced by the Cape Fear River's plume, to Onslow Bay, where riverine influence is minimal, Dafner et al. (2007) found dissolved organic nitrogen and phosphorous concentrations 2–3 times higher and chlorophyll *a* concentrations 5–10 times higher in Long Bay than in Onslow Bay. Nearshore hard bottom is highly concentrated in Long Bay (Map 7.1c), suggesting that declines in estuarine water quality are most likely to impact hard bottom in that area. *Monitoring of hard bottom should be initiated and coordinated with UNC-W or other ocean water quality monitoring programs to determine the effects of estuarine water quality, particularly nutrient and sediment loading, on hard bottom*.

Hard bottom in close proximity to shore is more vulnerable to pollutants than offshore hard bottom. Stormwater runoff and discharge of nutrient-rich estuarine waters can increase nutrient levels, potentially resulting in nuisance algal blooms. Problem levels of nutrients have generally not been found in North Carolina's coastal ocean waters, although, water quality sampling in these areas is extremely limited.[57] Residues of the organochlorine pesticides DDT, PCB, dieldrin, and endrin have been found in gag, red and black grouper, and red snapper (Stout 1980), indicating that toxins from stormwater runoff are a potential threat to the hard bottom community. *Additional water and tissue sampling at hard bottom sites are needed to determine if the benthos of the hard bottom community or the surrounding waters exhibit levels that exceed designated levels of concern.*

7.4.5. Non-native, invasive, or nuisance species

A relatively new threat to hard bottom ecosystem health and biodiversity is the successful invasion of Indo-Pacific lionfish (*Pterois volitans*/*miles* complex) in the South Atlantic Bight (Whitfield et al. 2002; Meister et al. 2005; Hamner et al. 2007; Whitfield et al. 2007). Lionfish were first documented in marine waters off North Carolina in 2000; by 2001, lionfish could be found at eight hard bottom locations (Whitfield et al. 2002). Documented sightings and collections indicate that lionfish distribution may be continuous from Cape Hatteras to the North Carolina-South Carolina Border (Meister et al. 2005; Whitfield et al. 2007), with abundances comparable to many native grouper species (Whitfield et al. 2007). Such a successful invasion is likely to impact natural hard bottom communities through direct predation, competition, and overcrowding (Whitfield et al. 2007). On natural and artificial reef patches in the Bahamas, Albins and Hixon (2008) found predation by a single lionfish at each patch reef reduced net recruitment of native fishes by a mean of 28.1 fish per reef over five weeks, representing an average reduction in net recruitment of 79%. This finding suggests that an increasing lionfish population on North Carolina hard bottoms has the potential to decrease the abundance of juvenile reef dwelling species, as well as increase the competition with native piscivores for this important food resource. Although there are few documented natural predators of the lionfish, several individuals have been found in the stomachs of native groupers in the Bahamas (Maljkovic and Van Leeuwen 2008). However, such large piscivores are systematically targeted by commercial and recreational fisheries which remove a significant portion of the population, and thus are not likely to substantially reduce the effects of lionfish on Atlantic hard bottom communities. Staff at the NOAA Center for Coastal Fisheries and Habitat Research have been conducting studies on lionfish to better understand lionfish distribution, density, life history, temperature tolerances, and genetics. NOAA also encourages reporting of all lionfish captured by rod and reel, as well as sightings by SCUBA divers. The information gained will be used to

[57] Refer to the Water Column (2.0) chapter for more information on water quality.

determine, and possibly mitigate, potential ecosystem and fisheries impacts due to the presence of lionfish. *Further information on Indo-Pacific lionfish biology and competitive/predatory interactions with native fish species is needed. Although complete eradication of lionfish in the marine waters off the North Carolina coast is unlikely, focused lionfish control efforts in strategic locations are needed to reduce the likelihood of potentially detrimental ecological effects.*

7.4.6. Climate change

Rapid increases in atmospheric carbon dioxide (CO_2) concentrations over the past century have led to global climatic changes (Harley et al. 2006; IPCC 2007). Because of this atmospheric increase, global air and ocean temperatures have risen by 0.4–0.8°C (IPCC 2007). This warming trend is expected to accelerate in the current century (IPCC 2007), with implications for hard bottom health and community structure. A study of hard bottom ledges off the North Carolina coast over a 15 year period reported an increased prevalence of tropical reef fishes and a decreased abundance of temperate species (Parker and Dixon 1998). The authors speculated that the observed shift in reef fish community structure was most likely in association with warmer winter bottom water temperatures allowing for range extensions of tropical species. An additional study on North Carolina outer shelf hard bottoms documented four tropical reef fishes new to continental United States waters and range extensions for ten tropical species (Quattrini et al. 2004), potentially indicating that species composition of reef fishes has become more tropical in nature. Such changes in reef fish community structure can have profound impacts on hard bottom by altering the trophic structure, thus changing habitat quality and productivity.

Perhaps the most insidious but poorly understood implication of atmospheric CO_2 loading on hard bottom habitat is that of ocean acidification (Harley et al. 2006; Kleypas et al. 2006; IPCC 2007). Ocean acidification is caused by an increased amount of CO_2 dissolved in ocean waters, which lowers the pH, decreases the availability of carbonate (CO_3^{-2}) ions, and lowers the saturation state of the major carbonate minerals (Feely et al. 2004; Orr et al. 2005). This process can have severe consequences for marine calcifying organisms that inhabit hard bottom in North Carolina, such as hard corals, gorgonians, coralline algae, mollusks, sponges, echinoderms, and calcitic plankton, such as such as foraminifera and coccolithophorids (Feely et al. 2004; Orr et al. 2005; Kleypas et al. 2006; Hoegh-Guldberg et al. 2007). Decreased carbonate ion concentrations considerably reduce the calcification rates of marine invertebrates and algae that build carbonate structures, diminishing growth rates, and increasing susceptibility to predation (Feely et al. 2004; Kleypas et al. 2006; Roberts et al. 2006; Hoegh-Guldberg et al. 2007). In addition, calcifying organisms may be unable to maintain exoskeletal structures in waters that are undersaturated with respect to carbonates, ultimately resulting in dissolution of their calcium carbonate skeletons (Orr et al. 2005). Thus, facing a rapidly acidifying ocean, the density and diversity of hard corals, gorgonians, coralline algae, mollusks, sponges, and other calcifying organisms on hard bottoms are likely to decline, leading to greatly reduced habitat complexity and biodiversity loss, including losses of reef-associated fish and invertebrates (Orr et al. 2005; Hoegh-Guldberg et al. 2007). *More research is needed to examine the potential ecological effects of ocean acidification on nearshore hard bottom in North Carolina*.

7.4.7. Management needs and accomplishments

The management needs noted by italics in the 2005 CHPP were addressed to some degree during 2005-2010. Some of the needs were refined and adopted as actions in the multi-agency CHPP implementation plans (IPs). There were also hard bottom-related actions that came directly from the implementation plans, without a specific call in the 2005 CHPP. However, the majority of IP actions affect either water column (see "Water column" chapter) or multiple bottom habitats (see "Ecosystem management and strategic habitat areas" chapter) and will not be duplicated here. Only hard bottom-focused actions from the IPs are listed in the "Needs and progress" sections. Emerging management needs are included without a reference and may or may not be refined and adopted as actions in 2009-2011 CHPP implementation plans.

7.4.7.1. Research needs and progress (2005-2010)

Accomplished research needs

1. *Investigate fish use of nearshore hard bottom (Street et al. 2005).* **There is additional research available from other states. See Section 7.2. "Ecological role and functions" for more information.**

2. *Investigate spawning on, and recruitment to, nearshore hard bottom to understand the importance of this habitat and document trends in fish utilization (Street et al. 2005).* **There is additional research on offshore spawning activity. See Section 7.2.6. "Specific biological functions" for more information.**

Research needs with progress

Research needs without progress

1. *Conduct further research to determine if and to what extent artificial reefs in North Carolina simply concentrate available fish or effectively increase fish biomass (Street et al. 2005).* **No specific progress. See Section 7.2.5. "Fish utilization of man-made structures" for more information.**

2. *Conduct research to determine if and to what extent hard bottom is being damaged by trawling activity in North Carolina, particularly shrimp trawls in the southern portion of the coast. The specific locations of trawl trips should be mapped. To assess potential effects of trawling, experimental trawls of predetermined duration, magnitude, and frequency should be conducted in a previously untrawled hard bottom location (Street et al. 2005).* **No specific progress. See Section 7.4.3.1. "Mobile bottom disturbing gear" for more information.**

3. *Coordinate with UNC-W or other ocean water quality monitoring programs to determine the effects of estuarine water quality, particularly nutrient and sediment loading, on hard bottom (Street et al. 2005).* **No specific progress. See Section 7.4.4. "Water quality degradation" for more information.**

4. *Conduct additional water and tissue sampling at hard bottom sites to determine if the benthos of the hard bottom community or the surrounding waters exhibit levels that exceed designated levels of concern (Street et al. 2005).* **No specific progress. See Section 7.4.4. "Water quality degradation" for more information.**

Emerging research needs

1. *Further information on Indo-Pacific lionfish biology and competitive/predatory interactions with native fish species is needed. Although complete eradication of lionfish in the marine waters off the North Carolina coast is unlikely, focused lionfish control efforts in strategic locations are needed to reduce the likelihood of potentially detrimental ecological effects.* **See Section 7.4.5. "Non-native, invasive, or nuisance species" for more information.**

2. *More research is needed to examine the potential ecological effects of ocean acidification on nearshore hard bottom in North Carolina.* **See Section 7.4.6. "Climate change" for more information.**

7.4.7.2. Management needs and progress (2005-2010)

Accomplished management needs

Management needs with progress

1. *Monitor the transport of sand from nourished beaches over time. Future research should attempt to determine if the probability or extent of burial are affected by sand volume, type, or grain size, by the time-of-year of project initiation, or by the distance between nourished beach and hard bottom.* **See Section 7.4.1.2. "Shoreline stabilization" for context.** A DENR Beach Management Plan should be developed and implemented which includes specific guidelines to minimize impacts to hard bottom from nourishment projects (Street et al. 2005). **See Section 6.4.1.1. "Water-dependent development" in the "Soft bottom" chapter for information on North Carolina's Beach and Inlet Management Plan.**

2. *Require adequate monitoring prior to creation and during use of the Ocean Dredged Material Disposal Site (ODMDS) off Cape Fear River to determine its effect on nearshore hard bottom habitat (Street et al. 2005).* **Prior to disposal, any fine-grained sediments that are dredged are chemically and biologically tested to ensure the environmental integrity of an ODMDS.** *The USACE should continue environmental monitoring during use of the two Wilmington ODMDS to determine their effect on adjacent hard bottom habitat (Street et al. 2005).* **See Section 7.4.4. "Water quality degradation" for more information.**

3. *Designate hard bottom within State Natural Heritage Areas as Strategic Habitat Areas for consideration of additional protection under the recent federal Executive Order 13158, which calls for strengthening and expansion of Marine Protected Areas in the United States or through additional state actions specifically designed to protect those sites (Street et al. 2005).* **The SAFMC identified several Marine Protected Areas (MPAs) in offshore federal waters through Amendment 14 to the South Atlantic Snapper Grouper Fishery Management Plan. The NMFS issued a final rule to implement Amendment 14 officially creating eight Type II MPAs in which fishing for or possession of snapper-grouper species are prohibited, but other types of fishing, such as trolling, are allowed. No specific progress with regard to state action. However, the MFC has the authority to establish no-take areas over nearshore hard bottom in North Carolina state waters. See Section 7.3.4. "Designated areas" for more information.**

Management needs without progress

1. *Construct artificial refugia (no-take artificial reefs) or designate existing artificial reefs as refugia (no-take, Marine Protected Areas) to enhance fisheries productivity (Street et al. 2005).* **No specific progress. See Section 7.3.3. "Hard bottom enhancement" for more information.**

2. *Construct numerous small complex sites surrounded by open areas to mimic natural nearshore hard bottoms and maximize habitat utilization at a shallow, nearshore site near Cape Lookout (Street et al. 2005).* **No specific progress. See Section 7.3.4. "Designated areas" for more information.**

3. *Designate nearshore ocean hard bottoms as Strategic Habitat Areas due to their importance as secondary nursery habitat and corridors for gag, black sea bass, and other fisheries resources (Street et al. 2005).* **Strategic Habitat Area assessments have not progressed to regions with significant hard bottom resources. See Section 7.3.4. "Designated areas" for more information.**

4. *Monitor hard bottom to assess the level of impact from hook and line fishing. Educating anglers on the impacts of anchor damage, lost fishing gear, and discarded litter to hard bottom habitat and associated species would be helpful in reducing those impacts (Street et al. 2005).* **No specific**

progress. However, there are some monitoring results from other states on the prevalence of marine debris in marine protected areas. See Section 7.4.3.3. "Rod and reel" for more information.

5. Develop and implement a state policy to prohibit oil and gas drilling in North Carolina's coastal waters to ensure protection of hard bottom and water column habitats (Street et al. 2005). **During 2008, a federal moratorium on offshore drilling for oil and natural gas, which covered much of the OCS in the Atlantic and Pacific oceans, was lifted. This opened the majority of federal waters, including those off the coast of North Carolina, to future oil and natural gas exploration, development, and production. There are emerging management needs related to lifting moratorium.**

6. *Ensure state cooperation with ASMFC, other states, and the communications companies to manage the placement of fiber optic cables in North Carolina offshore waters in a manner that minimizes impact to hard bottom and minimizes conflicts with existing activities (Street et al. 2005).* **No specific progress. Current CRC rules prohibit structures, such as cables and pipelines, from coming onshore on oceanfront beaches. See Section 7.4.1.3. "Energy infrastructure" for more information.**

7. *Maintain the state policy on waste water disposal in nearshore ocean waters to protect hard bottom vulnerable to damage from physical and water quality changes (Street et al. 2005).* **No changes. However, there is additional research on the impact of waste water disposal on nearshore hard bottom. See Section 7.4.4. "Water quality degradation" for more information.**

8. *Consider designating nearshore hard bottoms in Strategic Habitat Areas as MPAs, either through state or federal avenues, to provide some protection from fishing gear impacts and enhance fisheries production (Street et al. 2005).* **Strategic Habitat Area assessments have not progress to regions with significant nearshore hard bottom resources. See Section 7.3.4. "Designated areas" for more information.**

Emerging management needs

1. *An extensive and regular survey of nearshore hard bottom distribution and quality is needed to better evaluate status and trends.* **See Section 7.3.1. "Status of hard bottom habitat" for context.**

2. *More data is needed for evaluating the stock status of species in the reef fish complex off North Carolina.* **See Section 7.3.2. "Status of associated fishery stocks" for context.**

3. *Using the recommendations from the Ocean Policy Steering Committee, the CRC should modify existing rules pertaining to mining of submerged lands to require a 500 m dredging buffer around any exposed hard bottom, thus minimizing potential impacts to fish habitat functions. Furthermore, these buffers should be complied with.* **See Section 7.4.1.2. "Shoreline stabilization" for context.**

4. *Drilling on or in the vicinity of hard bottom resources on the Outer Continental Shelf (OCS) of North Carolina should be prohibited to minimize potential impacts to ecologically productive hard bottoms.* **See Section 7.4.1.3. "Energy infrastructure" for context.**

5. *North Carolina should continue to be engaged in the Minerals Management Service 5-year Lease Program and any proposed OCS energy development project.* **See Section 7.4.1.3. "Energy infrastructure" for context.**

6. *Should the State consider siting a wind facility in state or federal waters, proper placement of turbine foundations is necessary to minimize potential impacts to hard bottom habitat and minimize conflicts with existing activities.* **See Section 7.4.1.3. "Energy infrastructure" for more information.**

7.5. Hard bottom summary

Hard bottom is valuable to fish because it provides oases of structural complexity for foraging and refuge in marine waters. The presence of ocean hard bottom off North Carolina, along with appropriate water temperatures, allows for the existence of a temperate-to-subtropical reef fish community and a snapper-grouper fishery. Many fishery and non-fishery species spawn on nearshore hard bottoms, including black sea bass, Atlantic spadefish, sheepshead, tomtate, white grunt, pinfish, pigfish, damselfish, blennies, sand perch, and inshore lizardfish. Nearshore hard bottoms also serve as nursery areas for these species and provide important secondary nursery habitat for estuary-dependent fish, such as gag and black sea bass, as they move between the estuary and offshore reef areas. Because of their importance as spawning, nursery, and foraging habitat, all of the nearshore hard bottoms off North Carolina have been federally designated as Habitat Areas of Particular Concern for the snapper-grouper complex.

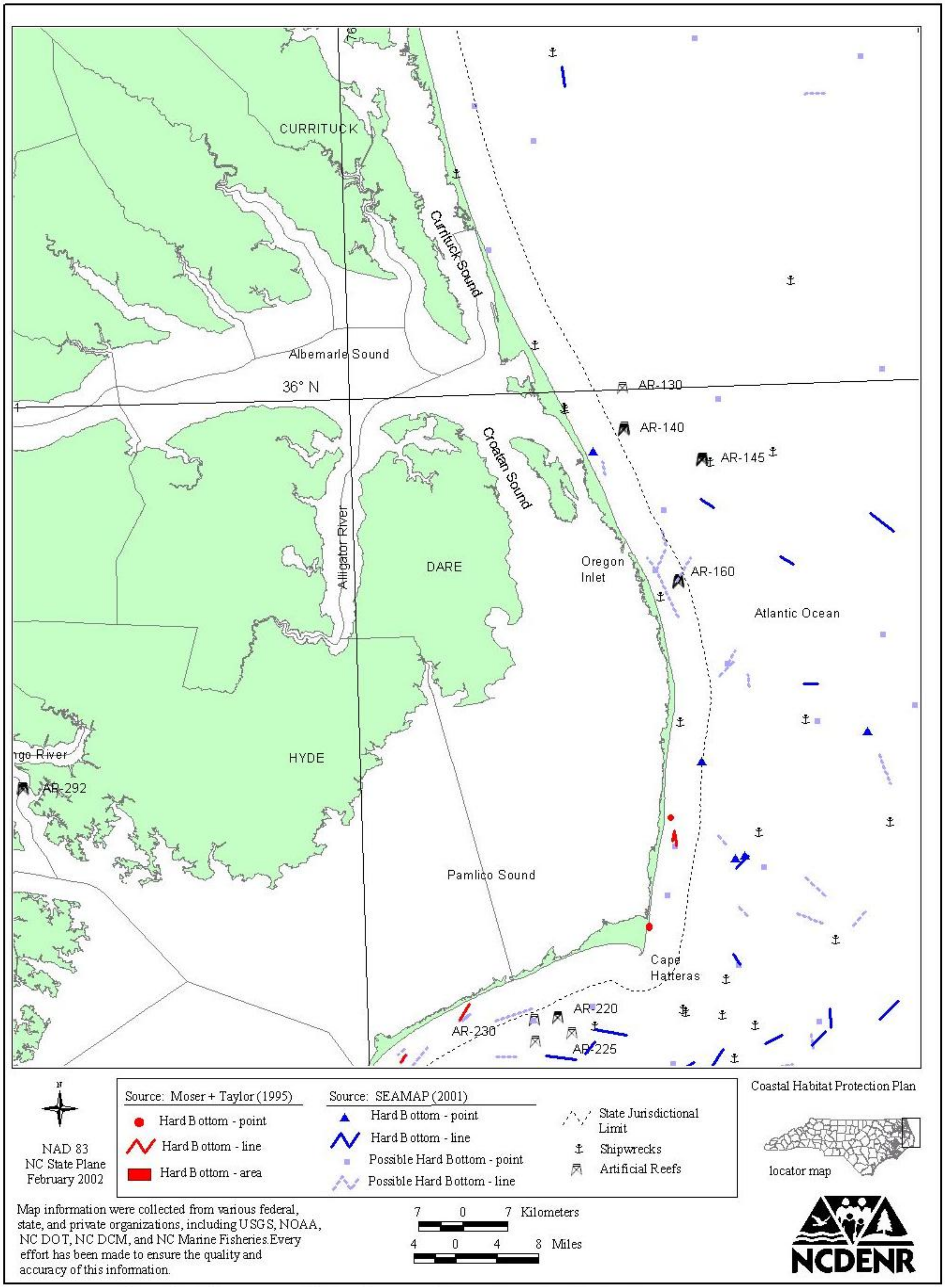
While the distribution of hard bottom off the North Carolina coast was mapped in the 1990s, little is known about the biological condition of specific hard bottom sites or how hard bottom distribution or quality has changed over time. However, increases in beach nourishment activities, which require an environmental assessment, have resulted in new information on localized hard bottom distribution and condition. Although not natural, wrecks and state-maintained artificial reefs add to the total amount of hard structure available to marine organisms and may reduce fishing pressure on natural reefs.

Because of the lack of baseline information, the primary management need for this habitat is continued research and monitoring specific to nearshore hard bottom to determine its functional importance. In addition, extensive and regular surveys of nearshore hard bottom distribution and quality are needed to determine status and trends. It is also essential to provide continual and expanding protection of existing hard bottom habitats to protect these areas from further degradation or destruction.

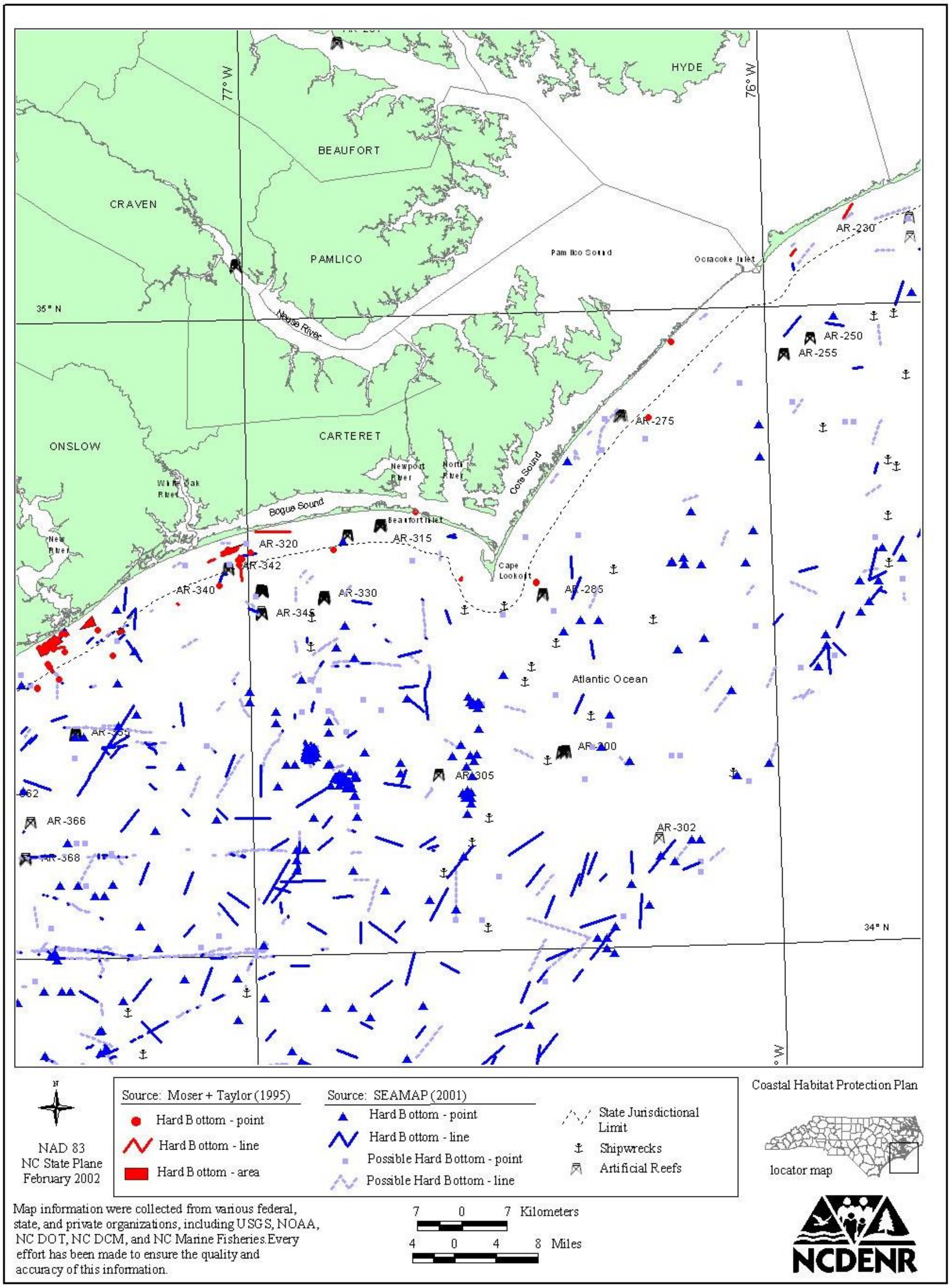
Several threats continue to pose an issue for nearshore hard bottom in North Carolina, including channel dredging, beach nourishment, bottom-disturbing fishing gear, and water quality degradation. Channel dredging can directly remove hard bottom habitat or increase turbidity to problematic levels. Sand transported from nourished beaches can cover up hard bottom structure. Bottom-disturbing fishing gear, such as bottom trawls and dredges, can uproot coral and damage the structure of hard bottom. Excess nutrients, sediments, or toxins can impact growth or survival of the invertebrates living on hard bottom structure. Water quality degradation to hard bottom originates from nonpoint sources, such as boating activity and estuarine or riverine discharges. The quality of waters discharging into marine areas may have a large overall effect on hard bottom, and can be addressed through the management needs discussed in the other estuarine habitat sections.

In addition to the above, several new and recently recognized threats jeopardize the health of hard bottom off North Carolina and have emerging management and research recommendations associated with them. These include offshore energy development, invasive species, and climate change. Offshore drilling for oil and natural gas can damage or dislodge corals, sponges, and algae at the platform anchor site, while disposal of drilling muds, as well as produced formation water (oily water produced after separation from oil), can cause acute or chronic toxic effects to hard bottom organisms and reef fishes. The invasion of the Indo-Pacific lionfish in marine waters off North Carolina will likely impact natural hard bottom communities through direct predation, competition, and overcrowding. Perhaps the largest threat to hard bottom health and stability comes from climate change. As global temperatures rise, tropical organisms may invade North Carolina hard bottoms with greater frequency, altering the natural trophic structure. Increasing atmospheric CO_2 concentrations decrease carbonate ion concentrations considerably, thus reducing the calcification rates of hard bottom invertebrates and algae that build carbonate structures and increasing their susceptibility to predation.

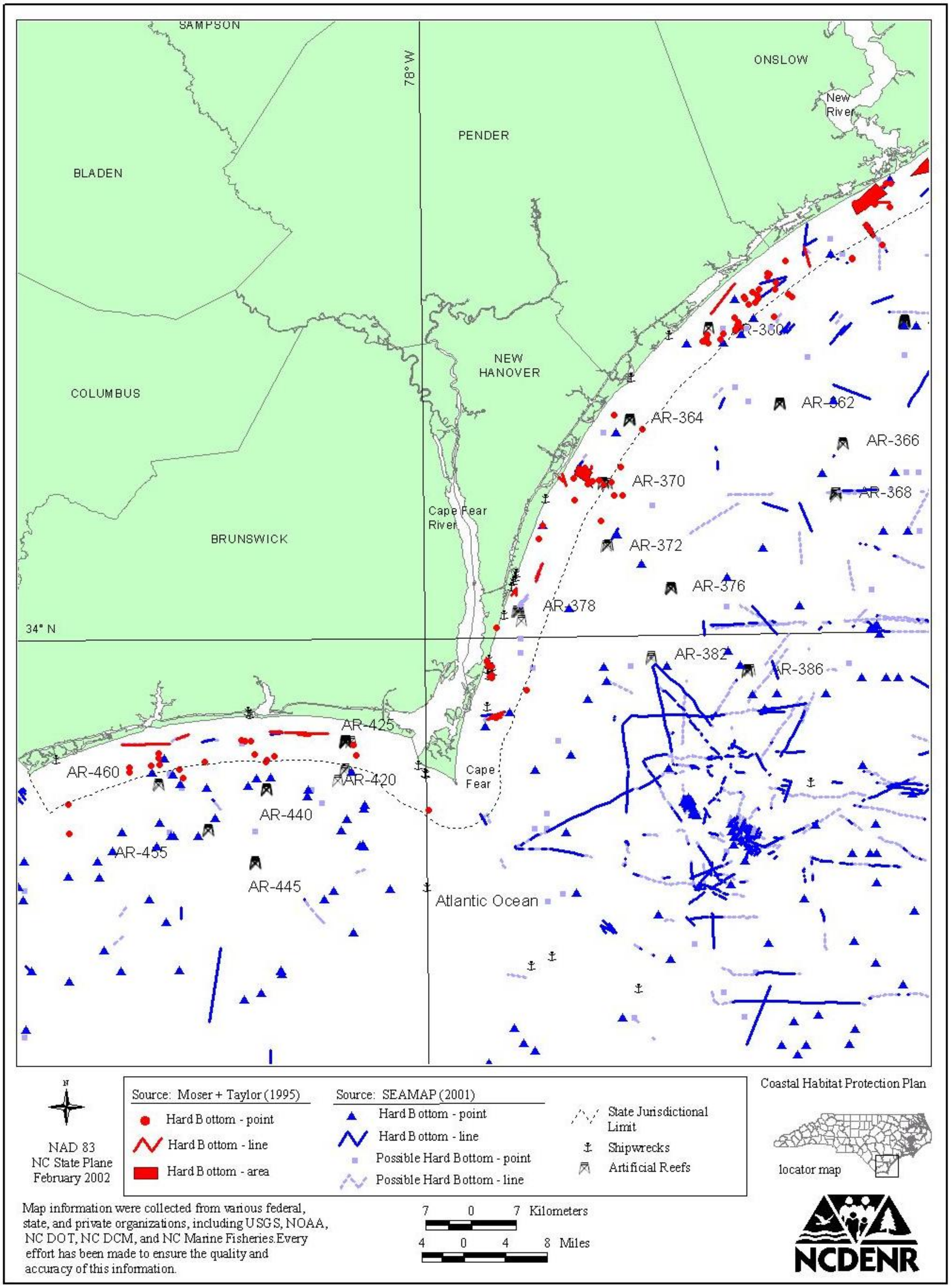
As a result of the 2005 CHPP, three of the 17 research and management needs have had some progress in being addressed. The three needs that have had some progress are all management recommendations. Two needs from the 2005 CHPP have been addressed or discontinued. Since the 2005 CHPP, there have been 10 emerging research and management recommendations added that include understanding climate change, invasive species, status of hard bottom-enhanced fishery species, and energy infrastructure. Of the three needs with progress, two are related to dredging and nourishment, while the third relates to designating strategic habitat areas.



Map 7.1a. Location of hard bottom, possible hard bottom, shipwrecks, and artificial reefs in state and federal waters off North Carolina - northern coast.



Map 7.1b. Location of hard bottom, possible hard bottom, shipwrecks, and artificial reefs in state and federal waters off North Carolina - central coast.



Map 7.1c. Location of hard bottom, possible hard bottom, shipwrecks, and artificial reefs in state and federal waters off North Carolina - southern coast.