STATE OF DEEP CORAL ECOSYSTEMS IN THE U.S. SOUTHEAST REGION: CAPE HATTERAS TO SOUTHEASTERN FLORIDA

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I. INTRODUCTION

Unique and productive deep coral habitats are found off the southeastern United States. This region may have the best developed, most extensive (Hain and Corcoran 2004) deep coral areas in U.S. waters. These deep reef systems have been largely ignored until recently, and this is partly due to their rugged bottom topography and the fact that they are usually overlain by extreme currents (i.e., Gulf Stream). Deep coral ecosystems face increasing threats world wide (Morgan et al. 2006; Roberts et al. 2006). Fisheries are expanding rapidly into deeper regions (Koslow et al. 2000; Roberts 2002), and hydrocarbon exploration and development are now also exploiting these depths. Two general deep coral habitats are reviewed for the southeastern U.S.: one is located along the shelf edge off east-central Florida, formed by the stony coral *Oculina varicosa*, and the second includes deeper water slope habitats dominated by the hard coral *Lophelia pertusa* (plus other corals and sponges) occurring off North Carolina and on the Blake Plateau off South Carolina through the Straits of Florida.

Deep coral habitats have been poorly studied, particularly in the western Atlantic. With the exception of the *Oculina* banks, references on deep corals off the southeastern U.S. are largely geological with a few biotic observations, mostly on invertebrates (Reed 2002a, 2002b; references in Sedberry 2001; Reed et al. 2006). Studies elsewhere revealed that deep reefs harbor extensive, species-rich invertebrate populations (Jensen and Frederiksen 1992; Rogers 1999; Buhl-Mortensen and Mortensen 2004). Fish studies related to the deep coral banks are rare. Our investigations of deep coral systems off the southeastern U.S. have revealed that many species of fishes (Ross and Quattrini 2007) and invertebrates are closely associated with this unique deep-reef habitat. Yet, it is unclear whether the deep coral habitat is essential to selected fishes or invertebrates or whether they occupy it opportunistically (see conflicting views in Auster 2005; Costello et al. 2005; Ross and Quattrini 2007).

We review the deep coral ecosystems off the southeastern U.S. Deep coral research to date, coral distributions, associated faunal assemblages, threats to the corals, and management strategies in the U.S. Exclusive Economic Zone (EEZ) are briefly summarized. This chapter covers the region from Cape Hatteras, NC, to Key Biscayne, FL, and a depth range of 60 to about 5000 m (deeper depths vary with EEZ boundary). We emphasize corals inhabiting waters deeper than 200 m, which is the bathymetric range where most of the deep corals in this region occur; the Florida *Oculina* reefs (60-100 m) are an exception.

History of Deep Coral Research off the Southeastern U.S.

Oculina Banks (<150 m)

Large reefs formed by *Oculina varicosa* are restricted in distribution to the shelf edge off east-central Florida. Although *O. varicosa* forms substantial structures, the reefs were heavily fished, and are concentrated in shallower waters (60-120 m) than other deep corals (see below), these extensive reefs were not described until the 1960s (see reviews in Reed 2002a,

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2002b; Reed et al. 2005). The first publication mentioning these corals along the outer shelf off Florida reported results from seismic transects, dredging, and drop cameras (Macintyre and Milliman 1970). However, commercial fishermen and Florida scientists apparently knew of these reefs earlier (Reed et al. 2005). Macintyre and Milliman (1970) noted *Oculina* clumps and coral debris along the shelf break from northern Florida southward and especially from Cape Canaveral to Palm Beach where ridges in 70-90 m were usually capped with *Oculina*. Surveys of these reefs, using manned submersibles, began in the 1970s (Avent et al. 1977). Since then, reef monitoring, utilizing submersibles and ROVs, has continued intermittently (Reed et al. 2005). Additionally, side-scan sonar surveys were conducted, and multibeam mapping is currently ongoing on these coral banks (Reed et al. 2005; A.N. Shepard, NURC, unpublished data). A variety of studies have documented coral growth, distributions, and upwelling effects on coral growth (Reed 1980, 1981, 1983), invertebrate communities associated with these reefs (Reed et al. 1982; Reed and Mikkelsen 1987), *Oculina* reproduction (Brooke and Young 2003, 2005), and fishes associated with the *Oculina* banks (Reed and Gilmore 1981; Gilmore and Jones 1992; Koenig et al. 2000, 2005; Reed et al. 2006).

These reefs were heavily fished during previous decades and incurred much damage and reduction in reef size due to impacts of fishing gear. Research continues, particularly in the zones protected by the South Atlantic Fishery Management Council (SAFMC). Funding is lacking, but habitat mapping, restoration, and monitoring are high priorities.

Deep-sea slope corals (>250 m)

Historically, deep coral research off the southeastern U.S. was temporally and spatially sporadic. Until recently deep coral research was often a by-product of non-coral projects.

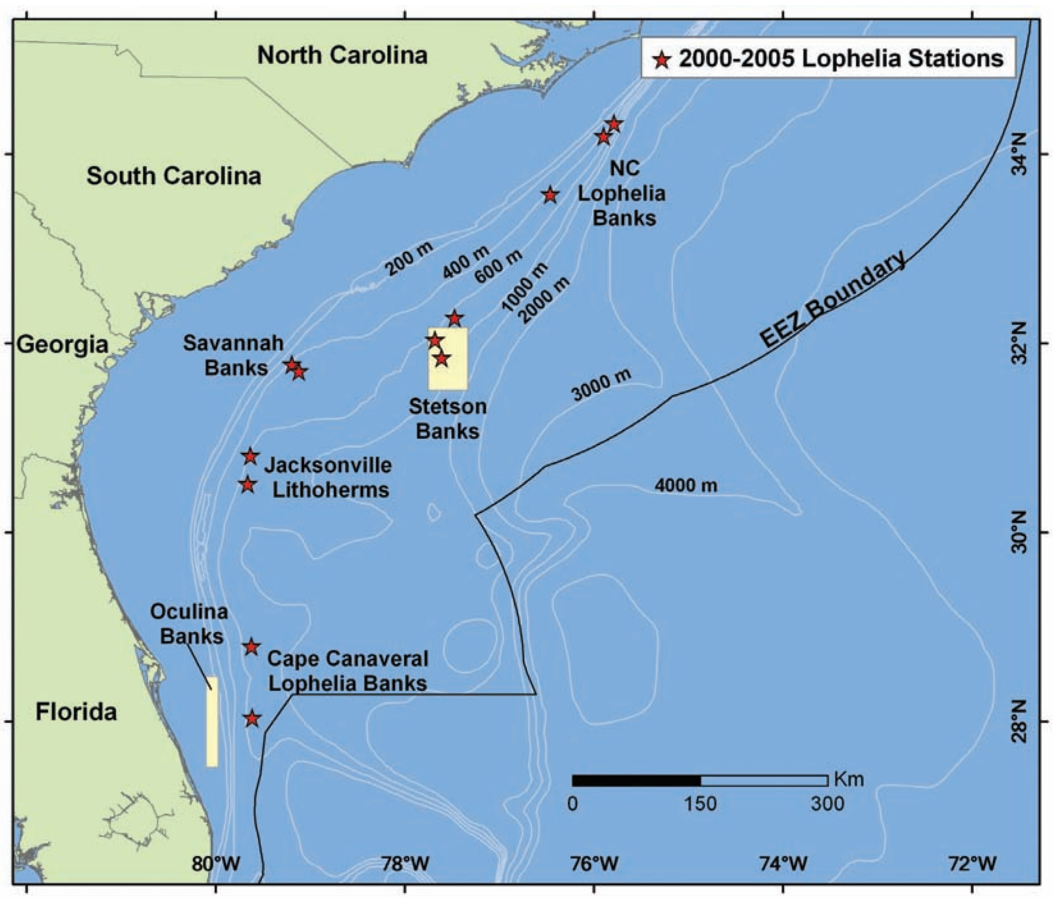


Figure 6.1. Southeastern United States regional report area, indicating general areas of *Oculina varicosa* reefs and the deeper coral (*Lophelia* mostly) habitats sampled by Ross et al. from 2000-2005 (red stars). The Stetson Bank (white box) is described in the text. Note that these areas do not represent all sites where deep (> 200 m) corals occur nor all sites visited by other researchers. See Reed et al. (2005, 2006) and Partyka et al. (in press) for additional deep coral sites in this region.

The major studies that documented deep corals in the area are briefly reviewed (in roughly chronological order); this review is not intended to be inclusive.

The first report of deep corals from the Blake Plateau resulted from the 1880 collections of the steamer *Blake* (Agassiz 1888). These collections were poorly documented, and the bottom on the Blake Plateau was characterized as being hard and barren (Agassiz 1888). The research vessel *Albatross* collected corals on the Blake Plateau in 1886 using beam trawls and tangles. Some *Lophelia* specimens in those collections were deposited in the National Museum of Natural History (Smithsonian Institution), but were otherwise poorly documented. Squires (1959) noted several scleractinian species collected by dredge in 1954 off Palm Beach, FL in 686 m. Cairns (1979) re-examined Squires' coral collections and corrected identifications, resulting in the following species: *Lophelia pertusa*, *Crispatotrochus* (=*Caryophyllia*) *squiresi*, *Enallopsammia profunda*, and *Tethocyathus variabilis*.

An area of very rough topography containing deep corals was discovered on the Blake Plateau off South Carolina, resulting from surveys by depth sounder in the mid-1950's (Stetson et al. 1962). However, confirmation that these features supported extensive coral habitat was not achieved until they were dredged and photographed in 1961 (Stetson 1961). Stetson et al. (1962) gave the first detailed accounting of this area now called the "Stetson Banks" (Figure 6.1), confirming the occurrence of two major species of hard corals, *Lophelia pertusa* and *Enallopsammia* (=*Dendrophyllia*) *profunda*. They also reported species of *Bathypsammia*, *Caryophyllia*, and *Balanophyllia* as well as abundant alcyonarians. Additional details from the 1961 cruise, including locations of hundreds of coral mounds, were described by Stetson et al. (1969).

Through the 1960s a series of geological papers based largely on precision echosounding data noted that numerous mounds, termed coral mounds, existed on the Blake Plateau and the Florida-Hatteras slope (e.g., Uchupi and Tagg 1966; Uchupi 1967; Zarudzki and Uchupi 1968). Pratt (1968) presented one photograph of *Lophelia* corals on the Blake Plateau ("Stetson Banks"). In 1967, five manned submersible dives using the DSRV *Alvin* were made in an area west of the "Stetson Banks." Two of these dives confirmed the occurrence of *Enallopsammia* (=*Dendrophyllia*) and *Lophelia* in the region (Milliman et al. 1967). Additionally, coral topped mounds (to 15 m high) were described from along the slope off Biscayne Bay, FL (around 700-825 m) (Neumann and Ball 1970), based on 1967 *Alvin* dives.

Although corals were discovered on the Blake Plateau in the 1880s and investigated in the late 1950s and early 1960s (Squires 1959; Stetson et al. 1962), such corals were not reported off North Carolina until the late 1960s. Based on seismic profiling, Uchupi (1967) first noted the occurrence of a coral mound off Cape Lookout, NC, which may be the same area illustrated (figure caption without comment) by Rowe and Menzies (1968). Rowe and Menzies (1969) later suggested that *Lophelia* sp. occurred off the Carolinas in "discontinuous banks" along the 450 m contour, but gave no specific data. Menzies et al. (1973) vaguely referenced a "Lophohelia" bank off Cape Lookout, repeating a figure in Rowe and Menzies (1969), and presented a bottom photograph of a reef in 458 m. Cairns (1979) plotted a locality for *Lophelia* off Cape Lookout. Aside from Uchupi's (1967) observations, the above North Carolina records mostly originated from a training cruise of the R/V *Eastward* (E-25-66, I.E. Gray, chief scientist) during which a coral bank was photographed by drop camera (station E-4937, 475 m) and dredged (E-4933, 425 m) on 30 June 1966. The Menzies et al. (1973, Figure 4-4 B) photograph is from that cruise. This coral bank was discovered accidentally (independently of Uchupi 1967) as a result of constantly running the *Eastward*'s depth sounder (L.R. McCloskey and G.T. Rowe, pers. comm.). There were a few other short *Eastward* cruises to this area off Cape Lookout directed by Menzies, Rowe, Gray, or McCloskey, but no coral data were published. This *Eastward* station area was trawled and surveyed by sonar in May 1983 (R/V *Delaware II* cruise, S.W. Ross, chief scientist), but no hard bottom or coral were found. Coral mounds were located in this vicinity during an undersea survey using the Navy's *NR-1* nuclear research submersible (15-18 Nov 1993, K.J. Sulak and S.W. Ross, unpublished data). Three major coral areas have been located and studied off North Carolina (Ross and Quattrini 2007; Partyka et al. in press), and other mounds may exist. All three areas off North Carolina were surveyed by multibeam sonar during October 2006 (Ross and Nizinski, unpublished data), revealing many mounds that had not been known. The slope off Cape Lookout appears to be the northern extent of deep corals in the southeast region.

Over the next three decades most studies around southeastern U.S. deep coral areas continued to be geological and generally not directed toward corals. Exceptions include Cairns (1979, 1981, 2000, 2001a), who listed ranges for deep sea Scleractinia and azooxanthellate corals in this region, relying mostly on museum records. Neumann et al. (1977) described hard carbonate mounds in the eastern Straits of Florida off Little Bahama Bank that were covered in various corals (*Lophelia* and *Enallopsammia*) and other invertebrates. They coined the term "lithoherms" for these structures. In this same area in 1982, and also using *Alvin*, researchers collected and aged several "coral" species, indicating that these animals lived from several hundred up to 1800 years (Griffin and Druffel 1989; Druffel et al. 1990, 1995). These corals have annual rings that contain a wealth of information about past climates, ocean productivity, and contamination. This significant discovery has vast implications for the scientific value of deep corals as proxies for climate change and recorders of environmental histories (Williams B et al. 2006; Williams et al. in press). Ayers and Pilkey (1981) documented several coral banks, collected corals, and dated some coral samples during a study of sediments of the Florida-Hatteras slope and inner Blake Plateau. Depending on location in a core, their dead coral samples ranged in age from 5,000 to 44,000 years old. They dated a living specimen at 680 years old, but suggested that this age probably reflected the age of the carbon pool in the surrounding water. Pinet et al. (1981) also mapped coral banks overlapping the same area as Ayers and Pilkey (1981). Blake et al. (1987) briefly mentioned the presence of some soft and hard corals on the Blake Plateau. Many deep-reef locations were indicated by the U.S. Geological Survey sidescan sonar mapping (cruises in 1987) of the continental slope (EEZ-SCAN 87 Scientific Staff 1991); however, habitats were not verified in this large scale geological survey. Perhaps the first study to document the invertebrate community associated with deep-coral habitat in this region reviewed biozonation of lithoherms in the northeastern Straits of Florida (Messing et al. 1990). Genin et al. (1992) noted that sponges and gorgonians were common along the outer Blake escarpment (2624-4016 m) based on observations made during *Alvin* dives in 1980. They suggested that these communities were unusually dense for sites lacking sediment. Popenoe (1994) discussed the distribution and formation of coral mounds on the Blake Plateau and presented a few bottom photographs. Paull et al. (2000) surveyed deep-coral habitats off the Florida-Georgia border, dated parts of the structures, and suggested that such habitat was very common. Their dating indicated that some mounds may range from 18,000 to 33,000 years old. Popenoe and Manheim (2001) extensively reviewed geology, history, and habitats of the Blake Plateau around the area of the Charleston Bump, discussing various parameters that may control coral mound formation. Wenner and Barans (2001) described benthic habitats of the Charleston Bump area and noted some of the invertebrates and fishes occurring with deep corals. George (2002) discussed a coral habitat, dominated by *Bathypsammia tintinnabulum*, southeast of Cape Fear, NC ("Agassiz Coral Hills") in 650-750 m. Apparently, the *B. tintinnabulum* used by Emilini et al. (1978) came from the collections noted by George (2002). A multibeam sonar survey of this site in 2006 (Ross and Nizinski, unpublished data) revealed a flat bottom with no suggestion of coral mounds. Reed (2002a, 2002b; Reed et al. 2006) described several large areas of deep corals on the Blake Plateau and listed some of the fauna observed. As part of a SEAMAP bottom mapping project, data and reports to be examined for evidence of deep corals in this area were summarized by Arendt et al. (2003). This project was completed in 2006 and will be incorporated into the South Atlantic Fishery Management Council's internet display.

Beginning in 2000 and continuing through the present, deep coral (or related habitat) research in the southeastern U.S. was stimulated by funding of studies through the NOAA Office of Ocean Exploration (see http://oceanexplorer.noaa.gov/explorations) and supplemented by other sources. Teams lead by Principal Investigators S.D. Brooke, S.A. Pomponi, S.W. Ross, and G.R. Sedberry explored deep-coral banks throughout the southeast, mapping habitats, cataloging fauna, and conducting basic biological studies. A multi-investigator effort to create detailed habitat classifications (Southeastern U.S. Deep-Sea Corals initiative, SEADESC) from past submersible dives in the area is underway (Partyka et al. in press). Future publications are forthcoming from the considerable data collected by these efforts.

II. GEOLOGICAL SETTING

Geology of the southeastern U.S. continental shelf, slope and rise has been well studied (see reviews in Pratt 1968; Avent et al. 1977; Schlee et al. 1979; Dillon and Popenoe 1988; Popenoe and Manheim 2001). The southeastern U.S. shelf and slope have been classified as a carbonate sedimentary province whose sediments are largely of terrigenous origin (Pratt 1968). The shelf edge (<200 m), including the region of the Florida *Oculina* banks, is marked by numerous topographic prominences of various origins (Macintyre and Milliman 1970; Avent et al. 1977; Thompson and Gilliland 1980), and these provide substrate for attachment of a largely subtropical fauna (including corals). Unlike the Middle Atlantic Bight and Gulf of Mexico, major canyons that cut across the slope are missing in the southeast region. From central North Carolina northward the slope is particularly steep and characterized by a slump topography (Pratt 1968). The Gulf Stream is and has been (since the early Tertiary) a dominant force shaping the bottom topology of the southeast region, and has scoured a steep channel along most of its length, often exposing hard substrates and creating a rugged topography.

The continental slope through much of the southeastern U.S. (central North Carolina to the Straits of Florida) is atypical of most U.S. slope configurations. It is unusually wide and is dominated by the Blake Plateau, a broad depositional feature formed by the Gulf Stream (400-1250 m depths, Popenoe and Manheim 2001). The Blake Plateau exhibits two major topographic breaks, one on its western margin, the Florida-Hatteras Slope (shelf to about 600 m), and the Blake Escarpment (descending to about 4800 m) on the southeastern margin (south of the Blake Spur). The eastern slope of the Blake Plateau north of the Blake Spur exhibits a more typical, less steep profile and grades into the Blake Ridge and Carolina Rise (Markl et al. 1970). The Blake Ridge contains extensive gas hydrate deposits and the only known methane seep community in this area (Borowski et al. 1997; van Dover et al. 2003). The Blake Plateau is an extension of the Bahamian carbonate province, with carbonates being contributed by pteropod and *Globigerina* material as well as corals and other invertebrates (Pratt and Heezen 1964). Numerous scarps, mounds, plateaus, and depressions occur in this region, and deep corals are common along the edges of the scarps and ridges and on the mounds (Stetson et al. 1962; Pratt and Heezen 1964). One dominant topographic structure of the Blake Plateau is the Charleston Bump, which presents a partial barrier to Gulf Stream flow, deflects the Gulf Stream seaward, and is heavily scoured by this current, exposing hard substrates (Popenoe and Manheim 2001). Manganese pavements and nodules are abundant over the plateau (Brundage 1972). The western side of the Blake Plateau particularly has been heavily eroded (mostly during the Pleistocene) by the Gulf Stream, exposing numerous depressions, Cretaceous to Miocene aged hard substrata, and mounds (Uchupi 1967).

The southern part of this region (to off Key Biscayne, southern border for this report) is mostly within the Straits of Florida. This area is swept by the Florida current (part of the Gulf Stream system), and the bottom exhibits closely spaced valleys, ridges, mounds and lithoherms that are part of a carbonate platform (Malloy and Hurley 1970; Neumann et al. 1977). The northwestern side of the Straits of Florida is bordered by the Miami Terrace, a carbonate platform in 200 to 400 m that exhibits varied hardbottom topography (Reed et al. 2005). A variety of deep corals occur on hard substrates of the Straits of Florida (Neumann et al. 1977; Messing et al. 1990; Reed et al. 2005, 2006).

III. OCEANOGRAPHIC SETTING

The dominant oceanographic feature that shapes much of the geology and biology of the outer shelf and slope off the southeastern U.S. is the Gulf Stream current (or Florida Current). This well studied system influences bottom conditions even at continental slope depths by cutting off shelf sediment delivery to offshore areas (mostly between northern Florida to southern North Carolina), transporting sediments northward, and facilitating high current speeds (up to

2.5 kn, 125 cm/s) on the bottom (Pratt 1968; Popenoe and Manheim 2001). The jet-like flow of the Gulf Stream has a surface width around 80-150 km with a depth of 800-1200 m, fastest current speeds being near the surface center (Bane et al. 2001). The Gulf Stream provides a seasonally stable temperature (generally >27° C) and salinity (generally >36 psu) regime for the outer shelf and slope. This current transports an increasingly massive volume of water as it moves northward (Bane et al. 2001). Inshore of the Gulf Stream (ca. <40 m depth) the physics of the continental shelf water column is dominated by tides, meteorology (e.g., winds, rainfall), and gravity waves (Pietrafesa 1983; Mathews and Pashuk 1986).

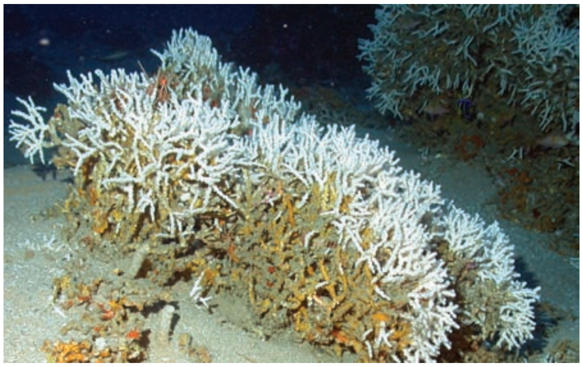
This complex current meanders (influenced in part by bottom topography) and produces eddies that spin away from the main current (Atkinson et al. 1985; Bane et al. 2001). As the Gulf Stream is deflected offshore away from the shelf edge, particularly off South Carolina (by the Charleston Bump) and off central North Carolina, nitrogen-rich deeper water upwells onto the outer shelf, leading to localized areas of enhanced carbon production (Atkinson et al. 1982; Lee et al. 1991). Much of this carbon is subsequently transported offshore (Lee et al. 1991). As the Gulf Stream has varied in position since the Pleistocene, it may alternately uncover deep bottom substrata suitable for deep coral settlement or facilitate burial of coral mounds (Zarudzki and Uchupi 1968).

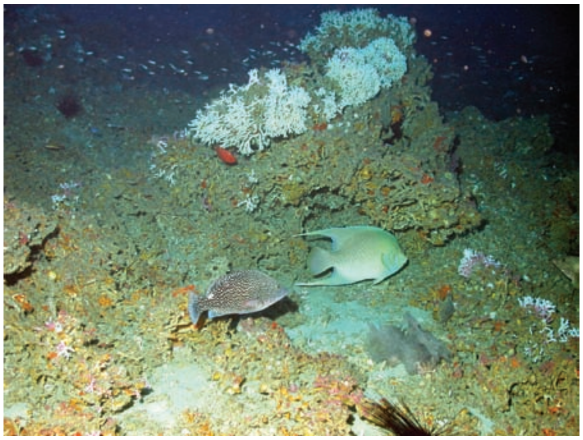
Being on the shelf edge, the Florida *Oculina* banks experience more temperate conditions. Bottom water temperatures can vary widely over short time scales (days to weeks) and on some banks can range from about 7° to 27° C (Avent et al. 1977; Reed 1981), being alternately washed by warm Gulf Stream or inshore waters and deeper, cold waters. The colder conditions are usually caused by upwelling, which also provides an increased amount of nutrients (Reed 1983). Bottom visibility on these banks is generally low, current speeds can be variable (sometimes >50 cm sec^{-1}), and sedimentation rates moderately high (15-78 mg cm^{-2} day^{-1}) (Reed 2002b).

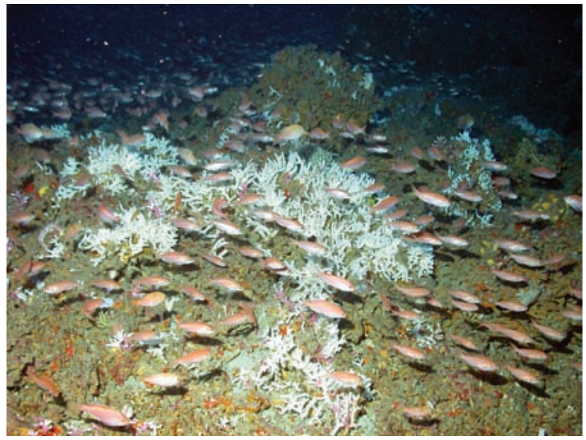
While the surface and upper water column oceanography beyond the shelf edge are fairly well studied, bottom conditions over most of the slope are not well known. Long term data are particularly lacking. High current speeds have been reported (see above), but currents can vary from near zero to >50 cm sec^{-1} over short time scales (pers. obs.). Bottom currents are more complex around coral mound or rocky features and are accelerated through valleys and over the tops of mounds/ridges (pers. obs.). Recent multibeam sonar mapping suggested that long term current scouring helped shape deep-coral mounds off North Carolina, but that conditions were different at the deeper Stetson area habitats (Ross and Nizinski, unpublished data). Bottom temperatures around southeastern U.S. deep coral habitats (370-780 m) ranged from 5.4° to 12.3° C and salinities varied little from 35 psu (Ross and Quattrini 2007). Similar environmental data from southeastern U.S. deep coral habitats were reported by Reed et al. (2006).

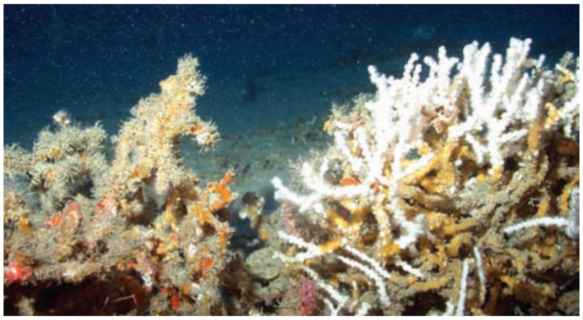
IV. STRUCTURE-FORMING DEEP CORALS OF THE SOUTHEASTERN U.S.

The southeastern U.S. slope area, including the slope off the Florida Keys, has a unique assemblage of deep-water scleractinians (Cairns and Chapman 2001). The warm temperate assemblage identified by Cairns and Chapman (2001), encompassing nearly the same geographic range as that covered here, consists of about 62 species, four of which are endemic to the region. This group of corals was characterized by many free-living species, few species living deeper than 1000 m, and many species with amphi-Atlantic distributions. For the southeastern U.S., in areas deeper than 200 m, we report a similar assemblage, consisting of 57 species of scleractinians (including 47 solitary and ten colonial structure-forming corals), four antipatharians, one zoanthid, 44 octocorals, one pennatulid, and seven stylasterids (Appendix 6.1). Thus, the region contains at least 114 species of deep corals (Classes Hydrozoa and Anthozoa). We note, however, that this list is conservative, and we expect that more species will be discovered in the region as exploration and sampling increase. Since solitary corals do not form reefs and are poorly known, we do not treat them in detail. Below we discuss the major structure-forming corals (Appendix 6.1) that most contribute to reef-like habitats in the southeastern U.S.









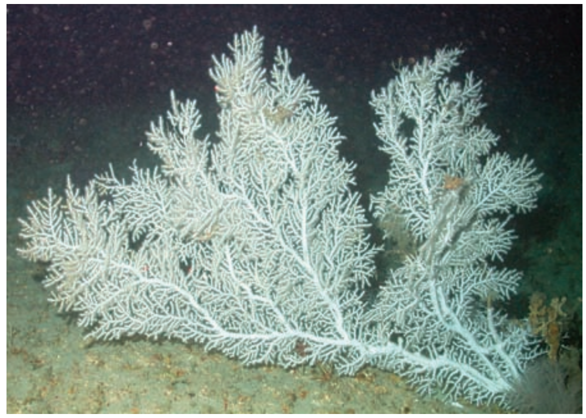


Figure 6.2. Selected photographs (May 2003) from the Florida *Oculina* HAPC. Photo credit: L. Horn, NOAA Undersea Research Center at UNC-Wilmington.

We hypothesize that high profile deep-coral reefs concentrate biota and enhance local productivity in ways similar to seamounts (Rogers 1994; Koslow 1997). The ridges and reef mounds, some rising over 100 m from open substrata, accelerate bottom currents which favors attached filter-feeding invertebrates and other biota. Thus, the growing reef alters the physics of the water column, enhancing the environment for continued coral growth and faunal recruitment (Genin et al. 1986).

a. *Stony Corals* (Class Anthozoa, Order Scleractinia)

The dominant structure-forming coral on the southeastern U.S. outer shelf (<200 m) is *Oculina varicosa* (ivory tree coral). Although it occurs from Bermuda and North Carolina south through the Gulf of Mexico and the Caribbean in 2-152 m depths, this coral only forms large reefs off east-central Florida, 27^{o} 32' N to 28^{o} 59' N, in 70-100 m (Figure 6.1; Reed 2002b). The shallow water form of *Oculina* may have symbiotic zooxanthellae, but the deeper form does not.

The deeper reefs are almost monotypic mounds and ridges which exhibit a vertical profile of 3-35 m (Avent et al. 1977; Reed 2002b). Superficially, these structures (Figure 6.2) resemble the deep reefs formed by *Lophelia pertusa*. Despite cool temperatures, the shelf edge *Oculina* exhibit rapid growth, probably facilitated by regular upwellings of nutrient rich water (Reed 1983).

Lophelia pertusa, the major structure-forming coral in the deep sea, is the dominant scleractinian off the southeastern U.S. This species has a cosmopolitan distribution, occurring on the southeastern U.S. slope, in the Gulf of Mexico, off Nova Scotia, in the northeastern Atlantic, the South Atlantic, the Mediterranean, Indian Ocean and in parts of the Pacific Ocean over a depth range of 50 to 2170 m (Cairns 1979; Rogers 1999). The 3380 m depth record off New York for *L. pertusa* reported by Squires (1959) was based on a misidentifed specimen (Cairns 1979). Coral habitats dominated by *L. pertusa* are common throughout the southeastern U.S. from about 370 to at least 800 m depth.

Although *Lophelia* may occur in small scattered colonies attached to various hard substrata, it also forms complex, high profile features. For instance, off North Carolina, *Lophelia* forms what may be considered classic mounds that appear to be a sediment/coral rubble matrix topped with almost monotypic stands of *L. pertusa* (Figure 6.3). Along the sides and around the bases of these banks are rubble zones of dead, gray coral pieces which may extend large distances away from the mounds. To the south sediment/coral mounds vary in size, and *L. pertusa* and other hard and soft corals populate the abundant hard substrata of the Blake Plateau in great numbers (Figures 6.4 and 6.5).

Data are lacking on how *Lophelia* coral banks in the southeastern U.S. are formed. Hypotheses for coral mound formation in the northeastern Atlantic were proposed (Hovland et al. 1998; Hovland and Risk 2003; Masson et al. 2003), but it is unclear how relevant these are off the southeastern U.S. The mounds off North Carolina and those in other locations off the southeastern U.S. (particularly east of south-central Florida) appear to be formed by successive coral growth, collapse, and sediment entrapment (Wilson 1979; Ayers and Pilkey 1981; Paull et al. 2000; Popenoe and Manheim 2001). Other coral formations in the area (especially on the Blake Plateau) seem to form by coral colonization of appropriate hard substrates, without mound formation by the corals. If bottom currents are too strong, mound formation may be prevented (Popenoe and Manheim 2001) because sediments cannot be trapped. Ayers and Pilkey (1981) suggested that Gulf Stream currents may erode coral mounds, and that present coral bank sizes may be related to historical displacements of that current. Assuming currents also carry appropriate foods, it may be that currents with variable speeds or at least currents of moderate speeds (fast enough to facilitate filter feeding but not too fast to prevent sediment entrapment) coupled with a supply of sediment are the conditions necessary to facilitate coral mound formation (Rogers 1999). Regardless of how coral formations are created, we agree with Masson et al. (2003) that elevated topography appears to be an important attribute for well developed coral communities.

Deep-coral reefs are fragile and susceptible to physical destruction (Fossa et al. 2002). It is estimated that these deep reefs may be hundreds to thousands of years old (Neumann et al. 1977; Wilson 1979; Ayers and Pilkey 1981; Mikkelsen et al. 1982; Mortensen and Rapp 1998); however, aging data are so limited (especially in the western Atlantic) that age of coral mounds in the western Atlantic is unclear. Recent drilling on coral mounds off Ireland indicated that these structures started forming over two million years ago and that formation was not related to hydrocarbon seeps (Williams T et al. 2006). While the genetic structure (gene flow, population relationships, taxonomic relationships) of *Lophelia* in the northeastern Atlantic is being described (Le Goff-Vitry et al. 2004), such studies are just beginning in the western Atlantic (C. Morrison et al. unpublished data). Preliminary genetic results from the southeast region suggest that the population structure of *L. pertusa* is more diverse than expected (C. Morrison et al. unpublished data). Understanding the population genetics and gene flow will provide insights into coral biology, dispersal and distribution of deep corals off the southeastern U.S.

Although *Lophelia* is the dominant hard coral off North Carolina, other scleractinians contribute to the overall complexity of the habitat (Table 6.1). Overall, species diversity of scleractinians increases south of Cape Fear, NC, but *L. pertusa*

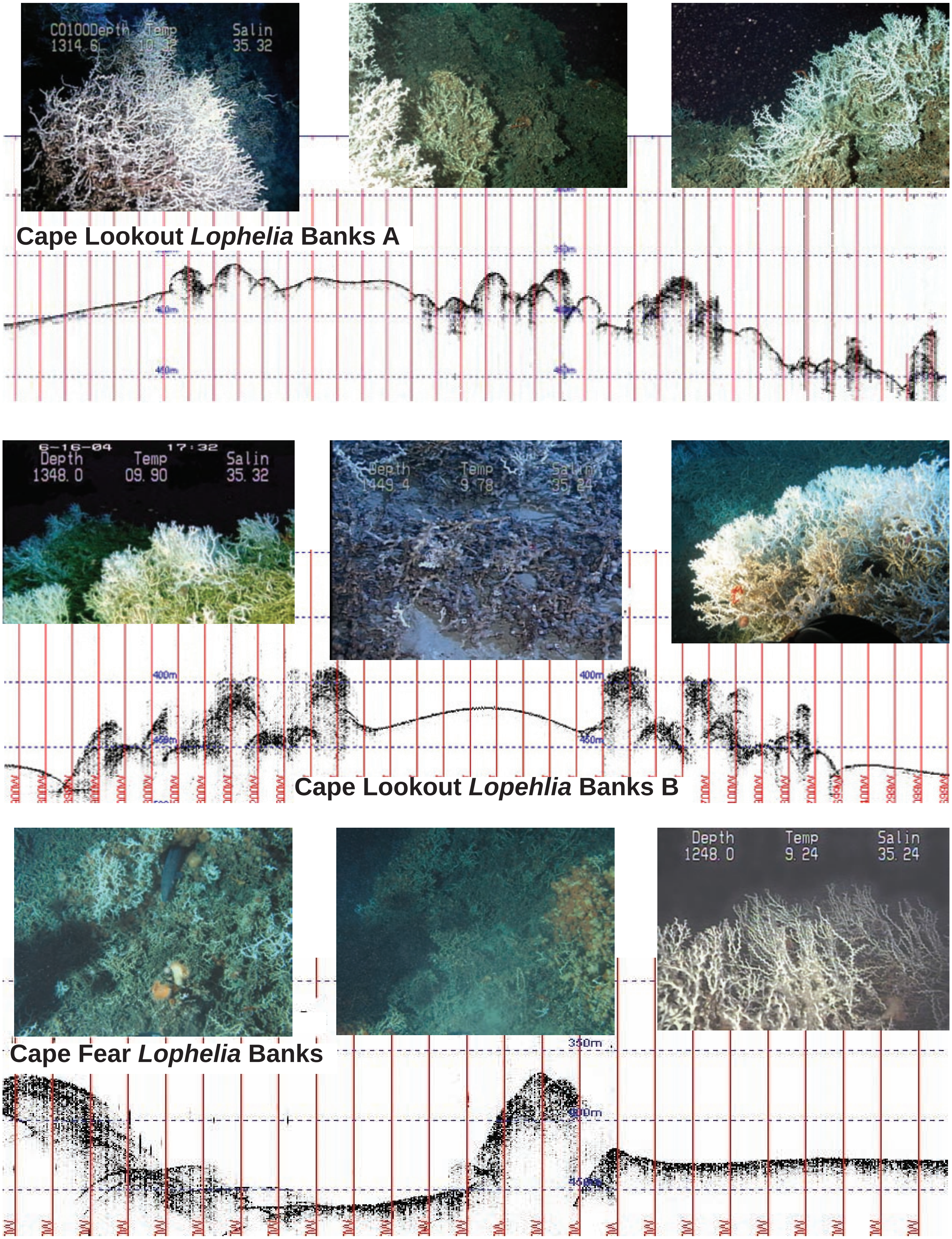


Figure 6.3. Depth sounder profiles and selected bottom views of the three North Carolina *Lophelia* coral banks. Top panel shows living (white) and dead (gray) corals near and on ridge tops. Middle panel also illustrates various live and dead corals as well as coral rubble (center photo). Bottom panel shows mixed corals, anemones, and conger eel (left photo), slope covered with anemones and corals (center photo), and the slender upright growth form of *Lophelia* (right photo). Habitat photographs do not correspond to a particular location on the depth sounder profiles. Profiles and photo credit: Ross et al. unpublished data.

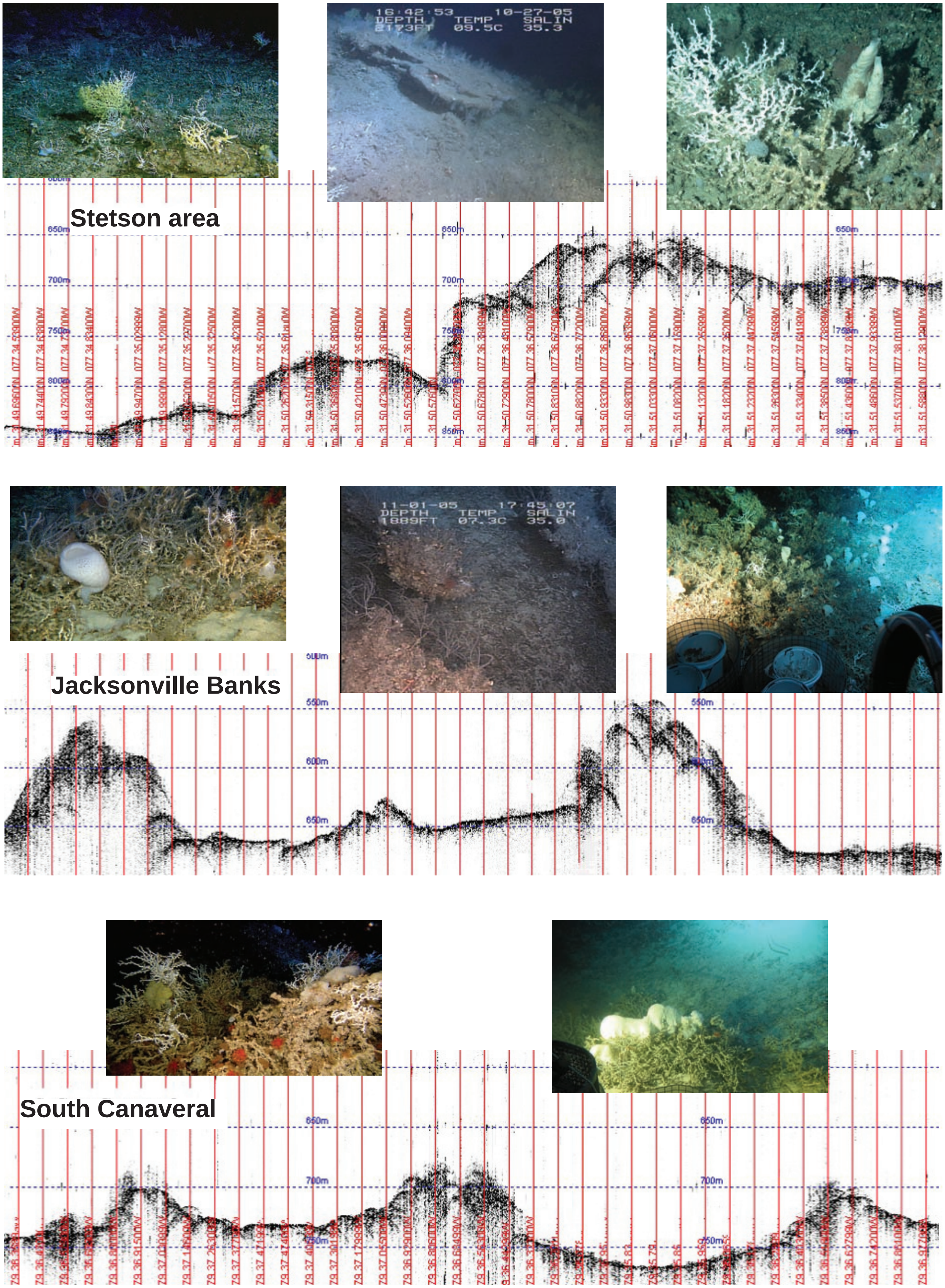


Figure 6.4. Depth sounder profiles and selected bottom views of coral (and sponge) habitats on the Blake Plateau south of North Carolina. Habitat photographs do not correspond to a particular location on the depth sounder profiles. Profiles and photo credit: Ross et al. unpublished data.

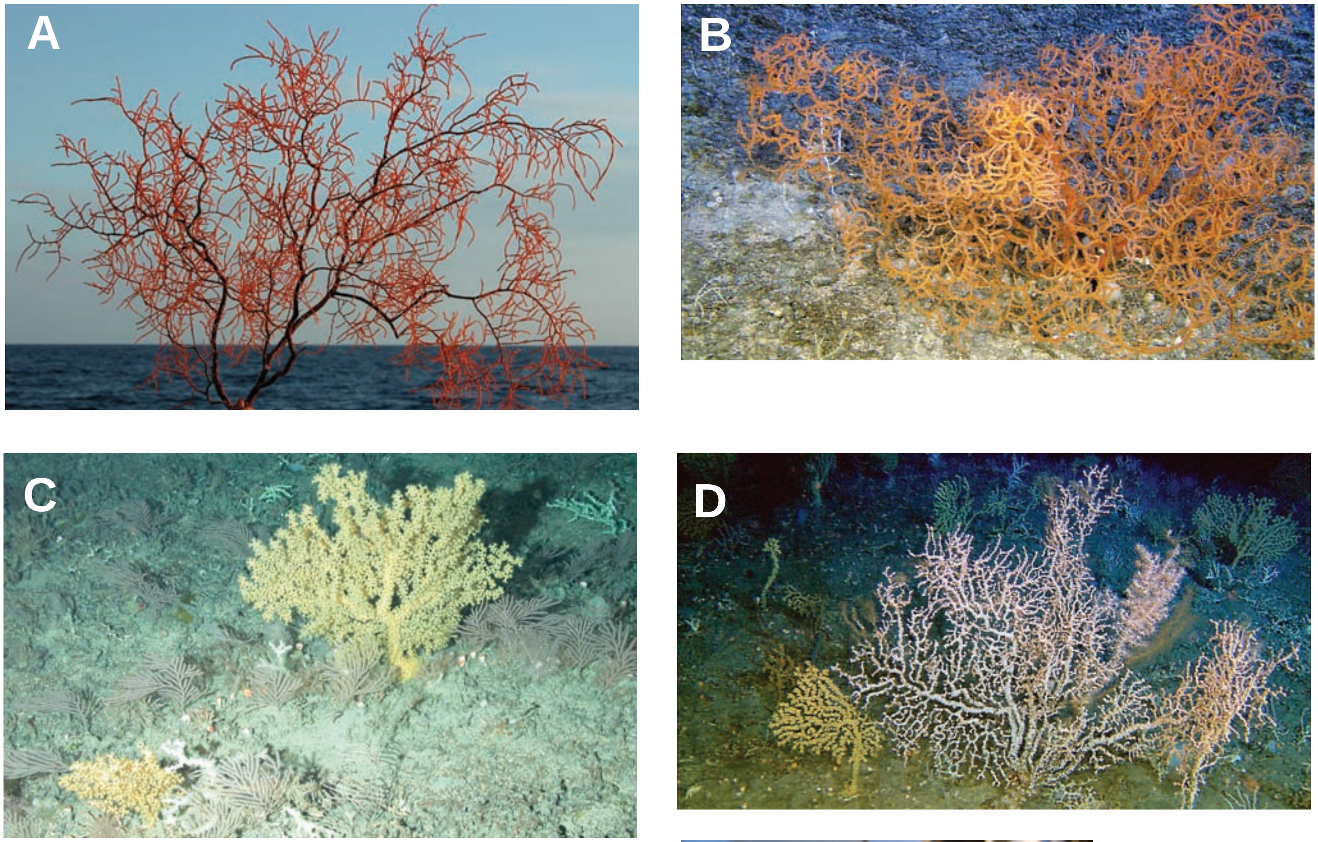


Figure 6.5. Examples of black (A,B; *Leiopathes* spp., possibly *Leiopathes glaberrima*), bamboo (D; *Keratoisis* spp., possibly *K. ornata*) and gold (E; *Gerardia* sp.) corals commonly found on the Blake Plateau south of North Carolina. Other corals (C) have not yet been identified. Photo credit: Ross et al. unpublished data.

is still dominant. For example, the colonial corals *Madrepora oculata* and *Enallopsammia profunda*, rare off Cape Lookout, NC, are relatively common south of Cape Fear, NC. These hard corals tend not to occur singly or as species-specific mounds, but rather live on or adjacent to the *Lophelia* mounds. A variety of solitary corals (Appendix 6.1) are also found off the southeastern U.S. Individuals are often attached to coral rubble or underlying hard substrata. Most species appear to be either uncommon or rare. But, in some instances, particularly in the central portion of the region, local abundance can be high. For example, aggregations of *Thecopsammia socialis* and *Bathypsammia fallosocialis* carpet the bottom adjacent to reef habitat at study sites off South Carolina and northern Florida (Ross et al., unpublished data).

b. *Black corals* (Class Anthozoa, Order Antipatharia)

Black corals (Families Leiopathidae and Schizopathidae, ca. four species) are important structure-forming corals on the southeastern U.S. slope (Figure 6.5; Table 6.1). These corals occur locally in moderate abundances, but their distributions seem to be limited to the region south of Cape Fear, NC. Colonies may reach heights of 1-2 m. Black coral colonies, occurring singly or in small aggregations, may be observed either in association with hard coral colonies or as separate entities. Some of these living components of the deep reefs attain ages of hundreds to thousands of years (Williams B et al. 2006; Williams et al. in press; C. Holmes and S.W. Ross, unpublished data), and thus, along with gold corals, are among the oldest known animals on Earth. Black corals form annual or regular bands, and these bands contain important chemical records on past climates, ocean physics, ocean productivity, pollution, and data relevant to global geochemical cycles. An effort to investigate these geochemical data is underway by U.S. Geological Survey (C. Holmes and S.W. Ross).

c. *Gold corals* (Class Anthozoa, Order Zoanthidae)

Gerardia spp. colonies are found most often singly away from other coral structure, but these corals are also found associated with colonies of other structure-forming corals such as *Lophelia pertusa*, *Keratoisis* spp., or antipatharians (*Leiopathes* spp.). Very little is known about this group of organisms. They apparently exhibit slow growth, reaching ages of at least 1800 years old (Griffin and Druffel 1989; Druffel et al. 1995) and may be valuable in paleoecology studies.

Table 6.1. Attributes of structure forming deep-sea corals of the southeastern United States.

Taxa	Reef-Building	Abun-dance	Max Colony Size	Morph-ology	Associations with Other Structure-Forming Invertebrates	Colony Spatial Dispersion	Overall Structural Importance
Lophelia pertusa	Yes	High	Large	Branching	Many	Clumped	High
Solenosmilia variabilis	No	Low	Small	Branching	Many	Clumped	Low
Enallopsammia profunda	No	Low-Medium	Small-Medium	Branching	Many	Clumped	Low-Medium
Madrepora oculata	No	Low	Small	Branching	Many	Clumped	Low
Oculina varicosa	Yes	High	Large	Branching	Many	Clumped	High
Madracis myriaster	No	Low	Small-Medium	Branching	Many	Clumped	Low
Leiopathes glaberrima	No	Medium	Medium-Large	Branching	Many	Solitary	Medium
Bathypathes alternata	No	Low	Medium-Large	Branching	Many	Solitary	Low
Keratoisis spp.	No	Medium	Medium-Large	Branching	Many	Solitary	Medium

Table Key	
Attribute	Measure
Reef-Building	Yes/No
Relative Abundance	Low/ Medium/ High
Size (width or height)	Small (< 30cm)/ Medium (30cm-1m)/ Large (>1m)
Morphology	Branching/ Non-branching
Associations	None/ Few (1-2)/ Many (>2)
Spatial Dispersion	Solitary/ Clumped
Overall Rating	Low/ Medium/ High

d. Gorgonians (Class Anthozoa, Order Gorgonacea)

The gorgonians are by far the most diverse taxon on the southeastern U.S. slope represented by seven families, 17 genera, and 32 species (Appendix 6.1). The diversity of gorgonians increases dramatically south of Cape Fear, NC. Additional sampling is likely to increase the numbers of known species in this group for this region. To date, material we collected off Jacksonville, FL represented a newly described species (*Thourella bipinnata* Cairns 2006); the specimen of *Chrysogorgia squamata* also collected off Jacksonville represented the fifth known specimen of this species and increased our knowledge of its geographic range (previously known only from the Caribbean).

Bamboo corals (Family Isididae, four species), possibly the best known members of this group because of their larger size and distinctive morphology, are also important structure-forming corals off the southeast region. (Figure 6.5; Table 6.1). They occur locally in moderate abundances, and their distributions also seem to be limited to the region south of Cape Fear, NC. Colonies may reach heights of 1-2 m. Bamboo coral colonies occur either singly or in small aggregations and may be observed either in association with hard coral colonies or as separate entities.

e. True soft corals (Class Anthozoa, Order Alcyonacea)

Three families, Alcyoniidae, Nephtheidae, and Nidaliidae, comprise the Alcyonacea off the southeastern U.S. No family is speciose; total known diversity for this group is only six species (Appendix 6.1). The most abundant species observed in the region is *Anthomastus agassizi*, which is relatively abundant at sites off Florida. It is usually attached to dead *Lophelia*, but some individuals have also been observed on dermosponges and coral rubble. The majority of the alcyonacean species are smaller in size, both in vertical extent and diameter, than the gorgonians. Thus, these corals add to the overall structural complexity of the habitat by attaching to hard substrata such as dead scleractinian skeletons and coral rubble.

Stoloniferans, a suborder (Stolonifera) within the Alcyonacea, are represented by one family (Clavulariidae) off the southeast region. Six species from four genera have been reported from the region (Appendix 6.1). One species, *Clavularia modesta*, is widespread throughout the western Atlantic; the other five species are known from North Carolina southward to the Caribbean.

f. Pennatulaceans (Class Anthozoa, Order Pennatulacea)

Little is known about pennatulids (sea pens) off the southeastern U.S. It is unlikely that this group contributes significantly to the overall complexity and diversity of the system. No sea pens have been observed during recent surveys (Ross et al., unpublished data) and based on museum records, only one species (*Kophobelemnon sertum*) is known in the region (Appendix 6.1).

g. Stylasterids (Class Hydrozoa, Order Anthoathecatae)

Although not found in great abundances, stylasterids (lace corals) commonly occur off the southeastern U.S. Seven species representing four genera have been reported from the region (Appendix 6.1). Individuals observed *in situ* are often attached to dead scleractinian corals or coral rubble. Abundance and diversity of stylasterids increase southward from the Carolinas.

V. SPECIES ASSOCIATIONS WITH DEEP CORAL COMMUNITIES

Oculina Banks (<150 m)

The fish community on the Florida shelf edge *Oculina* banks is typical of the southeastern U.S. shelf edge reef fauna (see review in Quattrini and Ross 2006). At least 73 species of fishes are known from the *Oculina* reefs (GOMFMC and SAFMC 1982; Koenig et al. 2005; Reed et al. 2006), and like the invertebrate community, this is a sub-tropically derived fauna. In recent years commercial fishing on these reefs has significantly depleted members of the snapper-grouper complex and caused habitat destruction (Koenig et al. 2000, 2005). Some groupers, *Mycteroperca microlepis* (gag) and *M. phenax* (scamp), use the reefs as spawning aggregation sites (Gilmore and Jones 1992); however, these have also been negatively impacted by habitat destruction (Koenig et al. 2000).

The Florida *Oculina* reefs support a diverse invertebrate fauna with mostly sub-tropical affinities (Figure 6.2). Densities of associated

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invertebrates rival those of shallow coral reef systems (see review in Reed 2002b). Avent et al. (1977) presented a preliminary list of benthic invertebrates dredged from some *Oculina* mounds. Analysis of 42 small *Oculina* colonies yielded about 350 invertebrate species, including 262 mollusc species (Reed and Mikkelson 1987), 50 decapod crustacean species (Reed et al. 1982), 47 amphipod species, 21 echinoderm species, 15 pycnogoid species, and 23 families of polychaetes (Reed 2002b). The invertebrate community has been reduced by habitat destruction (Koenig et al. 2000). Although *Oculina* habitats appear to have more associated mobile macroinvertebrates than deeper coral areas, large sponges and soft/horny corals are less abundant (Reed et al. 2006).

Deep-sea slope coral areas (>150 m, but most >300 m)

Deep coral habitat may be more important to western Atlantic slope species than previously known. Some commercially valuable deep-water species congregate around deep-coral habitat (Table 6.2). Various crabs, especially galatheoids, are abundant on the deep reefs, playing a role of both predator on and food for the fishes. Other invertebrates, particularly ophiuroids, populate the coral matrix in high numbers. On the relatively barren Blake Plateau, reefs (coral and hardgrounds) and surrounding coral rubble habitat seem to offer abundant shelter and food.

There are few deep-coral ecosystem references for the southeast region related to fishes, and those are generally qualitative (fishes neither collected nor counted) or fishes were not a specific target of the research (Popenoe and Manheim 2001; Weaver and Sedberry 2001; Reed et al. 2005, 2006). In the most detailed study of fishes to date, Ross and Quattrini (2007) identified 99 benthic or benthopelagic fish species on and around southeastern U.S. deep-coral banks, 19% of which yielded new distributional data for the region. Additional publications resulting from their fish database documented the anglerfish fauna (Caruso et al. 2007), midwater fish interactions with the reefs (Gartner et al. in review), a new species of eel (McCosker and Ross in press), and a new species of hagfish (Fernholm and Quattrini in press). Although some variability in fish fauna was observed over this region, most of the deep-coral habitat was dominated by relatively few fish species (Table 6.2, Figure 6.6). Many of these species are cryptic, being well hidden within the corals (e.g., *Hoplostethus occidentalis*, *Netenchelys exoria*, *Conger oceanicus*). Various reef habitats were characterized by *Laemonema melanurum, L. barbatulum, Nezumia sclerorhynchus, Beryx decadactylus*, and *Helicolenus dactylopterus* (Ross and Quattrini 2007). Nearby off reef areas were dominated by *Fenestraja plutonia*, *Laemonema barbatulum, Myxine glutinosa*, and *Chlorophthalmus agassizi*. *Beryx decadactylus* usually occurs in large aggregations moving over the reef, while most other major species occur as single individuals. The morid, *Laemonema melanurum*, is one of the larger fishes abundant at most sites with corals. This fish seems to rarely leave the prime reef area, while its congener *L. barbatulum* roams over a broader range of habitats. Although *Helicolenus dactylopterus* (Figure 6.6) can

Table 6.2. Dominant benthic fish species (in phylogenetic order) observed and/or collected during submersible dives (2000-2005) on or near southeastern U.S. *Lophelia* habitat based on Ross and Quattrini (2007). Asterisk (*) indicate commercially important species

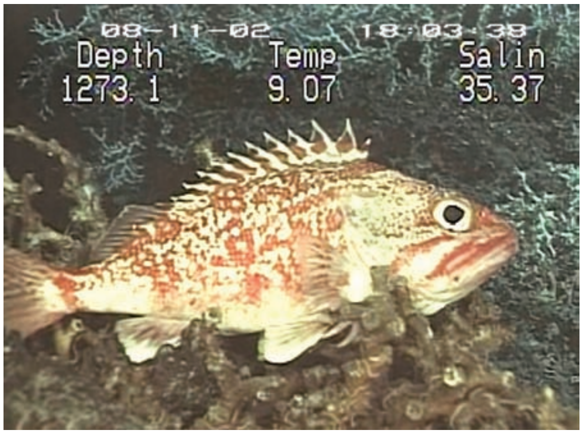
Scientific name	Common name (if known)
Myxinidae (mixed Myxine glutinosa and Eptatretus spp.)	hagfishes
Scyliorhinus retifer	chain dogfish
Scyliorhinus meadi	
Cirrhigaleus asper	roughskin dogfish
Dysommina rugosa	
Synaphobranchus spp.	cutthroat eels
*Conger oceanicus**	conger eel
Netenchelys exoria	
Nezumia sclerorhynchus	
Laemonema barbatulum	shortbeard codling
Laemonema melanurum	reef codling
Physiculus karrerae	
Lophiodes beroe	
Hoplostethus occidentalis	western roughy
*Beryx decadactylus**	red bream
*Helicolenus dactylopterus**	blackbelly rosefish
Idiastion kyphos	
Trachyscorpia cristulata	Atlantic thornyhead
*Polyprion americanus**	wreckfish

Polyprion americanus (wreckfish)

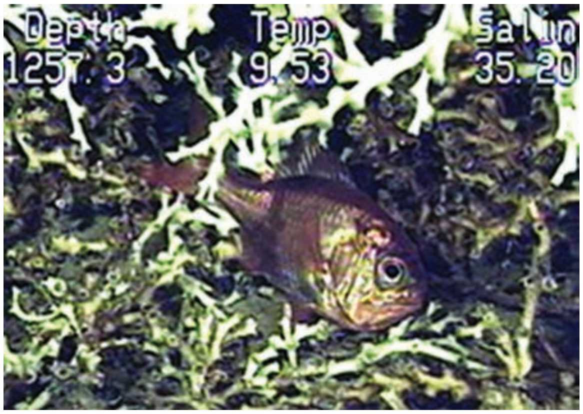
Beryx decadactylus (red bream)

Laemonema melanurum (reef codling)

Conger oceanicus (conger eel)



Helicolenus dactylopterus (blackbelly rosefish)



Hoplostethus occidentalis (western roughy)

Figure 6.6 Photographs of some common fish species of the southeastern US deep (> 200 m) coral habitats Photographs credit: S.W. Ross.

be common in all habitats, it occurs most often around structures. It is intimately associated with the coral substrate, and it is abundant around deep-reef habitat. Results (Ross and Quattrini 2007) suggested that some of the fishes observed around the deep-coral habitats may be primary (obligate) reef fishes.

One of the most impressive biological aspects of these coral habitats (aside from the corals themselves) is the diverse and abundant invertebrate fauna (Table 6.3 and Reed et al. 2006). *Eumunida picta* (galatheoid crab; squat lobster) and *Novodinia antillensis* (brisingid seastar) were particularly obvious (Figure 6.7), perched high on coral bushes to catch passing animals or filter food from the currents. One very different aspect of the North Carolina deep-coral habitat compared to the rest of the southeast region is the massive numbers of the brittle star, *Ophiacantha bidentata*, covering dead coral colonies, coral rubble, and to a lesser extent, living *Lophelia* colonies (Figure 6.7). It is perhaps the most abundant macroinvertebrate on these banks and may constitute a major food source for fishes (Brooks et al. 2007). In places the bottom is covered with huge numbers of several species of anemones (Figure 6.7). The hydroid fauna is also rich with many species being newly reported to the area and some species being new to science (Henry et al. in press). The abundance of filter feeders suggests a food rich habitat. Various species of sponges, echinoderms, cnidarians (Messing et al. 1990) and crustaceans (Wenner and Barans 2001) also have been reported from deep-coral reefs off Florida, the northeastern Straits of Florida and the Charleston Bump region (Reed et al. 2006). Reed et al. (2006) provided a preliminary list of invertebrates, mostly sponges and corals, from some deep-coral habitats on the Blake Plateau and Straits of Florida; however, most taxa were not identified to species. Lack of data on the invertebrate fauna associated with deep corals is a major deficiency.

Although the invertebrate assemblage associated with northeastern Atlantic *Lophelia* reefs has been described as being as diverse as shallow water tropical coral reefs (e.g., Jensen and Frederickson 1992), data analysis of invertebrates associated with western Atlantic deep corals is too preliminary to speculate on the degree of species richness. Preliminary data on the invertebrate fauna (Nizinski et al. unpublished data) seem to indicate a faunal and habitat transition with latitude. In addition to changes in reef structure and morphology (see above), relative abundance within a single species decreases, overall species diversity increases, and numerical dominance between species decreases with decreasing latitude. In contrast to some fishes, the reef associated invertebrate assemblage appears to use deep reefs more opportunistically.

VI. STRESSORS ON DEEP CORAL ECOSYSTEMS OF THE SOUTHEASTERN U.S.

Very little direct information exists to evaluate the health or condition of deep-coral reefs along the coast of the southeastern U.S. However, the potential for impacts to deep-sea ecosystems is of great concern because communities at these greater depths are not able to sustain heavy fishing pressures, as the general longevity of their species, slow growth, and low dispersal rates often prevent recovery from damaging impacts (Koslow et al. 2000; Roberts 2002; Cheung et al. 2007). A large portion of the *Oculina* banks was closed to fishing due to destruction of habitat and concern for conservation of corals and the associated fauna. There is concern that fisheries may soon target other deep-coral ecosystems in the region.

Fishing Effects

Major human induced damage to habitat and biota has been documented on the east-central Florida shelf edge, *Oculina* reef tract. Extensive damage to corals and fish stocks from fishing operations was reported (Coleman et al. 1999; Koenig et al. 2000, 2005), including decreased numbers and biomass of corals, decreased amounts of coral habitat, and declining fish stocks. The primary fish targets (snapper, grouper, porgy) on the *Oculina* reefs are also generally considered overfished throughout the waters off the southeastern U.S. (SAFMC unpublished data).

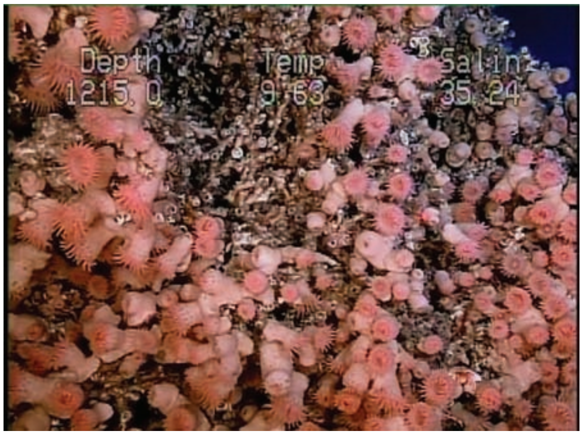
On the slope some commercially-exploited deep-water fishes, like *Polyprion americanus* (wreckfish; Vaughan et al. 2001) and *Helicolenus dactylopterus* (blackbelly rosefish), utilize *Lophelia* habitat extensively (Ross and Quattrini 2007). Swordfish have been observed along the deep reefs (Reed et al. 2006; Ross and Quattrini 2007). Other potentially exploitable species, such as royal red shrimps, rock crabs, golden crab, squid, bericiform fish species, and eels, are also associated with deep-coral habitats. Signs of past fishing effort (trash, lost gear) were observed on some banks, but the extent to which fishermen sample these areas is unknown; therefore, estimations of fishing impact (Table 6.4) are problematic. The potential for new deep-water fisheries on and around these banks is unknown. At this time our impression is that benthic fishing impacts to corals and benthic fishery species beyond 200 m in this region are minimal.

Table 6.3. Preliminary list of dominant benthic megainvertebrates observed or collected on or near southeastern U.S. deep coral habitats. Corals are listed separately in Appendix 6.1. References are 1= Nizinski et al. unpublished data, 2= Reed et al. 2006, 3 = Henry et al. in review.

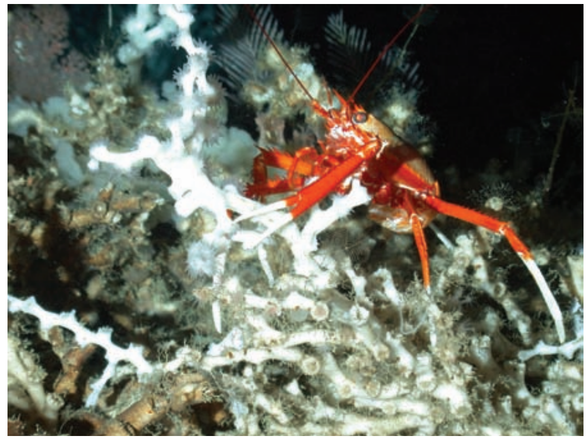
Dominant Non-Coralline Invertebrate Taxa	
Phylum Porifera (Sponges) Class Demospongiae multiple species[1,2] Class Hexactinellida (glass sponges) multiple species[1,2] including *Aphrocallistes beatrix*[1]	Phylum Cnidaria Class Hydrozoa (Hydroids) multiple species (≥ 37 species)[3] Class Anthozoa Order Actinaria (anemones) multiple species including *Actinaugi rugosa* (Venus flytrap anemone)[1] Order Zoanthidea (zoanthids) multiple species[1,2]
Phylum Mollusca Class Cephalopoda Squids, *Ilex* sp.[1] Octopus, multiple species[1] Class Gastropoda *Coralliophila* (?) sp.[1]	Phylum Annelida Class Polychaeta (polychaetes) multiple species including *Eunice* sp.[1]
Phylum Arthopoda Subphylum Crustacea Class Malacostraca Order Decapoda Infraorder Anomura Family Chirostylidae (squat lobster) *Eumunida picta* [1,2] *Gastroptychus salvadori*[1] *Uroptychus* spp.[1] Family Galatheidae (squat lobster) *Munida* spp.[1] *Munidopsis* spp.[1] Superfamily Paguroidea (hermit crabs and their relatives) multiple species[1] Infraorder Brachyura Family Pisidae *Rochinia crassa* (inflated spiny crab)[1] Family Geryonidae *Chaceon fenneri* (golden deepsea crab)[1,2] Family Portunidae *Bathynectes longispina* (bathyal swimming crab)[1,2] Other taxa Shrimps, multiple species[1]	Phylum Echinodermata Class Crinoidea (crinoids) multiple species[1] Class Asteroidea (sea stars) multiple species[1,2] Order Brisingida (brisingid sea star) Family Brisingidae *Novodinia antillensis*[1] Class Ophiuroidea (brittle stars) multiple species[1], including *Ophiacantha bidentata*[1] Class Echinoidea (sea urchins) Order Echinoida Family Echinidae *Echinus gracilis*[1] *E. tylodes*[1] Order Echinothurioida Family Echinothuriidae *Hygrosoma* spp.[2] Order Cidaroida Family Cidaridae *Cidaris rugosa*[1] *Stylocidaris* spp.[2]

Effects Of Other Human Activities

Other anthropogenic activities could have negative impacts on deep-coral habitats, but presently most of these do not appear to be issues. Currently there is a federal moratorium on hydrocarbon exploration in this region, and there are no active offshore production operations. If this moratorium is lifted, the potential impacts to deep-coral habitat should be carefully considered. Cable laying could cause physical damage to coral habitat, but to date such damage has not been documented off the southeastern U.S. Construction of a proposed liquefied natural gas (LNG) terminal with associated benthic pipelines off south Florida could impact deep-coral habitat.

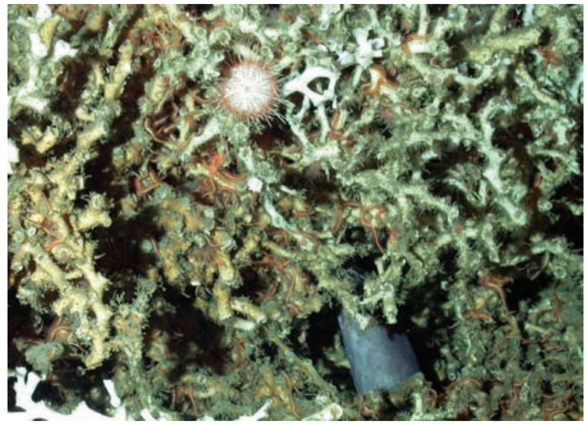


wall of unidentified anemones



Eumunida picta (squat lobster) on *Lophelia* coral

Novodinia antillensis (brisingid sea star)



Ophiacantha bidentata (brittle stars) intertwined within the *Lophelia* coral matrix and *Echinus* sp. top center.

Bathynectes longispinus (bathyal swimming crab)

Antedonidae (swimming crinoid)

Figure 6.7. Photographs of common invertebrates of the southeastern U.S. deep (>200 m) coral habitats. Photo credit: Ross et al. unpublished data.

Bottom disturbance through construction of offshore tanker ports may impact coral areas, especially off Florida where deep water is closer to shore. Construction of wind farms for energy production has been recently proposed for offshore areas. While these would likely be in waters shallower than those occupied by deep corals, designs for deeper water systems exist. Coral growth can keep up with a certain amount of sedimentation (Reed 2002b), but high rates of sedimentation are detrimental to corals (Rogers 1990). We are unaware of references

Table 6.4. Potential fishing gear impacts to deep water corals in the southeastern United States.

Gear Type	Severity of Impact	Extent of Impact	Geographic Extent of Use in Region	Overall Rating of Gear Impact
Bottom Trawl	High	High	Low	High
Mid-water Trawl	Low	Low	Low	Low
Dredge	High	Medium	Low	Medium
Bottom-set Longline	Medium	Low	Low	Low
Bottom-set gillnet	Medium	Low	Low	Low
Traps or Pots	Medium	Low	Low	Low

documenting sedimentation impacts to deep corals of the southeast region (except *Oculina*, Reed 2002b), and if they exist, most such impacts would usually not be anthropogenic. Active disposal activities (e.g., industrial, municipal, or military wastes) seem to be either rare or absent in deep waters of this region. There do not appear to be any deep coral harvesting activities off the southeastern U.S., although there is potential for this (GOMFMC and SAFMC 1982). Some mineral resources exist throughout the area (e.g., sand, manganese), but we are unaware of any current mining of these along the southeastern U.S. shelf edge or slope.

Climate change has not noticeably impacted southeastern U.S. deep corals. Impacts from rising ocean temperature to azooxanthellate deep corals would be different, but unknown, than those to shallow corals where zooxanthellae are expelled. Changes in sea level (increases) are likely to have little impact. However, climate changes that would impact the speed and direction of the Gulf Stream current or the overall North Atlantic conveyor system could have far reaching and difficult to predict impacts on deep corals. Changes in these currents could affect sediment transport, food delivery, dispersal mechanisms, as well as ambient temperature and salinity conditions. Ocean acidification from increased atmospheric CO_2 is a recently identified potential impact to corals (Guinotte et al. 2006).

To date only one invasive species, the lionfish (*Pterois volitans*), has been documented from this area within a depth range to impact the *Oculina* bank communities (Meister et al. 2005). While widespread and seemingly abundant, lionfish have not yet been reported from the *Oculina* area. Their maximum reported depth off the southeastern U.S. is 99 m (Meister et al. 2005); thus, they are not expected at the deeper slope coral areas.

VII. MANAGEMENT OF FISHERY RESOURCES AND HABITATS

All scleractinian and black corals off the southeastern U.S. are listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The purpose of this international agreement between governments is to ensure that international trade in specimens of wild animals and plants does not threaten their survival. Thus, CITES imposes restrictions on international trade in non-fossil corals.

The South Atlantic Fishery Management Council, in cooperation and collaboration with the National Marine Fisheries Service (NMFS), is responsible for management of habitat and most fishery resources in federal waters of the southeastern U.S. (see www.safmc.net). Management is executed through single species or species group fishery management plans. Plans that regulate the snapper/grouper complex, coastal pelagics, and dolphin/wahoo relate to species using the shelf edge *Oculina* banks. Fewer species are exploited in the deeper slope waters. Harvest of golden deep-sea crab (*Chaceon fenneri*) is regulated through a fishery management plan, and wreckfish are managed as part of the snapper/grouper complex. The SAFMC is moving from single species management toward an ecosystem-based approach which incorporates a broader appreciation of ecosystem interactions.

Swordfish, tunas, sharks and billfishes are managed by the Highly Migratory Division of NMFS.

Although not applicable to deep corals in this region, other species (e.g., sea turtles, whales) are protected through such regulations as the Endangered Species Act and the Marine Mammal Protection Act. Sea turtles may occur on the *Oculina* banks; however, most of the slope deep-coral habitat is too deep for sea turtles and many marine mammals. In areas to be explored for hydrocarbons or mined for minerals within the EEZ, the Minerals Management Service (U.S. Dept. of Interior) requires geohazards surveys, including documentation of corals, and conducts environmental impact reviews of these activities.

Protection of coral habitat, including deep-water forms, in this region was established in a Coral, Coral Reef, and Live/Hardbottom Habitat Fishery Management Plan (FMP) under the Magnuson-Stevens Fishery Conservation and Management Act (GOMFMC and SAFMC 1982). This FMP summarized biological and other data on all corals off the southeastern U.S. and in the Gulf of Mexico. Additionally, optimum harvest of stony corals and sea fans throughout the waters off the southeastern U.S. was set at zero (collection for education and research purposes is permitted). The recent reauthorization of the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (P.L. 109-479) allows councils to designate zones for the protection of deep corals and requires research on and monitoring of deep coral habitats. The only deep coral protected area off the southeastern U.S., the *Oculina* Habitat Area of Particular Concern (HAPC), was described in GOMFMC and SAFMC (1982), but no other deep-coral areas were so designated. Designation of the *Oculina* banks as an HAPC became final in 1984, and use of bottom disturbing gear was prohibited (Reed 2002b). Over the next 14 years, these regulations were refined and expanded in a series of Amendments to the FMP. Increased protection of the *Oculina* banks was granted in 1994, with a total fishing ban within the original HAPC. The HAPC was doubled in size in 2000, and the new expanded area is now closed to towed bottom gear. In 2004, the ban on fishing was extended indefinitely.

No other deep-coral habitats are designated or fall within marine protected areas (MPAs), HAPCs or marine sanctuaries. No corals in the area are listed as Endangered or Threatened under the Endangered Species Act. If other deep-coral reefs prove to be important habitat with a unique fauna (as they seem to be), these reefs should be considered for protection as are the *Oculina* coral reefs. There are a variety of potential threats to the deep-coral habitats (see above). MPAs or HAPCs may be viable options for protecting these systems. However, considerable amounts and types of data, especially detailed maps, are critical for evaluating how and whether to protect deep-coral ecosystems (Miller 2001).

The SAFMC is currently evaluating management strategies for southeastern U.S. deep corals. Considering the needs of the SAFMC to evaluate and manage deep-water habitats in a timely manner, the brief, unpublished descriptions of southeastern U.S. deep-coral banks provided by Ross (2006) and Reed (2004) served as interim tools facilitating potential management options for deep-coral habitats. Based on these reports six large areas were recommended as deep coral HAPCs; these recommendations were modified in 2006 (Figure 6.8). These proposed HAPC areas are included in the current regional FMP and Ecosystem Plan (R. Pugliese, pers. comm.). A research plan is being prepared by a SAFMC committee to outline gaps in our knowledge and to address the immediate need for data pertaining to deep-coral habitats on the southeastern U.S. continental slope.

VIII. REGIONAL PRIORITIES TO UNDERSTAND AND CONSERVE DEEP CORAL COMMUNITIES

Basic data are lacking for the majority of coral habitats >200 m. Recommendations below largely result from basic data needs. Considering their habitat value for deep-sea communities, their fragility, and a general lack of data, locating, describing, and mapping deep corals and conducting basic biological studies in these habitats are global and regional priorities (McDonough and Puglise 2003; Roberts and Hirshfield 2003; Puglise et al. 2005).

Recommendations

- Detailed mapping of the southeastern U.S. shelf edge and slope is critical to better understand these habitats and evaluate their contributions to slope ecology. Such mapping is the foundation for most other research and management activities. Multibeam mapping should be conducted as soon as possible, especially in the depth range of 350-800 m. While this recommendation relates to the whole slope off the southeastern U.S., priority should be given to known coral sites and areas of suspected coral mounds.

- Of the many important ecological/biological studies that could be proposed, a broad trophodynamics study of coral banks and surrounding areas (whole water column) would provide the most impact for funds expended. Knowing the flow of energy in a system facilitates evaluation of anthropogenic impacts and allows predictions about the consequences of natural change. Such information is critical to ecosystem based management.

- Species composition and distributions of deep corals within the region require better documentation. Collection efforts for corals for identification by taxonomic experts, should be initiated. The overall deep-coral fauna is also poorly known. Better documentation of the whole living habitat matrix and associated fauna, as was done for *Oculina* reefs, is needed.

- Deep corals and the underlying mounds need to be aged. Accurate growth data on the major structure forming corals (e.g., *Lophelia*, *Madrepora*, bamboo and black corals) are

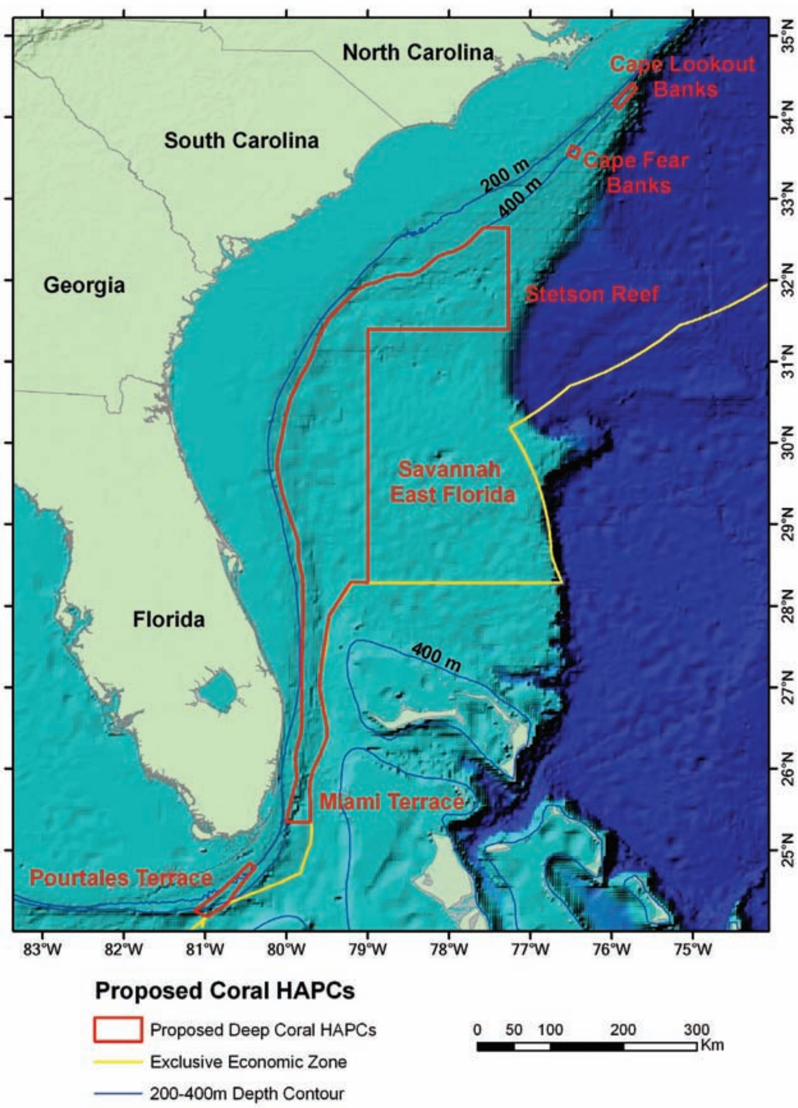


Figure 6.8. Deep coral areas (red outlines) proposed for protection as Habitat Areas of Particular Concern by the South Atlantic Fishery Management Council.

critical to evaluate how banks are formed and their present status (accreting, eroding). This type of research may need to be coupled with local sedimentation and bottom current studies.

- Significant amounts of paleoclimate or paleoenvironmental data can be obtained from some coral species. Such studies should be pursued.

- Genetic studies should continue or be initiated for the major coral species and dominant associated fauna to examine taxonomic status, dispersal, relationships among coral banks, and community genetics.

- If protected areas are established for southeastern U.S. deep-coral banks, plans for long term monitoring, research, education, and enforcement should accompany this strategy. The SAFMC is developing such a plan. Funding should be made available to execute the plans.

- Any deep-water fisheries that currently exist or that develop on or near the deep-coral banks should be carefully monitored and regulated as deep-water fauna are highly vulnerable to over fishing, and the habitat is subject to permanent destruction.

IX. CONCLUSION

The southeast region contains a huge area of diverse deep-coral habitat. Rugged topography and hard substrata are common on the outer shelf edge and slope and this physical structure facilitates development of coral mounds and other coral habitats. However, detailed maps are lacking, and a major mapping effort must be initiated. Accurate maps are crucial to our understanding of the extent of this habitat, for planning research, and to our ability to manage deep-coral habitat. A recent multibeam mapping cruise (Ross and Nizinski unpublished data), covering most of the known North Carolina sites and portions of the Stetson banks, revealed numerous mounds (probably coral mounds), ridges, scarps, and depressions that were unknown. Based on these and other findings, it seems probable that the waters off the southeastern U.S. contains the greatest diversity and concentrations of reef building deep corals on the U.S. continental slope.

The three North Carolina *Lophelia* areas represent the northernmost deep-coral banks off the southeastern U.S. Significant deep-coral habitats are not apparent on the U.S. East coast again until north of Cape Cod. Because these banks seem to be a northern terminus for a significant zoogeographic region, they may be unique in biotic resources as well as habitat expression. The banks so far examined off North Carolina are different from much of the coral habitat to the south on the Blake Plateau. The North Carolina features are dominated by dense thickets of living *L. pertusa* that cover the tops and sides of the banks; the banks are surrounded by extensive coral rubble zones. Unlike areas to the south, the diversity of other corals is low.

Southeastern U.S. deep-coral systems support a well developed community that appears to be faunistically different from surrounding non-reef habitats. The fish community on these deep reefs is composed of many species that do not (or at least rarely) occur off the reefs (Ross and Quattrini 2007). Therefore, they may be considered primary reef fishes, in a way similar to those on shallow reefs. Many fish species thought to be rare and/or outside their reported ranges have been found on these reefs (Ross and Quattrini 2007). Most likely these species only appeared to be rare because they occurred in areas that were difficult to sample by conventional means. Thus, these deep-coral habitats support a fish community that appears to be tightly coupled to the habitat and has essentially escaped detection until recently. Invertebrate communities are also very diverse and well developed; however, their associations with the reef habitat seem to be more opportunistic than is the case for certain fish species. However, invertebrate groups are poorly known on the slope reefs, and additional data are required from diverse habitats to evaluate habitat associations and allow comparisons with other ecosystems.

It is clear that the continental slope of the southeast region is important for corals and biodiversity. This is evidenced from the numerous new coral habitats discovered, the wide ranging extent and diversity of corals, numerous species from a variety of taxa newly recorded for the area, the many species new to science, and the fact that more fishes were recorded around these banks than any other deep-coral habitats worldwide. Some corals also provide important scientific data that will increase our understanding of climate and oceanographic changes. Some corals and/or associated fauna (e.g., sponges) may have significant biomedical value. The overall impact of biodiversity in marine systems is significant (Worm et al. 2006), and while biodiversity of southeastern U.S. deep-coral systems is still poorly documented, these ecosystems are obviously a major component of regional slope ecology. Their protection, coupled with ongoing research, is necessary.

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Appendix 6.1. Checklist of deep corals occurring off the southeastern United States (Cape Hatteras, NC to Key Biscayne, FL) at 200-1000 m depth (except shallower *Oculina*). Higher taxa are in phylogenetic order; families, genera and species are in alphabetical order. Some species have cosmopolitan distributions; however, only the northwestern Atlantic portion of their geographic ranges are reported. MR = museum records (holdings of the National Museum of Natural History, Smithsonian Institution). C & B = Cairns & Bayer (2002, 2003, 2004a, 2004b) *** = Cairns (1979, 2000), Cairns et al. 1999, Cairns & Chapman 2001, unpublished records. S = azooxanthellate solitary scleractinian corals. State of knowledge for the solitary corals is limited; therefore, species-specific geographic and bathymetric ranges are not given. Species included in this list have either been reported from the southeastern U.S. or are likely to occur in the region based on Cairns (1979, 2000), Cairns et al. 1999, and data obtained from unpublished records.

Higher Taxon	Species	Distribution	Depth Range(m)	Reference
Phylum Cnidaria				
Class Anthozoa				
Subclass Hexacorallia				
Order Scleractinia				
Family Anthemiphylliidae	*Anthemiphyllia patera* Pourtalès, 1878			S
Family Caryophylliidae	*Anomocora fecunda* (Pourtalès, 1871)			S
	Asterosmilia marchadi (Chevalier, 1966)			S
	Asterosmilia prolifera (Pourtalès, 1871)			S
	Caryophyllia ambrosia caribbeana Cairns, 1979			S
	Caryophyllia antillarum Pourtalès, 1874			S
	Caryophyllia berteriana Duchassing, 1850			S
	Caryophyllia polygona Pourtalès, 1878			S
	Cladocora debilis Milne Edwards & Haime, 1849			S
	Concentrotheca laevigata (Pourtalès, 1871)			S
	Crispatotrochus squiresi (Cairns, 1979)			S
	Dasmosmilia lymani (Pourtalès, 1871)			S
	Deltocyathus agassizii Pourtalès, 1867			S
	Deltocyathus calcar Pourtalès, 1874			S
	Deltocyathus eccentricus Cairns, 1979			S
	Deltocyathus italicus (Michilotti, 1838)			S
	Deltocyathus moseleyi Cairns, 1979			S
	Deltocyathus pourtalesi Cairns, 1979			S

Higher Taxon	Species	Distribution	Depth Range	Reference
	Desmophyllum dianthus (Esper, 1794)			S
	Labyrinthocyathus facetus Cairns, 1979			S
	Labyrinthocyathus langae Cairns, 1979			S
	Lophelia pertusa (Linnaeus, 1758)	Nova Scotia - FL Straits; eastern Gulf of Mexico; Lesser Antilles	95-2000; commonly 500-800	***
	Oxysmilia rotundifolia (Milne Edwards & Haime, 1848)			S
	Paracyathus pulchellus (Philippi, 1842)			S
	Premocyathus cornuformis (Pourtalès, 1868)			S
	Solenosmilia variabilis Duncan, 1873	GA - Suriname	220-1383	***
	Stephanocyathus coronatus (Pourtalès, 1867)			S
	Stephanocyathus diadema (Moseley, 1876)			S
	Stephanocyathus laevifundus Cairns, 1977			S
	Stephanocyathus paliferus Cairns, 1977			S
	Tethocyathus cylindraceus (Pourtalès, 1868)			S
	Tethocyathus recurvatus (Pourtalès, 1878)			S
	Tethocyathus variabilis Cairns, 1979			S
	Trochocyathus rawsonii Pourtalès, 1874			S
Family Dendrophylliidae	*Balanophyllia cyathoides* (Pourtalès, 1871)			S
	Balanophyllia floridana Pourtalès, 1868			S
	Bathypsammia fallosocialis Squires, 1959			S
	Bathypsammia tintinnabulum (Pourtalès, 1868)			S
	Cladopsammia manuelensis (Chevalier, 1966)	Straits of FL; northern Gulf of Mexico; Arrowsmith Bank, Yucatan	55-366	***
	Eguchipsammia gaditana (Duncan, 1873)	NC, GA; Arrowsmith Bank, Yucatan	146-505	***
	Enallopsammia profunda (Pourtalès, 1867)	MA - Straits of Florida	403-1748	***
	Enallopsammia rostrata (Pourtalès, 1878)	GA; off Nicaragua	300-1646	***

Higher Taxon	Species	Distribution	Depth Range	Reference
	Thecopsammia socialis Pourtalès, 1868			S
Family Flabellidae	*Flabellum atlanticum* Cairns, 1979			S
	Flabellum moseleyi Pourtalès, 1880			S
	Javania cailleti (Duchassaing & Michelotti, 1864)			S
	Polymyces fragilis (Pourtalès, 1868)			S
Family Fungiacyathidae	*Fungiacyathus symmetricus* (Pourtalès, 1871)			S
Family Guyniidae	*Pourtalocyathus hispidus* (Pourtalès, 1878)			S
	Schizocyathus fissilis Pourtalès, 1874			S
	Stenocyathus vermiformis (Pourtalès, 1868)			S
Family Oculinidae	*Madrepora carolina* (Pourtalès, 1871)	NC - FL; Greater Antilles; western Caribbean; Gulf of Mexico	53-801; commonly 200-300	***
	Madrepora oculata Linnaeus, 1758	GA - Rio de Janeiro, Brazil; Gulf of Mexico	144-1391	***
	Oculina varicosa Lesueur, 1821	NC - FL; West Indies; Bermuda	3-150	***
Family Pocilloporidae	*Madracis myriaster* (Milne Edwards & Haime, 1849)	GA - Suriname; throughout the Caribbean and Gulf of Mexico	20-1220	***
Family Turbinoliidae	*Cryptotrochus carolinensis* Cairns, 1988			S
	Deltocyathoides stimpsonii (Pourtalès, 1871)			S
Order Antipatharia				
Family Leiopathidae	*Leiopathes glaberrima* (Esper, 1788)	GA; FL; Gulf of Mexico (FL;AL; LA); Jamaica; Campeche Bank, Mexico; Venezuela	37; 220-685	20 MR; Ross et al. unpub.
	Leiopathes spp.			
Family Schizopathidae	*Bathypathes alternata* Brook, 1889	SC; GA; FL; Yucatan Channel (off Arrowsmith Bank)	412-658	3 MR; Ross et al. unpub.
	Parantipathes sp.			
Order Zoanthidae				
Family Gerardiidae	*Gerardia* spp.			

Higher Taxon	Species	Distribution	Depth Range	Reference
Subclass Octocorallia				
Order Alcyonacea				
Family Alcyoniidae	*Anthomastus agassizi* Verrill, 1922	Canada (Nova Scotia, Newfoundland); MA; DE; GA; FL; Bahamas	320-3186	28 MR; Ross et al. unpub.
	Anthomastus grandiflorus Verrill, 1878	Canada (off Nova Scotia, Newfoundland); MA; VA; NC	137-457; 750-2919	41 MR
	Bellonella rubistella (Deichmann, 1936)	FL; Bahamas; Colombia; Venezuela; Trinidad; Tobago; Suriname; Dominican Republic; St. Lucia	24-329	25 MR
Family Clavulariidae	*Clavularia modesta* (Verrill, 1874)	Canada (off Nova Scotia, Newfoundland); ME; MA; SC; GA; FL	29-861	63 MR
	Scleranthelia rugosa (Pourtalès, 1867)	SC; Bahamas; Dominican Republic; Martinique	175-586	9 MR
	Telesto fruticulosa Dana, 1846	NC; SC; GA; FL	13-105	218 MR
	Telesto nelleae Bayer, 1961	NC; Straits of FL (off Havana, Cuba); Bahamas	27-298; 1023-1153	19 MR
	Telesto sanguinea Deichmann, 1936	SC; FL; Gulf of Mexico (off FL, LA)	24-134	44 MR
	Trachythela rudis Verrill, 1922	FL	805	1 MR
Family Nephtheidae	*Gersemia fruticosa* (Sars, 1890)	Canada (off Nova Scotia, Newfoundland); MA; DE; VA; FL	91-368; 770; 2107-3506	42 MR
	Pseudodrifa nigra (Pourtalès, 1868)	SC; GA; FL; Bahamas; Straits of FL (off FL Keys; Havana, Cuba); Gulf of Mexico (off FL Keys)	60-878; 1153-1023	47 MR; Ross et al. unpub.
Family Nidaliidae	*Siphonogorgia agassizii* (Deichmann, 1936)	FL; Gulf of Mexico (FL; TX)	14-159; 350-400	27 MR
Order Gorgonacea				
Family Chrysogorgiidae	*Chrysogorgia multiflora* Deichmann, 1936	GA; FL; Bahamas; Straits of FL (off Key West); Gulf of Mexico (FL Keys); Lesser Antilles; Brazil	320-1354	Cairns, 2001b; 14 MR
	Chrysogorgia squamata (Verrill,1883)	Jacksonville, Fl; Caribbean	430-1050	Ross et al. unpub.

Higher Taxon	Species	Distribution	Depth Range	Reference
Family Coralliidae	*Corallium* sp.			
	Corallium niobe Bayer, 1964	off Jupiter Inlet; Bahamas	659-677; 1023	3 MR
Family Gorgoniidae	*Eunicella modesta* (Verrill, 1883)	Savannah lithoherms, GA; east coast FL *Lophelia* reefs	518-732	Reed 2004; Ross et al. unpub.
Family Isididae	*Acanella eburnea* (Pourtalès, 1868)	Hudson Canyon; SC; FL; Bahamas; Gulf of Mexico (FL; LA; TX); Caribbean Sea (Nevis)	309-2100	34 MR
	Keratoisis flexibilis (Pourtalès, 1868)	GA; FL; eastern Gulf of Mexico; Bahamas; Campeche Bank, Mexico; Guadeloupe; Colombia; Venezuela	170-878	29 MR
	Keratoisis ornata Verrill, 1878	Canada (off Nova Scotia, Newfoundland); MA; GA; FL; Bahamas; Cuba	274-3236	45 MR; Ross et al. unpub.
	Lepidisis longiflora Verrill, 1883	FL; Caribbean Sea (Nevis)	743-1125	2 MR
Family Paragorgiidae	*Paragorgia arborea* (Linnaeus, 1782)	Canada; MA; NJ; MD; VA; NC	247-680	9 MR
	Paragorgia johnsoni Gray, 1862	Florida Straits (off Palm Beach); Bahamas	522-608	6 MR
Family Plexauridae	*Paramuricea placomus* (Linnaeus, 1758)	Canada (off Nova Scotia); GA; FL; Straits of FL (off Havana, Cuba)	247-805	6 MR
	Paramuricea sp.			
	Swiftia casta (Verrill, 1883)	MA; SC; GA; FL; Straits of FL (off FL Keys; Havana, Cuba); Bahamas; Gulf of Mexico (FL; LA); Yucatan Channel (off Arrowsmith Bank)	40-1953	49 MR
	Swiftia exserta (Ellis & Solander, 1786)	GA; FL; Straits of FL (off FL Keys); Bahamas; Puerto Rico; Gulf of Mexico (FL; MS); Mexico; Panama; Colombia; Venezuela; Tobago; French Guiana; Guyana; Brazil	18-494	54 MR

Higher Taxon	Species	Distribution	Depth Range	Reference
	Swiftia koreni (Wright & Studer, 1889)	Lydonia Canyon; FL; Gulf of Mexico (off FL Keys)	221-858	3 MR
Family Primnoidae	*Callogorgia americana americana* Cairns & Bayer, 2002	Straits of Florida; Lesser Antilles	183-732	C & B, 2002
	Callogorgia gracilis (Milne Edwards & Haime, 1857)	off central Florida; Bahamas; Antilles; off Honduras; northern Gulf of Mexico	82-514	C & B, 2002
	Calyptrophora gerdae Bayer, 2001	Straits of FL	229-556	Bayer, 2001
	Calyptrophora trilepis (Pourtalès, 1868)	SC; GA; Bahamas	593-911	Bayer, 2001; 8 MR
	Candidella imbricata (Johnson, 1862)	New England seamounts; Bermuda; eastern coast FL; Bahamas; Antilles; northern Gulf of Mexico	514-2063	C & B, 2004b
	Narella bellissima (Kukenthal, 1915)	Straits of FL (off Delray Beach); Bahamas; Lesser Antilles	161-792	C & B, 2003
	Narella pauciflora Deichmann, 1936	Straits of FL (off Delray Beach); Bahamas; Cuba; Puerto Rico; Campeche Bank, Mexico	738-1473	C & B, 2003
	Narella versluysi (Hickson, 1909)	Bermuda; Straits of FL (off St. Lucie Inlet, Palm Beach, Delray Beach;Bahamas); Cuba	677-900	C & B, 2003
	Paracalyptrophora duplex Cairns & Bayer, 2004	Straits of FL (off Cape Canaveral - Cuba); Bahamas; Lesser Antilles	374-555	C & B, 2004a
	Paracalyptrophora simplex Cairns & Bayer, 2004	Insular side Straits of FL (off Palm Beach, north of Little Bahama Bank), Bahamas to Yucatan Channel	165-706	C & B, 2004a
	Plumarella aurea (Deichmann, 1936)	off SC to Cuba	310-878	C & B, 2004b
	Plumarella dichotoma Cairns & Bayer, 2004	off SC to FL	494-1065	C & B, 2004b
	Plumarella laxiramosa Cairns & Bayer, 2004	off North and South Carolina	348-572	C & B, 2004b

Higher Taxon	Species	Distribution	Depth Range	Reference
	Plumarella pellucida Cairns & Bayer, 2004	off NC, through Straits of FL; Bahamas	549-1160	C & B, 2004b
	Plumarella pourtalesii (Verrill, 1883)	off NC, through Straits of FL; Cuba; Bahamas	183-882	C & B, 2004b
	Thouarella bipinnata Cairns, 2006	off northern FL; Straits of FL; off Little Bahama Bank; off Guyana	507-1000	Cairns, 2006; Ross et al. unpub.
Order Pennatulacea				
Family Kophobelemnidae	*Kophobelemnon sertum* Verrill, 1885	off NC	1542	1 MR
Class Hydrozoa				
Order Anthoathecatae				
Suborder Filifera				
Family Stylasteridae	*Crypthelia floridana* Cairns,1986	eastern, southwestern FL	593-823	Cairns, 1986
	Distichopora foliacea Pourtalès, 1868	GA; Straits of FL (off FL Keys); SE Gulf of Mexico; Yucatan Channel (off Arrowsmith Bank)	183-527	Cairns, 1986
	Pliobothrus symmetricus Pourtalès, 1868	SC through Lesser Antilles	73-922; commonly 150-400	Cairns, 1986
	Stylaster complanatus Pourtalès, 1867	GA; Bahamas; Yucatan Peninsula; Virgin Islands	183-707	Cairns, 1986
	Stylaster erubescens Pourtalès, 1868	SC - SW FL; Bahamas; Cay Sal Bank; Yucatan Channel (off Arrowsmith Bank)	146-965; commonly 650-850	Cairns, 1986
	Stylaster laevigatus Cairns, 1986	SC; Bahamas; Cuba; Yucatan Channel (off Arrowsmith Bank)	123-759; commonly 300-400	Cairns, 1986
	Stylaster miniatus (Pourtalès, 1868)	SC; Straits of FL (off FL Keys); Bahamas; Cuba	146-530	Cairns, 1986