Appendix A. Deep-Water Coral Reefs of Florida, Georgia and South Carolina: A Summary of the Distribution, Habitat, and Associated Fauna.

Report Prepared for the South Atlantic Fishery Management Council.

DEEP-WATER CORAL REEFS OF FLORIDA, GEORGIA AND SOUTH CAROLINA: A SUMMARY OF THE DISTRIBUTION, HABITAT, AND ASSOCIATED FAUNA

by
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ABSTRACT

This report was compiled at the request of the South Atlantic Fishery Management Council (SAFMC) to provide a preliminary, general summary on the status of current knowledge concerning deep-water (> 200 m) reefs off the southeastern U.S. from Florida to North Carolina. The outcome will provide target areas of deep-water, live-bottom habitats for: 1) potential designation as Habitat Areas of Particular Concern (HAPC) or Marine Protected Areas (MPA) by the SAFMC, and 2) high-resolution habitat maps and habitat characterization studies. The resource potential of the deep-water habitats in this region is unknown in terms of fisheries and novel compounds yet to be discovered from associated fauna that may be developed as pharmaceutical drugs. Although these habitats have not been designated as MPAs or HAPCs, they are incredibly diverse and irreplaceable resources. Activities involving bottom trawling, pipelines, or oil/gas production could negatively impact these reefs. This report primarily summarizes recent submersible data regarding deep-water reefs off Florida but also includes sites off Georgia and South Carolina. A report on the North Carolina reefs has been submitted separately by Dr. Steve Ross, UNCW. This report does not include the deep-water *Oculina* reefs off central eastern Florida or deep shelf-edge reefs with hermatypic coral (<100 m). The sites included in this report are the following: 1) Stetson Reefs- hundreds of pinnacles along the eastern Blake Plateau off South Carolina include a 152-m tall pinnacle (822 m depth) where recent submerisible dives discovered live bushes of *Lophelia* coral, sponges, gorgonians, and black coral bushes. 2) Savannah Lithoherms- numerous lithoherms at depths of 550 m with relief up to 60 m provide live-bottom habitat. 3) East Florida *Lophelia* Reefs- echosounder transects along a 222-km stretch off eastern Florida (depth 700-800 m) mapped hundreds of 15-152 m tall coral pinnacles and lithoherms. 4,5) Miami Terrace and Pourtales Terrace- Miocene age terraces off southeastern Florida and the Florida reef tract provide high-relief, hard-bottom habitats and rich benthic communites. 6) SW Florida Lithoherms- in the Gulf of Mexico off the southwestern Florida shelf slope, 15-m tall *Lophelia* coral lithoherms (500 m depth) are described the first time from SEABEAM and ROV dives.

JUSTIFICATION

The South Atlantic Fishery Management Council (R. Pugliese) requested that this preliminary summary report on the state of knowledge of Deep Sea Coral Ecosystems (DSCE) in the region be available in time for the Habitat Advisory Panel meeting of the SAFMC, October 26, 2004. The Council needs immediate scientific data and maps as it considers designation of new Habitat Areas of Particular Concern (HAPC) to protect DSCE areas. Such protection may be needed to prevent long-term (perhaps permanent) damage, such as has occurred on shallower *Oculina* reefs off Florida and *Lophelia* banks in the northeastern Atlantic, both destroyed in part by trawling. After trawlers were banned from the *Oculina* HAPC, there is justified concern that trawlers may move to deeper habitats in search of valuable commercial fisheries, such as royal red shrimp or benthic finfish. NOAA is currently developing priority mapping sites, including Marine Protected Areas and DSCE. NOAA OE funding for 2005 will likely support habitat mapping of shelf-edge and deep-water reef habitats in the South Atlantic Bight and Gulf of Mexico. Data compiled in this report provides potential targets for future mapping, MPAs and HAPCs. The resource potential of the deep-water habitats in this region is unknown in terms of fisheries and novel compounds yet to be discovered from associated fauna that may be developed as pharmaceutical drugs. Although these habitats are not currently designated as MPAs or HAPCs, they are incredibly diverse and irreplaceable resources. Activities involving bottom trawling, pipelines, or oil/gas production could negatively impact these reefs.

OBJECTIVES

Objectives of this report and accompanying DVD are the following:

1) Compile list of references regarding geology and biology of deep-water reef habitats in the South Atlantic Bight, Straits of Florida and southwest Florida slope.
2) Describe general habitat for each reef type and region (northeastern Florida, Straits of Florida, southwest Florida slope, and areas of DSCE off Georgia and South Carolina).
3) Provide representative digital still images and video clips for examples of reef types and regions (on DVD).
4) Provide species list of dominant benthic invertebrates that are directly associated with these reefs based on recent collections and observations by the PI (based on current status of taxonomic identifications).
5) Provide species list of fish that are directly associated with these reefs based on recent collections and observations by the PI (based on current status of taxonomic identifications).
6) Provide general maps of known DSCE reefs in the region.

BACKGROUND

Deep-water reefs are sometimes defined as bioherms, coral banks, or lithoherms (Teichert, 1958; Stetson et al., 1962; Neumann et al., 1977; Wilson, 1979; Reed, 1980; Freiwald et al. 1997; Fosså et al. 2000; Paull et al., 2000). Some deep-water reefs consist of caps of living coral on mounds of unconsolidated mud and coral debris, such as some *Oculina* and *Lophelia* coral reefs (Reed 2002a,b), whereas deep-water lithoherms are defined as high-relief, lithified carbonate limestone mounds rather than unconsolidated mud mounds (Neumann et al., 1977). Rogers (1999) has suggested that deep-water coral bioherms fall within the definition of a coral reef based on their physical and biological characteristics. Various types of deep-water, high-relief bioherms are common off the southeastern United States, along the base of the Florida-Hatteras Slope, on the Blake Plateau, in the Straits of Florida, and eastern Gulf of Mexico. Only a small percentage of deep-water reefs have had their benthic and fish resources characterized.

Recent research expeditions by Principal Investigator (PI), J. Reed, Harbor Branch Oceanographic Institution (HBOI), using HOVs (human occupied vehicle) and ROVs (remotely operated vehicle) along with previous research by the PI in the 1990s and 1980s, have compiled new information on the status, distribution, habitat, and biodiversity of some of these relatively unknown and newly discovered deep reef ecosystems. In 2004, during a State of Florida funded mission with the *Johnson-Sea-Link* (*JSL*) Submersible, the PI discovered nearly 300 potential targets during echosounder transects that may be newly discovered deep-water reefs off the east coast of Florida, some of which are up to 168 m (550 feet) in height at depths of 732 m (2400 feet) (Reed and Wright, 2004; Reed et al., 2004b). Expeditions in 2002 and 2003 for biomedical research by the PI and funded by the National Oceanic and Atmospheric Administration's Office of Ocean Exploration (NOAA OE) enabled preliminary exploration of additional deep-water reef sites in the western Atlantic (Blake Plateau) and eastern Gulf of Mexico on southwest Florida shelf slope (Reed, 2003, 2004; Reed and Pomponi, 2002b; Reed et al., 2002, 2003, 2004d). These were the first HOV and ROV dives ever to document the habitat and benthic biodiversity of some of these relatively unknown deep-water reefs. A small scale, high-definition topographic SEABEAM map was also conducted by the PI at the southwest Florida site. Considerable work remains to analyze these data and prepare for scientific publications (three papers in preparation or submitted by PI: Florida's Deep-Water *Lophelia* Reefs; Miami Terrace Deep-Water Reefs; Deep-Water Sinkholes and Bioherms of Pourtales Terrace- Habitat and Biology). These are very preliminary analyses based on only a few submersible or ROV dives at the various sites.

<u>Florida DSCE</u>

Deep sea coral ecosystems (DSCE) in U.S. EEZ waters exist along the eastern and southwest Florida shelf slope (in addition to the *Oculina* Marine Protected Area and deep shelf-edge reefs with hermatypic coral). These include a variety of high-relief, hard-bottom, live-bottom habitats at numerous sites along the base of the Florida-Hatteras Slope off northeastern and central eastern Florida, the Straits of Florida, the Miami Terrace and Pourtales Terrace off southeastern Florida, and the southwestern Florida shelf slope. The predominate coral on these reefs are the azooxanthellate, colonial scleractinian corals, *Lophelia pertusa*, *Madrepora oculata*, and *Enallopsammia profunda*; various species of hydrocorals of the family Stylasteridae, and species of the bamboo octocoral of the family Isididae. Various types of high-relief, live-bottom habitat have been discovered in the area: *Lophelia* mud mounds, lithoherms, sinkholes, ancient Miocene escarpments and karst topographic features (Reed 2002b; Reed et al., 2004a,b). These all provide hard-bottom substrate and habitat for sessile macrofauna including deep-water corals, octocorals (gorgonians), black coral, and sponges, which in turn provide habitat and living space for a relatively unknown but biologically rich and diverse community of associated fish, crustaceans, mollusks, echinoderms, polychaete and sipunculan worms, and other macrofauna, many of which are undoubtedly undescribed species. Our preliminary studies have found new species of octocorals and sponges from some these sites (Reed et al., 2004 a,b).

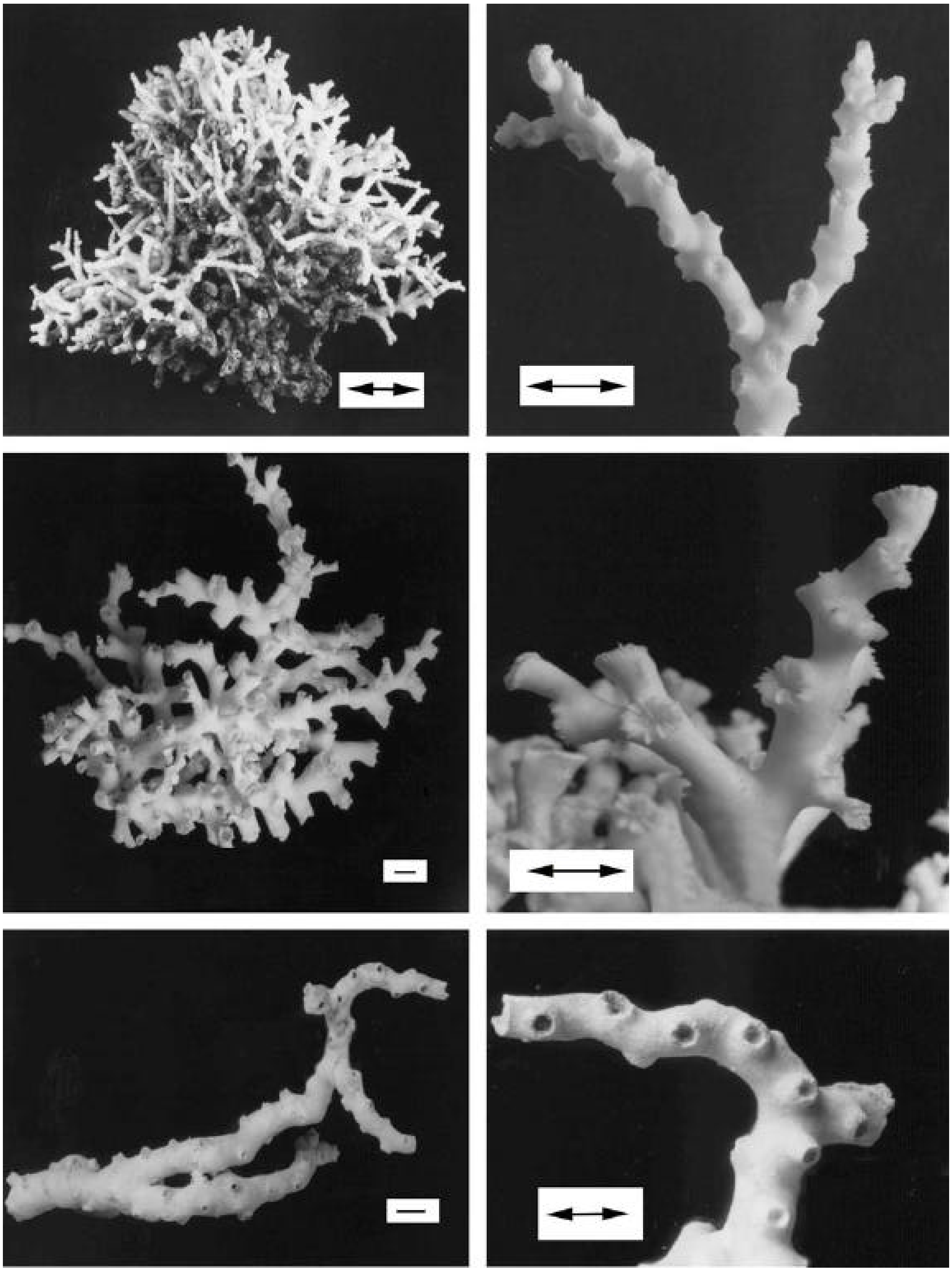
RESULTS

<u>Coral Description and Distribution (from Reed, 2002a)</u>

The dominant colonial scleractinian coral species forming deep-water reefs in the western North Atlantic region are *Oculina varicosa*, *Lophelia pertusa*, and *Enallopsammia profunda*, although other branching colonial scleractinia may also occur, including *Solenosmilia variabilis* and *Madrepora oculata* (Figs. 1 and 2). Numerous solitary coral species are also common (Cairns, 1979).

Lophelia pertusa (*Linnaeus*, 1758) (= *L. prolifera*): This coral forms massive, dendroid, bushy colonies, 10-150 cm in diameter, with anastomosing branches (Figure 1). Its distribution ranges in the western Atlantic from Nova Scotia to Brazil and the Gulf of Mexico, and also in the eastern Atlantic, Mediterranean, Indian, and eastern Pacific Oceans at depths of 60-2170 m (Cairns, 1979). Along with *Enallopsammia profunda*, it is the primary constituent of deep-water reefs at the base of

Figure 1. Coral colony and branch tip: top- *Oculina varicosa* (80m); middle- *Lophelia pertusa* (490m); bottom- *Enallopsammia profunda* (585m). (scale lines = 1 cm; top left fig. Scale = 5 cm) (from Reed, 2002a; Hydrobiologia 471: 57-69)



the Florida-Hatteras slope and at depths of 500-800 m from Miami to South Carolina (Figure 3, Region B and C). In addition, over 200 banks have been mapped at depths of 640-869 m (Region D) on the outer eastern edge of the Blake Plateau (Stetson et al., 1962; Popenoe and Manheim, 2001). Elsewhere deep-water *Lophelia* reefs are known from the Gulf of Mexico (Ludwick & Walton, 1957; Moore & Bullis, 1960; Newton et al., 1987) and the eastern Atlantic off Norway and Scotland (Teichert, 1958; Wilson, 1979a; Mortensen et al., 1995; Freiwald et al., 1997, 1999). In the eastern Atlantic, *Madrepora oculata* commonly occurs with *Lophelia* rather than *E. profunda*.

Enallopsammia profunda (Pourtalès, 1867) (=*Dendrophyllia profunda*): This species also forms dendroid, massive colonies up to 1 m in diameter (Figure 1). It is endemic to the western Atlantic and ranges from the Antilles in the Caribbean to Massachusetts at depths of 146-1748 m (Cairns, 1979). *E. profunda* occurs with *L. pertusa* at Regions B, C, and D (Figure 3). It appears to be the primary constituent of the deep-water reefs at Site D except at the tops of the mounds where *L. pertusa* is more prevalent (Stetson et al., 1962).

Six regions (B-D, G-I) of deep-water reef habitats off southeastern U.S. from Florida to South Carolina may be considered targets for potential HAPCs (Figs. 3-8). Figure 3 shows the general boundaries of Regions A-H off eastern Florida, Georgia, and South Carolina. It also includes the *Oculina* Reefs (A) that are already designated as an HAPC and two regions (E,F) that are within Bahamian waters, but are not discussed in this report (see Reed 2002a,b). Recent submersible dive sites and echosounder locations of high-relief reef habitat off the east coast are shown in Figure 4 (see Table 1 for corresponding dive sites). Details of the *Lophelia* mounds of Region D (Stetson's Reefs) are shown in Figure 5 (Popenoe and Mannheim, 2001). Figure 6 shows the bathymetry and submersible dive sites at Region G, Miami Terrace Escarpment. Figure 7 shows the bathymetry and submersible dive sites at Region H, Pourtales Terrace. Figure 8 shows the bathymetry and ROV dive sites in the Gulf of Mexico at Region I, Southwest Florida Lithoherms.

Figure 2. Depth range and maximum relief of deep-water coral reefs off southeastern U.S.A. Dominant colonial coral listed for each site (see Figure 3 for site locations). (from Reed, 2002a; Hydrobiologia 471: 57-69)

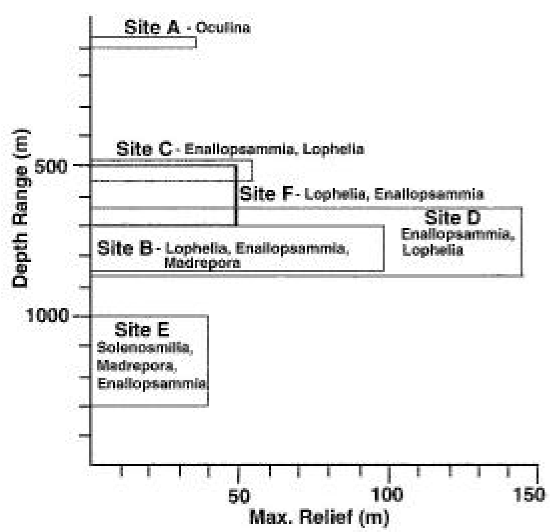


Figure 3. Deep-water coral reef regions off southeastern U.S.A. (see Table 1 for locations).

?= *Johnson-Sea-Link* I and II submersible dive sites and echosounder sites of high-relief reefs; Regions: A=*Oculina* Coral Reefs, B= East Florida *Lophelia* Reefs, C= Savannah *Lophelia* Lithoherms, D= Stetson's Reefs (D1= region of dense pinnacles), E= *Enallopsammia* Reefs (Mullins et al., 1981), F= Bahama Lithoherms (Neumann et al., 1977), G= Miami Terrace Escarpment. (from Reed et al., 2004b; chart from NOAA, NOS, 1986)

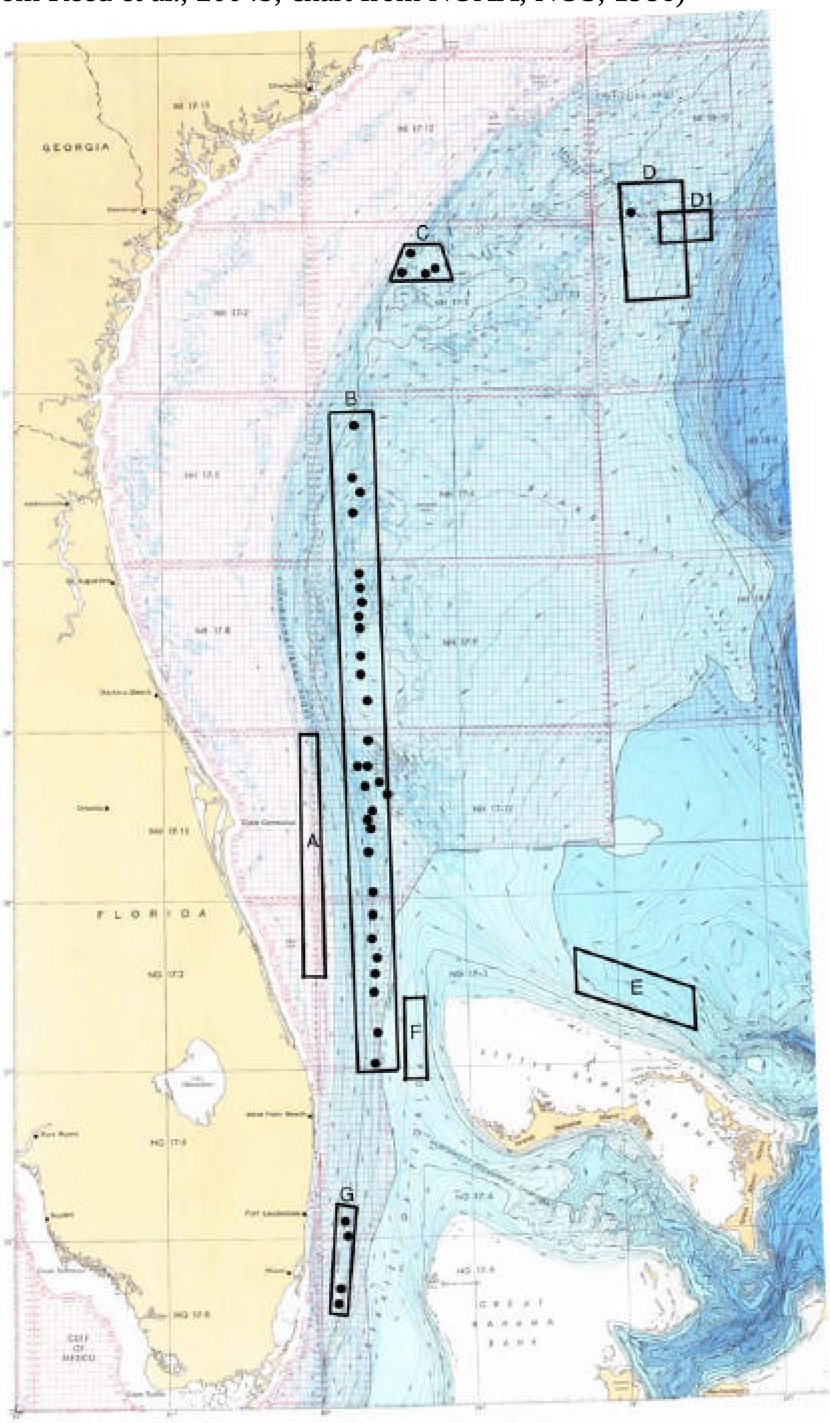


Figure 4. Submersible dive sites and echosounder sites on deep-water reefs off southeastern U.S.A. (see Table 1 for locations). ?# = *Johnson-Sea-Link* I and II submersible dive sites, F# = high-relief pinnacles from echosounder transects. (from Reed et al., 2004b; chart from NOAA, NOS, 1986)

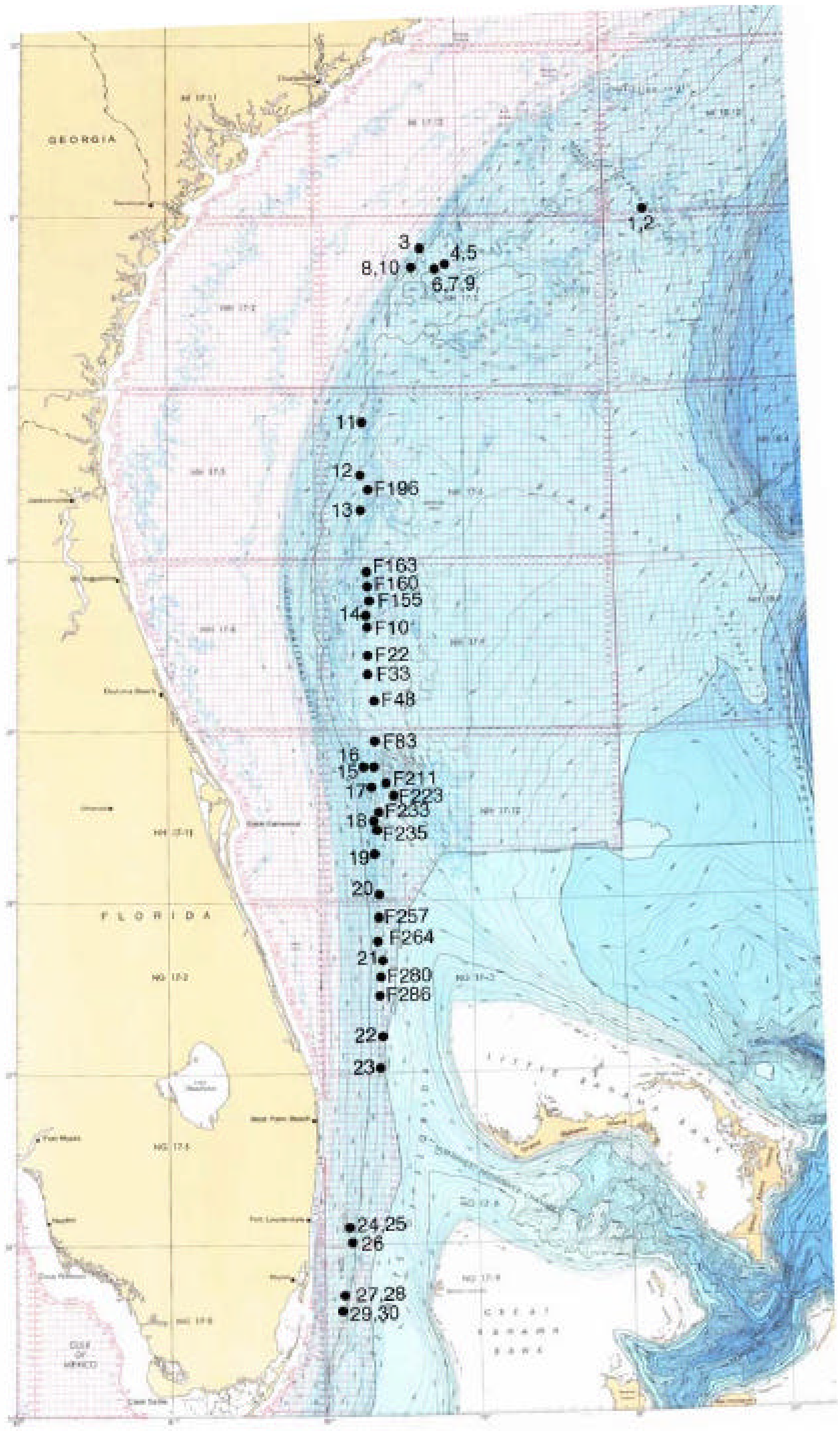


Figure 5. Detailed chart of high-relief region with *Lophelia* coral mounds on Charleston Bump, Blake Plateau. (from Popenoe and Manheim, 2001; American Fisheries Society Symposium 25: 43-94)

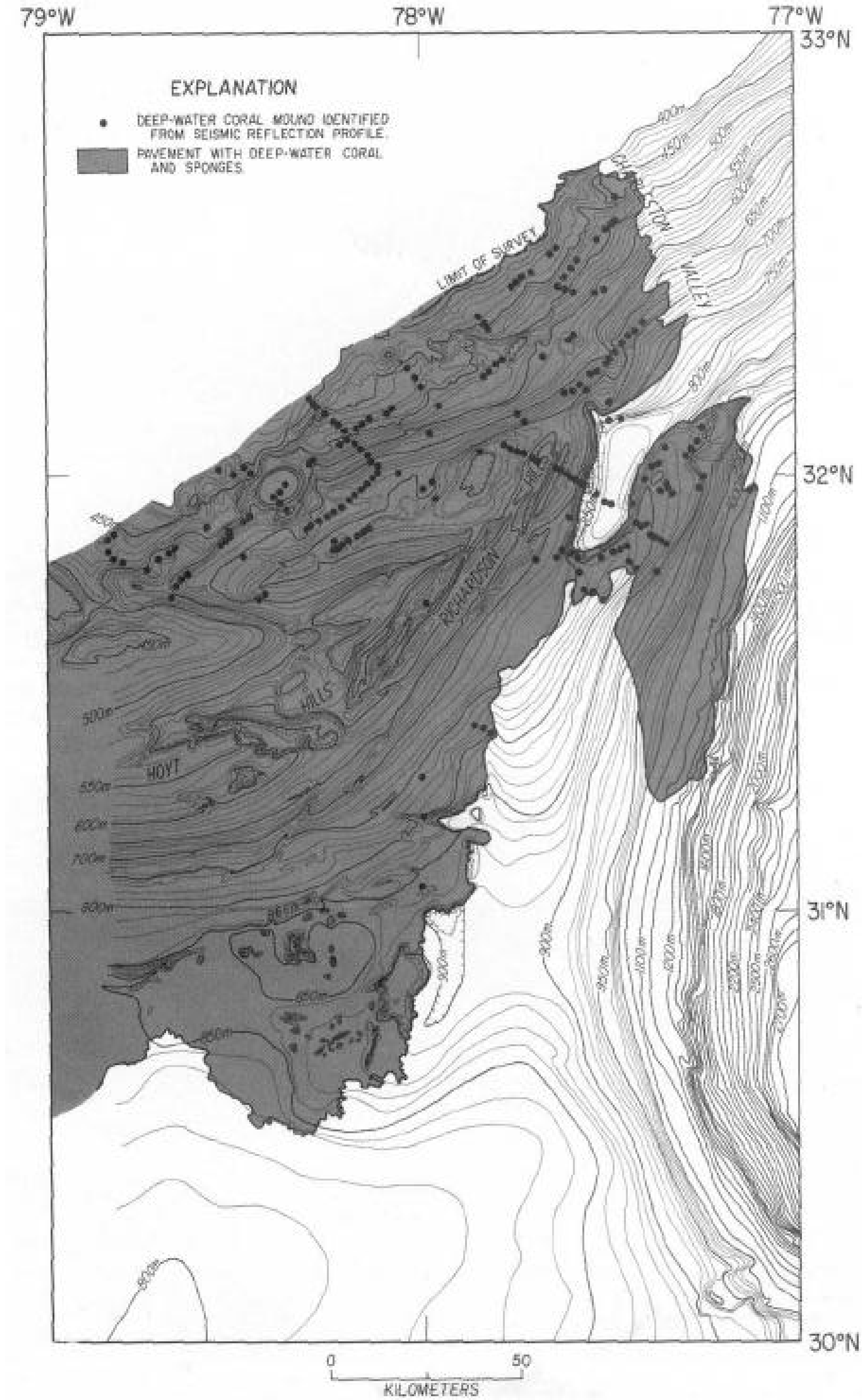


Figure 6. Bathymetry and submersible dive sites on Miami Terrace Escarpment at Region G (see Table 1 for locations). ?= *Johnson-Sea-Link* I submersible dive sites. (from Reed et al., 2004b; chart from Ballard and Uchupi, 1971; MTS Journal 5: 43-48)

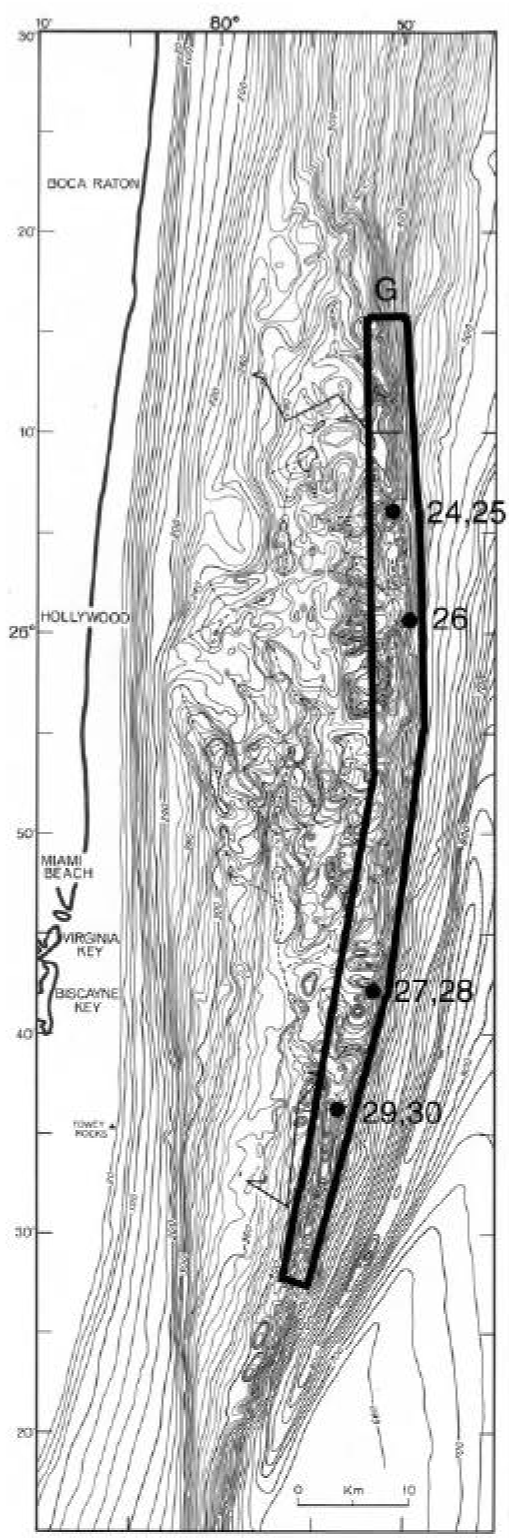


Figure 7. Bathymetry and submersible dive sites on Pourtalès Terrace at Region H (see Table 2 for locations). ?= *Johnson-Sea-Link* and *Clelia* submersible dive sites; JS= Jordan Sinkhole, MS= Marathon Sinkhole, TB1= Tennessee Humps Bioherm #1, TB2= Tennessee Humps Bioherm #2, AB3= Alligator Humps Bioherm #3, AB4= Alligator Humps Bioherm #4. (from Reed et al., 2004b; chart from Malloy and Hurley, 1970; Geol. Soc. Amer. Bull. 81: 1947-1972)

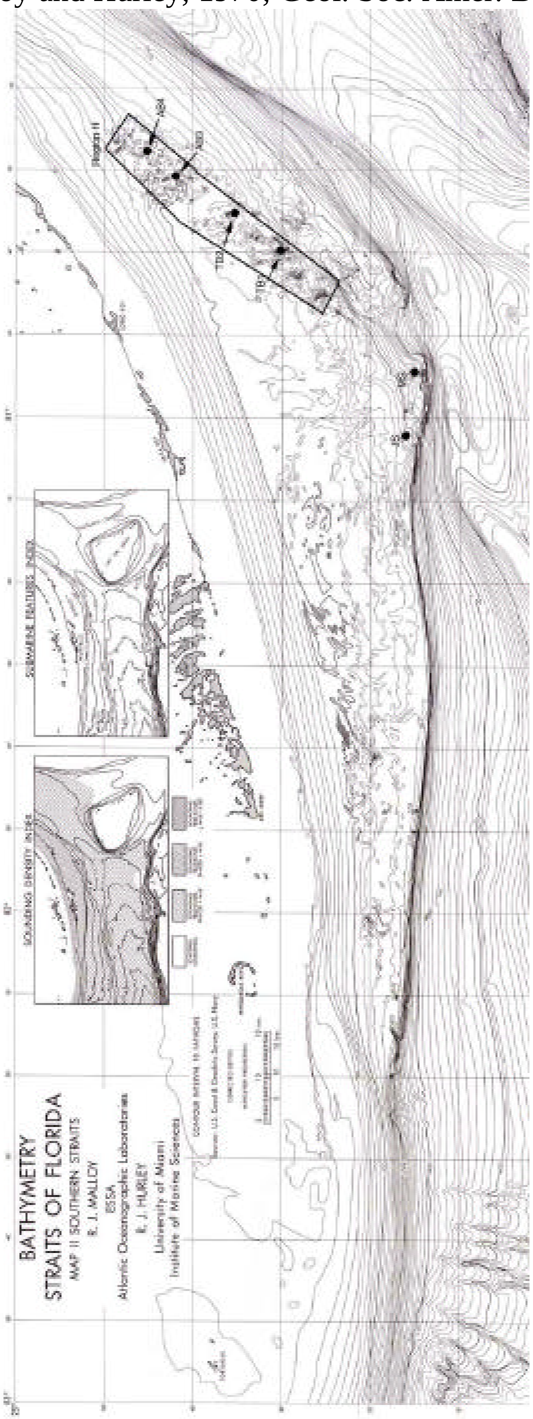
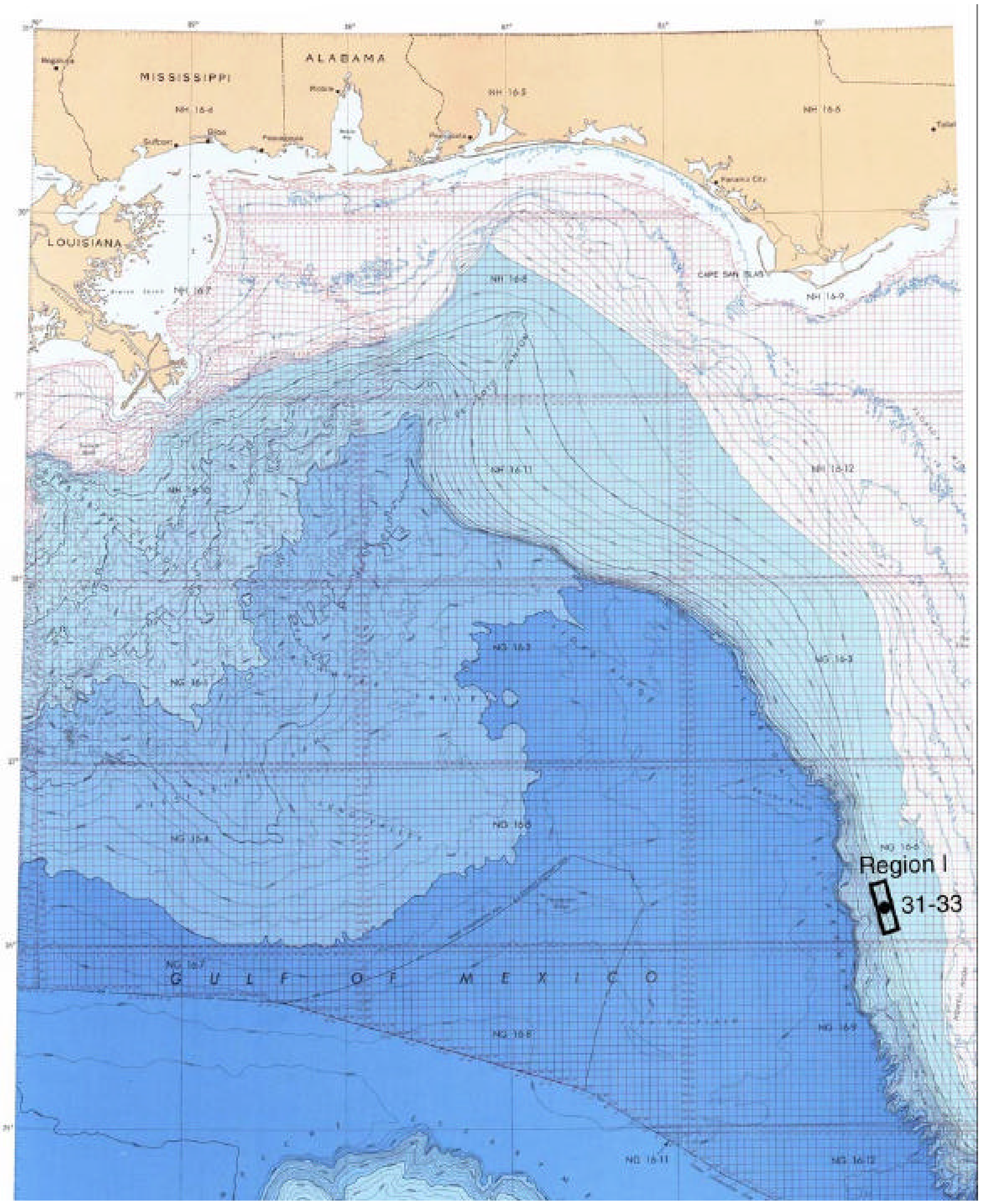


Figure 8. Deep-water coral lithoherms and ROV dive sites at Region I off southwest Florida slope (see Table 1 for locations). ?= *Innovator* ROV dive sites. (from Reed et al., 2004b; chart from NOAA, NOS, 1986)



<u>Deep-water Coral Reef Communities (from Reed, 2002a,b)</u>

The deep-water coral reefs support very rich communities of associated invertebrates. Faunal diversity on the *Oculina* reefs is equivalent to many shallow-water tropical reefs. Over 20,000 individual invertebrates were found living among the live and dead branches of 42 small *Oculina* colonies from deep and shallow water, yielding 230 species of mollusks, 50 species of decapods, 47 species of amphipods, 21 species of echinoderms, 15 species of pycnogonids, and numerous other taxa (Reed et al., 1982; Reed & Hoskin, 1987; Reed & Mikkelsen, 1987; Child, 1998). A striking difference between the *Oculina* and *Lophelia* reefs is that larger sessile invertebrates such as massive sponges and gorgonians are common on the *Lophelia* reefs but are not common on the deep-water *Oculina* reefs. The coral itself is a dominant component providing habitat on both the *Oculina* and *Lophelia* reefs. The percentage of live coral coverage is generally low on the majority of *Lophelia* and *Oculina* reefs in this region (1-10%); however, some areas may have nearly 100% live cover and some areas may have extensive areas of 100% dead coral rubble.

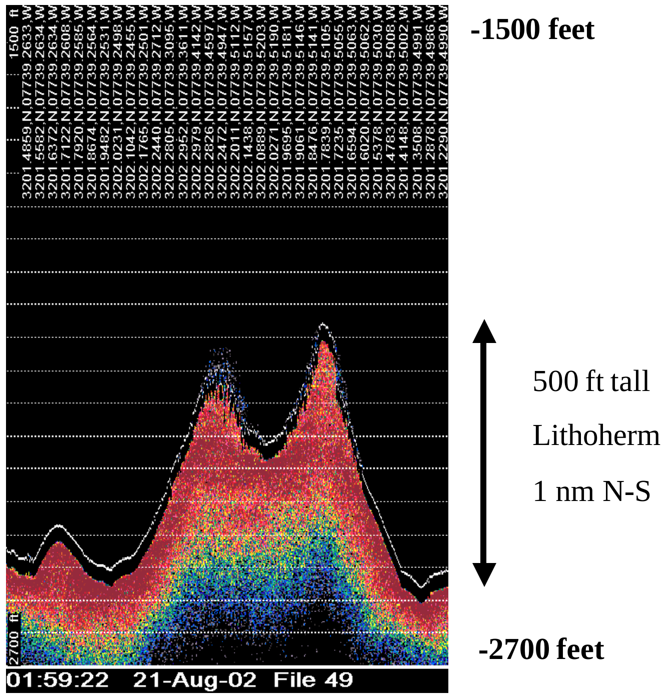
In comparison, Rogers' (1999) review of literature on deep-water *Lophelia* coral reefs in the northeastern Atlantic recorded 886 species of associated invertebrates. Quantified analyses of live and dead colonies of *Lophelia pertusa* from the Faeroe shelf off of Scotland resulted in 298 species, dominated by Polychaeta (67 sp.), Bryozoa (45 sp.), Mollusca (31 sp.), Porifera (29 types), and Crustacea (15 sp.) (Jensen & Frederiksen, 1992). Studies of infauna associated with the *Lophelia* reefs of the western Atlantic reefs off North Carolina have just begun (Ross, in prep).

<u>Region D: Stetson Reefs, Eastern Blake Plateau (from Reed, 2002a; Reed et al., 2004b)</u>

This site is on the outer eastern edge of the Blake Plateau, ~120 nm SE of Charleston, South Carolina, at depths of 640-869 m (Table 1, Figs. 3-5). Over 200 coral mounds up to 146 m in height occur over this 6174 km^2 area that was first described by Thomas Stetson from echo soundings and bottom dredges (Stetson et al., 1962; Uchupi, 1968). These were described as steep-sloped structures with active growth on top of the banks. Live coral colonies up to 50 cm in diameter were observed with a camera sled. *E. profunda* (=*D. profunda*) was the dominant species in all areas although *L. pertusa* was concentrated on top of the mounds. Densest coral growth occurred along an escarpment at Region D1. Stetson *et al*. (1962) reported an abundance of hydroids, alcyonaceans, echinoderms, actiniaria, and ophiuroids, but a rarity of large mollusks. The flabelliform gorgonians were also current-oriented. Popenoe and Manheim (2001) have made detailed geological maps of this Charleston Bump region which also indicate numerous coral mounds (Fig. 5).

Recent fathometer transects by the PI indicated dozens and possibly hundreds of individual pinnacles and mounds within the small region that we surveyed which is only a fraction of the Stetson Bank area (Reed and Pomponi, 2002b; Reed et al., 2002; Reed et al., 2004b). From our fathometer transects, two pinnacle regions were selected. Three submersible dives were made on "Pinnacle 3" and four dives on "Stetson's Peak" which is described below (Table 1). A small subset of the Stetson Bank area was first mapped by six fathometer transects covering ~28 nm^2 (6 nm x 4.7 nm; 31°59.03'N to 32°05.03'N and 77°42.75'W to 77°37.98'W), in which six major peaks or pinnacles and four major scarps were plotted. The base depth of these pinnacles ranged from 689 m to 643 m, with relief of 46 to 102 m. A subset of this was further mapped with 70 fathometer transects spaced 250 m apart (recording depth, latitude and longitude ~ every 3 seconds), covering an area of 1 x 1.5 nm (32°00.5'N to 32°01.5'N and 77°40.0'W to 77°42.5'W), resulting in a 3-D bathymetric GIS Arcview map of a major feature, which we named Stetson's Pinnacle (Fig. 9).

Figure 9. Echosounder profile of Stetson's Pinnacle (depth 780 m, relief 153 m). (from Reed et al., 2004b)



Stetson's Pinnacle was 780 m at the south base and the peak was 627 m (differential GPS coordinates of submersible at the peak: 32°01.6882'N, 77°39.6648'W). This represents one of the tallest *Lophelia* coral lithoherms known, nearly 153 m in relief. The linear distance from the south base to the peak was ~0.5 nm. The lower flank of the pinnacle from ~762 m to 701 m on the south face was a gentle slope of 10-30° with a series of 3-4 m high ridges and terraces that were generally aligned 60-240° across the slope face. These ridges were covered with nearly 100% *Lophelia* coral rubble, 15-30 cm colonies of live *Lophelia*, and standing dead colonies of *Lophelia*, 30-60 cm tall. Very little rock was exposed, except on the steeper exposed, eroded faces of the ridges. Some rock slabs, ~30 cm thick, have slumped from these faces. From 701 m to 677 m the slope increased from ~45° to 60°. From 671 m to the peak, the geomorphology was very complex and rugged, consisting of 60-90° rock walls and 3-9 m tall rock outcrops. Colonies of *Lophelia*, 30-60 cm tall, were more common, and some rock ledges had nearly 100% cover of live *Lophelia* thickets. The top edge of the pinnacle was a 30 cm thick rock crust which was undercut from erosion; below this was a 90° escarpment of 3-6 m. The peak was a flat rock plateau at 625- 628 m and was approximately 0.1 nm across on a S-N submersible transect. The north face was not explored in detail but is a vertical rock wall from the peak to ~654 m then grades to a 45° slope with boulders and rock outcrops.

Dominant sessile macrofauna consisted of scleractinia, stylasterine hydrocorals, gorgonacea and sponges (Table 3). The colonial scleractinia were dominated by colonies of *Lophelia pertusa* (30-60 cm tall) and *Enallopsammia profunda*, and *Solenosmilia variabilis* were present. Small stylasterine corals (15 cm tall) were common and numerous species of solitary cup corals were abundant. Dominant octocorallia consisted of colonies of Primnoidae (15-30 cm tall), paramuriceids (60-90 cm), Isididae bamboo coral (15-60 cm), stolonifera, and stalked Nephtheidae (5-10 cm). Dominant sponges consisted of Pachastrellidae (25 cm fingers and 25-50 cm plates), Corallistidae (10 cm cups), Hexactinellida glass sponges (30 cm vase), *Geodia* sp. (15-50 cm spherical), and *Leiodermatium* sp. (50 cm frilly plates). Although motile fauna were not targeted, some dominant groups were noted. No large decapods crustaceans were common although some red portunids were observed. Two species of echinoids were common, one white urchin and one stylocidaroid. No holothurians or asteroids were noted. Dense populations of Ophiuroidea were visible in close-up video of coral clusters and sponges. No large Mollusca were noted except for some squid. Fish consisted mostly of benthic gadids and rattails. On the steeper upper flank, from 671 to 625 m the density, diversity, and size of sponges increased; 15-50 cm macro sponges were more abundant. Massive *Spongosorites* sp. were common, Pachastrellidae tube sponges were abundant, and Hexactinellida glass sponges were also common. On the peak plateau the dominant macrofauna were colonies of *Lophelia pertusa* (30-60 cm tall), coral rubble, *Phakellia* sp. fan sponges (30-50 cm), and numerous other demosponges were abundant. No large fish were seen on top.

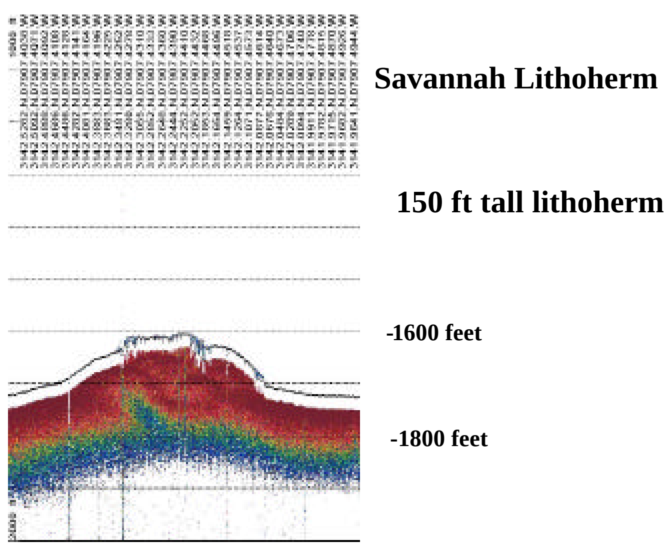
Region C: Savannah Lithoherms, Blake Plateau (from Reed, 2002a; Reed et al., 2004b)

A number of high-relief lithoherms occur within this region of the Blake Plateau, ~90nm east of Savannah, Georgia (Table 1; Figs. 3,4). Region C is at the base of the Florida-Hatteras Slope, near the western edge of the Blake Plateau, and occurs in a region of phosphoritic sand, gravel and rock pavement on the Charleston Bump (Sedberry, 2001). Wenner and Barans (2001) described 15-23 m tall coral mounds in this region that were thinly veneered with fine sediment, dead coral fragments and thickets of *Lophelia* and *Enallopsammia*. They found that blackbellied rosefish and wreckfish were frequent associates of this habitat. In general, the high-relief *Lophelia* mounds occur in this region at depths of 490-550 m and have maximum relief of 61 m (Table 1). *JSL*-II dives 1690, 1697 and 1698 reported a coral rubble slope with <5% cover of 30 cm, live coral colonies (Reed, 2002a). On the reef crest were 30-50 cm diameter coral colonies covering ~10% of the bottom. Some areas consisted of a rock pavement with a thin veneer of sand, coral rubble, and 5-25 cm phosphoritic rocks. At *Alvin* dive sites 200 and 203, Milliman *et al*. (1967) reported elongate coral mounds, approximately 10 m wide and 1 km long, that were oriented NNE-SSW. The mounds had 25-37^o slopes and 54 m relief. Live colonies (10-20 cm diameter) of *E. profunda* (=*D. profunda*) dominated and *L. pertusa* (=*L. prolifera*) was common. No rock outcrops were observed. These submersible dives found that these lithoherms provided habitat for large populations of massive sponges and gorgonians in addition to the smaller macroinvertebrates which have not been studied in detail. Dominant macrofauna included large plate-shaped sponges (*Pachastrella monilifera*) and stalked, fan-shaped sponges (*Phakellia ventilabrum*), up to 90 cm in diameter and height. At certain sites (*JSL*-II dive 1697), these species were estimated at 1 colony/10 m^2. Densities of small stalked spherical sponges (*Stylocordyla* sp., Hadromerida) were estimated in some areas at 167 colonies/10 m^2. Hexactinellid (glass) sponges such as *Farrea*? sp. were also common. Dominant gorgonacea included *Eunicella* sp. (Plexauridae) and *Plumarella pourtalessi* (Primnoidae).

Recent fathometer transects by the PI at Savannah Lithoherm Site #1 (JSL II-3327) extended 2.36 nm S-N (31^{o}40.3898'N to 31^{o}42.7558'N along the longitude of 79^{o}08.5'W) revealed a massive lithoherm feature that consisted of five major pinnacles with a base depth of 549 m, minimum depth of 465 m, and maximum relief of 83 m (Reed and Pomponi, 2002b; Reed et al., 2002; Reed et al., 2004b). The individual pinnacles ranged from 9 to 61 m in height. A single submersible transect, south to north, on Pinnacle #4 showed a minimum depth of 499 m. The south flank of the pinnacle was a gentle 10-20^o slope, with ~90% cover of coarse sand, coral rubble and some 15 cm rock ledges. The peak was a sharp ridge oriented, NW-SE, perpendicular to the prevailing 1 kn current. The north side face of the ridge was a 45^o rock escarpment of about 3 m which dropped onto a flatter terrace. From a depth of 499 to 527 m, the north slope formed a series of terraces or shallow depressions, ~9-15 m wide, that were separated by 3 m high escarpments of 30-45$^{\backslash o}$. Exposed rock surfaces showed a black phosphoritic rock pavement. The dominant sessile macrofauna occurred on the exposed pavement of the terraces and in particular at the edges of the rock outcrops and the crest of the pinnacle. The estimated cover of sponges and gorgonians was 10% on the exposed rock areas. Colonies of *Lophelia pertusa* (15-30 cm diameter) were common but not abundant with ~1% coverage. Dominant Cnidaria included several species of gorgonacea (15-20 cm tall), Primnoidae, Plexauridae (several spp.), *Antipathes* sp. (1 m tall), and *Lophelia pertusa* (Table 3). Dominant sponges included large *Phakellia ventilabrum* (fan sponges, 30-90 cm diameter), Pachastrellidae plate sponges (30 cm), Choristida plate sponges (30 cm), and Hexactinellid glass sponges. Motile fauna consisted of decapod crustaceans (*Chaceon fenneri*, 25 cm; and Galatheidae, 15 cm) and mollusks. Few large fish were observed but a 1.5 m swordfish, several 1 m sharks, and numerous blackbelly rosefish were noted.

A fathometer transect by the PI at Savannah Lithoherm Site 2 extended 4.6 nm, SW to NE (31^{o}42.0812'N, 79^{o}07,6333'W to 31^{o}45.5025'N, 79^{o}04.0797'W), mapped 8 pinnacles with maximum depth of 549 m and relief of 15-50 m (Fig. 10).

Figure 10. Echosounder profile of Savannah Lithoherm, Site 2, Pinnacle #1 (depth 537 m, relief 50 m). (from Reed et al., 2004b)



Submersible dives were made on Pinnacles 1, 5 and 6 of this group (Table 1). Pinnacle 1 was the largest feature of this group; the base was 537 m and the top was 487 m. The south face, from a depth of 518 to 510 m, was a gentle 10^o slope, covered with coarse brown sand and

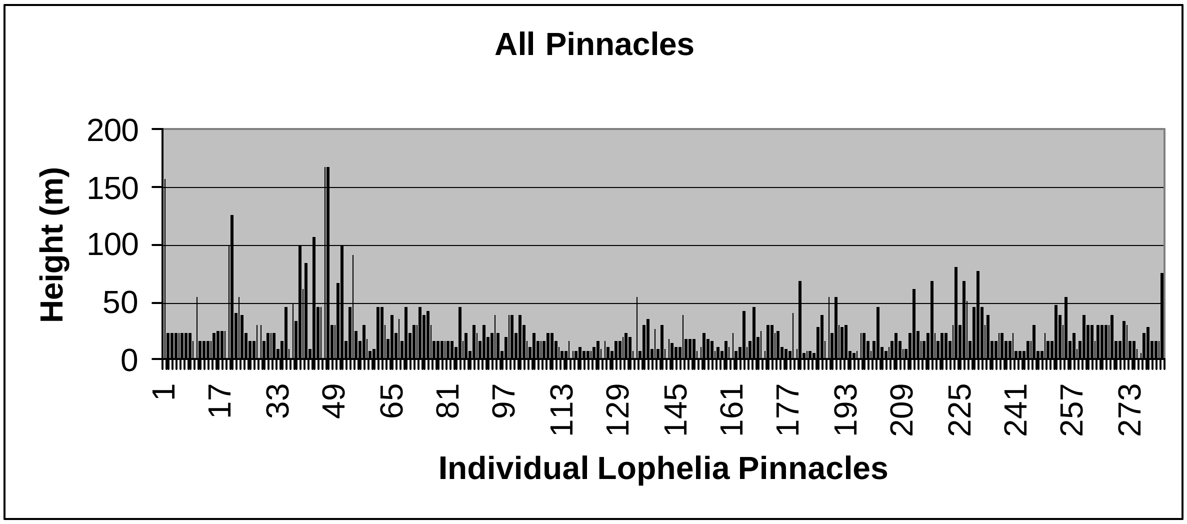
Lophelia coral rubble. A 3-m high ridge of phosphoritic rock, extended NE-SW, cropped out at a depth of 510 m. This was covered with nearly 100% cover of 15 cm thick standing dead *Lophelia* coral and dense live colonies of *Lophelia pertusa* (15-40 cm). From depths of 500 m to 495 m were a series of exposed rock ridges and terraces, that were 3-9 m tall with 45^o slopes. Some of the terraces were ~30 m wide. Each ridge and terrace had thick layers of standing dead *Lophelia*, and dense live coral. These had nearly 100% cover of sponges (*Phakellia* sp., *Geodia* sp., Pachastrellidae, and Hexactinellida), scleractinia (*Lophelia pertusa, Madrepora oculata*), stylasterine hydrocorals, numerous species of gorgonacea (Ifalukellidae, Isididae, Primnoidae), and 1 m bushes of black coral (*Antipathes* sp.). Deep deposits of sand and coral rubble occurred in the depressions between the ridges. The north face, from 500 m to 524 m was a gentle slope of 10^o, that had deep deposits of coarse brown foraminiferal sand and coral rubble. Exposed rock pavement was sparse on the north slope, but a few low rises with live bottom habitat occurred at 524 m. Dominant mobile fauna included decapod crustaceans (*Chaceon fenneri*, 15 cm Galatheidae), rattail fish, and 60 cm sharks were common.

Region B: Florida *Lophelia* Pinnacles (from Reed, 2002a; Reed et al., 2004b)

Numerous high-relief *Lophelia* reefs and lithoherms occur in this region at the base of the Florida-Hatteras Slope and at depths of 670-866 m (Table 1, Figs. 3, 4). The reefs in the southern portion of this region form along the western edge of the Straits of Florida and are 15-25 nmi east of the *Oculina* coral banks Marine Protected Area (MPA). Along a 222-km stretch off northeastern and central Florida (from Jacksonville to Jupiter), nearly 300 mounds from 8 to 168 m in height (25-550 ft) were recently mapped by the PI using a single beam echosounder (Fig. 11; Reed et al., 2004b). Between 1982 and 2004, dives with the *Johnson-Sea-Link* (*JSL*) submersibles and ROVs by the PI confirmed the presence of *Lophelia* mounds and lithoherms in this region (Reed, 2002a; Reed et al., 2002; Reed and Wright, 2004; Reed et al., 2004b). The northern sites off Jacksonville and southern Georgia appeared to be primarily lithoherms which are pinnacles capped with exposed rock (described in part by Paull et al., 2000), whereas the features from south of St. Augustine to Jupiter were predominately *Lophelia* coral pinnacles or mud mounds capped with dense 1-m-tall thickets of *Lophelia pertusa* and *Enallopsammia profunda* with varying amounts of coral debris and live coral. Dominant habitat-forming coral species were *Lophelia pertusa, Madrepora oculata*, *Enallopsammia profunda*, bamboo coral (Isididae), black coral (Antipatharia), and diverse populations of octocorals and sponges (Reed et al., 2004b).

Paull et al. (2000) estimated that over 40,000 coral lithoherms may be present in this region of the Straits of Florida and the Blake Plateau. Their dives with the *Johnson-Sea-Link* submersible and the U.S. Navy's submarine NR-1 described a region off northern Florida and southern Georgia of dense lithoherms forming pinnacles 5 to 150 m in height with 30-60^o slopes that had thickets of live ahermatypic coral (unidentified species, but photos suggest *Lophelia* and/or *Enallopsammia*). The depths range from 440 to >900 m but most mounds were within 500-750 m. Each lithoherm was ~100-1000 m long and the ridge crest was generally oriented perpendicular to the northerly flowing Gulf Stream current (25-50 cm s^{-1} on flat bottom, 50-100 cm s^{-1} on southern slopes and crests). Thickets of live coral up to 1 m were mostly found on the southern facing slopes and crests whereas the northern slopes were mostly dead coral rubble. These were termed lithoherms since the mounds were partially consolidated by a carbonate crust, 20-30 cm thick, consisting of micritic wackestone with embedded planktonic foraminifera, pteropods, and coral debris (Paull et al., 2000).

Figure 11. Height of *Lophelia* pinnacles and lithoherms on echosounder transects from Jacksonville to Jupiter, Florida at depths of 600 to 800 m. (from Reed et al., 2004b)



A recent echosounder transect by the PI revealed a massive lithoherm, 3.08 nm long (N-S) that consisted of at least 7 individual peaks with heights of 30-60 m (Fig. 12; Reed and Wright, 2004; Reed et al., 2004b). The maximum depth was 701 m with total relief of 157 m. Three submersible dives (JSL II-3333, 3334; I-4658) were made on Peak 6 of pinnacle #204B (30°30.1194'N, 79°39.4743'W) which was the tallest individual feature of the lithoherm with maximum relief of 107 m and a minimum depth at the peak of 544 m (Reed et al., 2004b). The east face was a 20-30° slope and steeper (50°) near the top. The west face was a 25-30° slope which steepened to 80° from 561 m to the top ridge. The slopes consisted of sand and mud, rock pavement and rubble. A transect up the south slope reported a 30-40° slope with a series of terraces and dense thickets of 30-60 cm tall dead and live *Lophelia* coral that were mostly found on top of mounds, ridges and terrace edges. One peak at 565 m had dense thickets of live and dead standing *Lophelia* coral (~20% live) and outcrops of thick coral rubble. Dominant sessile fauna consisted of *Lophelia pertusa*, abundant Isididae bamboo coral (30-60 cm) on the lower flanks of the mound, Antipatharia black coral, and abundant small octocorals including the gorgonacea (*Placogorgia* sp., *Chrysogorgia* sp, and Plexauridae) and Nephtheidae soft corals (*Anthomastus* sp., *Nephthya* sp.). Dominant sponges consisted of *Geodia* sp., *Phakellia* sp., *Spongosorites* sp. Petrosiidae, Pachastrellidae, and Hexactinellida (Table 3).

Further south off Cape Canaveral, echosounder transects by the PI on *Lophelia* Pinnacle #113 (28°47.6258'N, 79°37.5859'W) revealed a 61 m tall pinnacle with maximum depth of 777 m (Table 1; Fig. 13). The width (NW-SE) was 0.9 nm and consisted of at least 3 individual peaks or ridges on top, each with 15-19 m relief. One submersible dive (JSL II-3335) reported 30-60° slopes, with sand, coral rubble, and up to 10% cover of live coral. No exposed rock was observed. This appeared to be a classic *Lophelia* mud mound.

Figure 12. Echosounder profile of Jacksonville Lithoherm, Pinnacle #204B (depth 701 m, relief 157 m). (from Reed et al., 2004b)

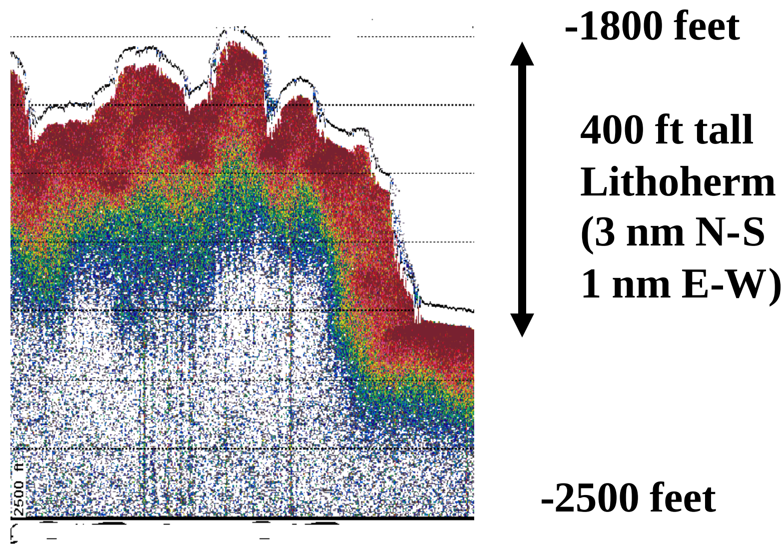
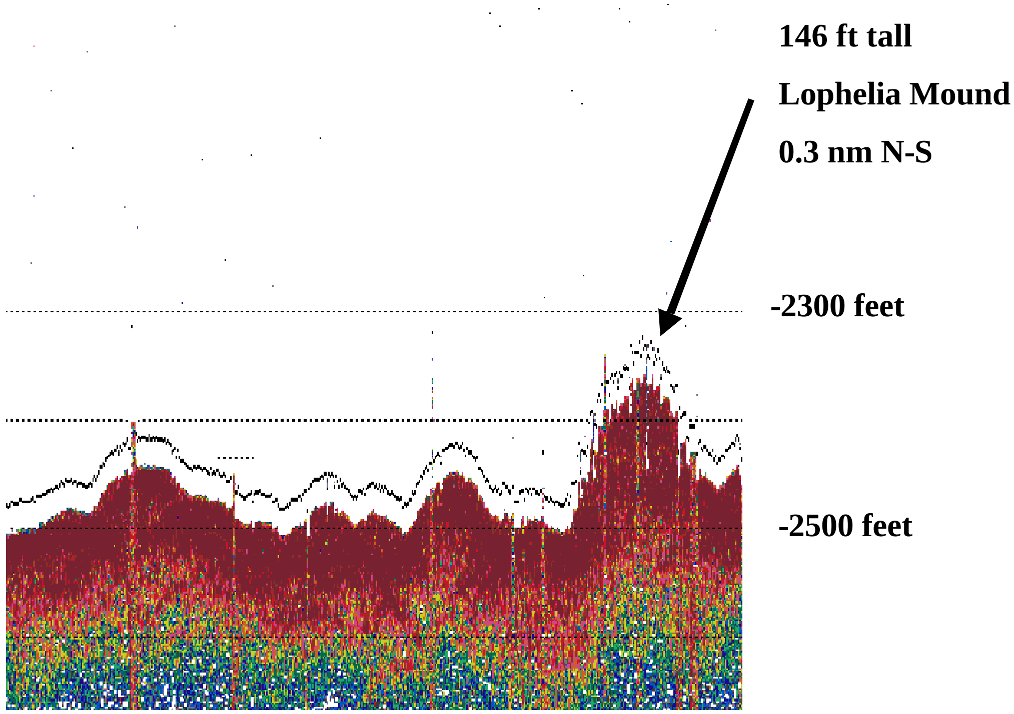


Figure 13. Echosounder profile of Cape Canaveral *Lophelia* Reef, Pinnacle #113 (depth 777 m, relief 61 m). (from Reed et al., 2004b)



The second dive site (JSL II-3336) at Pinnacle #151 (28°17.0616'N, 79°36.8306'W) was also a deep-water *Lophelia* coral reef comprised entirely of coral and sediment (Table 1). Maximum depth was 758 m, with 44 m relief, and ~0.3 nm wide (N-S). The top was a series of ridged peaks from 713 to 722 m in depth. The lower flanks of the south face was a 10-20° slope of fine light colored sand with a series of 1-3 m high sand dunes or ridges that were linear NW-SE. The ridges had ~50% cover of thickets of *Lophelia pertusa* coral. The thickets consisted of 1 m tall dead, standing and intact, *Lophelia pertusa* colonies. Approximately 1-10% were alive on the outer parts (15-30 cm) on top of the standing dead bases. There was very little broken dead coral rubble in the sand and there was no evidence of trawl or mechanical damage. Most of the coral was intact, and the dead coral was brown. The sand between the ridges was fine and light colored, with 7-15 cm sand waves. The upper slope steepened to 45° and 70-80° slope near the upper 10 m from the top. The top of the pinnacle had up to 100% cover of 1-1.5 m tall coral thickets, on a narrow ridge that was 5-10 m wide. The coral consisted of both *Lophelia pertusa* and *Enallopsammia profunda*. Approximately 10-20% cover was live coral of 30-90 cm. The north slope was nearly vertical (70-80°) for the upper 10 m then consisted of a series of coral thickets on terraces or ridges. No exposed rock was visible and the entire pinnacle appeared to be a classic *Lophelia* mud mound.

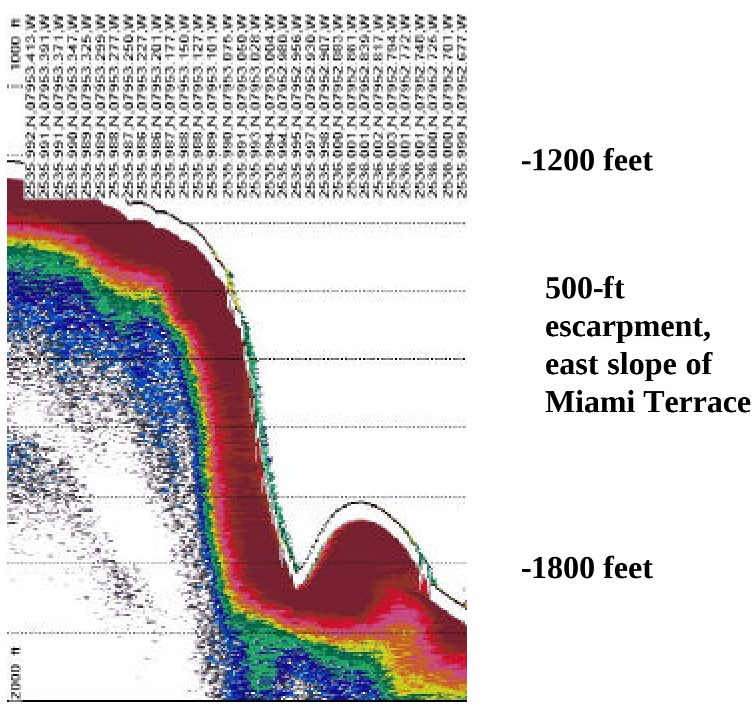
No discernable zonation of macrobenthic fauna was apparent from the base to the top. Corals consisted of *Lophelia pertusa*, *Enallopsammia profunda*, *Madrepora oculata*, and some stylasterine hydrocorals. Dominant octocoral gorgonacea included Primnoidae (2 spp.), Isididae bamboo coral (*Isidella* sp. and *Keratoisis flexibilis*), and the alcyonaceans *Anthomastus* sp. and *Nephthya* sp (Table 3). Dominant sponges consisted of several species of Hexactinellida glass sponges, large yellow demosponges (60-90 cm diameter), Pachastrellidae, and *Phakellia* sp. fan sponges. Echinoderms included urchins (cidaroid and *Hydrosoma*? sp.) and comatulid crinoids, but no stalked crinoids. Some large decapod crustaceans included *Chaceon fenneri* and large galatheids. No mollusks were observed but were likely within the coral habitat that was not collected. Common fish were 2 m sharks, 25 cm eels, 25 cm skates, chimaera, and blackbelly rosefish (Table 4).

Region G: Miami Terrace Escarpment (from Reed et al., 2004b)

The Miami Terrace is a 65-km long carbonate platform that lies between Boca Raton and South Miami at depths of 200-400 m in the northern Straits of Florida. It consists of high-relief Tertiary limestone ridges, scarps and slabs that provide extensive hard bottom habitat (Uchupi, 1966, 1969; Kofoed and Malloy, 1965; Uchupi and Emery, 1967; Malloy and Hurley, 1970; Ballard and Uchupi, 1971; Neumann and Ball, 1970). At the eastern edge of the Terrace, a high-relief, phosphoritic limestone escarpment of Miocene age with relief of up to 90 m at depths of 365 m is capped with *Lophelia pertusa* coral, stylasterine hydrocoral (Stylasteridae), bamboo coral (Isididae), and various sponges and octocorals (Reed et al., 2004b; Reed and Wright, 2004). Dense aggregations of 50-100 wreckfish were observed here by the PI during *JSL* submersible dives in May 2004 (Reed et al., 2004b). Previous studies in this region include geological studies on the Miami Terrace (Neumann and Ball, 1970; Ballard and Uchupi, 1971) and dredge- and trawl-based faunal surveys in the 1970s primarily by the University of Miami (e.g., Halpern, 1970; Holthuis, 1971, 1974; Cairns, 1979). *Lophelia* mounds are also present at the base of the escarpment (~670 m) within the axis of the Straits of Florida, but little is known of their distribution, abundance or associated fauna. Using the *Aluminaut* submersible, Neumann and Ball (1970) found thickets of *Lophelia*, *Enallopsammia* (=*Dendrophyllia*), and *Madepora* growing on elongate depressions, sand ridges and mounds. Large quantities of *L. pertusa* and *E. profunda* have also been dredged from 738-761 m at 26°22' to 24'N and 79°35' to 37'W (Cairns, 1979).

Recent JSL submersible dives and fathometer transects by the PI at four sites (Reed Site #BU4, 6, 2, and 1b) indicated the outer rim of the Miami Terrace to consist of a double ridge with steep rocky escarpments (Table 1; Fig. 6; Reed and Wright, 2004; Reed et al., 2004b). At Miami Terrace Site #BU4, the narrow N-S trending east ridge was 279 m at the top and had a steep 95 m escarpment on the west face. The east and west faces of the ridges were 30-40^{o} slopes with some near vertical sections consisting of dark brown phosphoritic rock pavement, boulders and outcrops. The crest of the east ridge was a narrow plateau ~10 m wide. At Site #BU6, the crest of the west ridge was 310 m and the base of the valley between the west and east ridges was 420 m. At Site #BU2, the echosounder transect showed a 13 m tall rounded mound at a depth of 636 m near the base of the terrace within the axis of the Straits of Florida. The profile indicated that it is likely a *Lophelia* mound. West of this feature the east face of the east ridge was a steep escarpment from 567 m to 412 m at the crest. The west ridge crested at 321 m. Total distance from the deep mound to the west ridge was 2.9 nm. Site #BU1b was the most southerly transect on the Miami Terrace. An E-W echosounder profile at this site indicated a double peaked east ridge cresting at 521 m, then a valley at 549 m, and the west ridge at 322 m. The east face of the west ridge consisted of a 155 m tall escarpment (Fig. 14).

Figure 14. Echosounder profile of Miami Terrace Escarpment, Site #BU1b, west ridge (depth 549 m at base, relief 155 m). (from Reed et al., 2004b)



There were considerable differences among the sites in habitat and fauna; however, in general, the lower slopes of the ridges and the flat pavement on top of the terrace were relatively barren. However, the steep escarpments especially near the top of the ridges were rich in corals, octocorals, and sponges. Dominant sessile fauna consisted of the following Cnidaria: small (15-30 cm) and large (60-90 cm) tall octocoral gorgonacea (*Paramuricea* spp., *Placogorgia* spp., Isididae bamboo coral); colonial scleractinia included scattered thickets of 30-60 cm tall *Lophelia pertusa* (varying from nearly 100% live to 100% dead), *Madrepora oculata* (40 cm), and *Enallopsammia profunda*; stylasterine hydrocorals (15-25 cm); and Antipatharia (30-60 cm tall) (Table 3). Diverse sponge populations of Hexactinellida and Demospongiae included: *Heterotella* sp., *Spongosorites* sp., *Geodia* sp., *Vetulina* sp., *Leiodermatium* sp., *Petrosia* sp., Raspailiidae, Choristida, Pachastrellidae, and Corallistidae. Other motile invertebrates included *Asteroporpa* sp. ophiuroids, *Stylocidaris* sp. urchins, Mollusca, Actiniaria, and Decapoda crustaceans (*Chaceon fenneri* and Galatheidae). Schools of ~50-100 wreckfish (*Polyprion americanus*), ~60-90 cm in length, were observed on several submersible dives along with blackbelly rosefish, skates, sharks, and dense schools of jacks (Table 4).

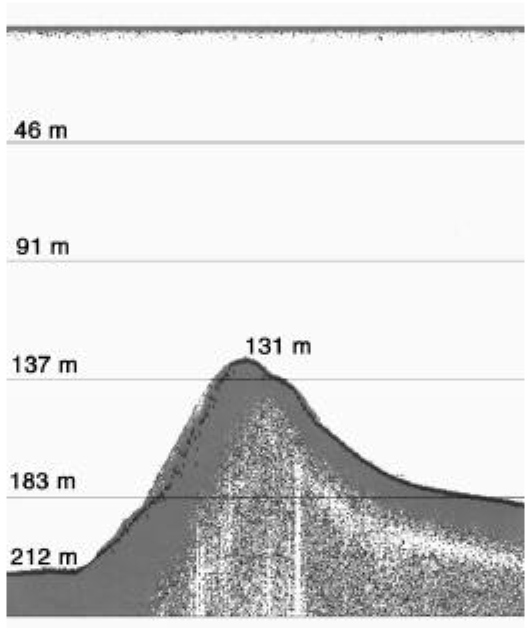
Region H: Pourtalès Terrace Lithoherms (from Reed et al., 2004a)

The Pourtalès Terrace provides extensive, high-relief, hard-bottom habitat, covering 3,429 km^2 (1,000 nm^2) at depths of 200-450 m. The Terrace parallels the Florida Keys for 213 km and has a maximum width of 32 km (Jordan, 1954; Jordan and Stewart, 1961; Jordan et al., 1964; Gomberg, 1976; Land and Paull, 2000). Reed et al. (2004a) surveyed several deep-water, high-relief, hard-bottom sites including the Jordan and Marathon deep-water sinkholes on the outer edge of the Terrace, and five high-relief bioherms on its central eastern portion (Table 2, Fig. 7). The *JSL* and *Clelia* submersibles were used to characterize coral habitat and describe the fish and associated macrobenthic communities. These submersible dives were the first to enter and explore any of these features. The upper sinkhole rims range from 175 to 461 m in depth and have a maximum relief of 180 m. The Jordan Sinkhole may be one of the deepest and largest sinkholes known. The high-relief area of the middle and eastern portion of the Pourtalès Terrace is a 55 km-long, northeasterly trending band of what appears to be karst topography that consists of depressions flanked by well defined knolls and ridges with maximum elevation of 91 m above the terrace (Jordan et al., 1964; Land and Paull, 2000). Further to the northeast of this knoll-depression zone is another zone of 40-m high topographic relief that lacks any regular pattern (Gomberg, 1976). The high-relief bioherms (the proposed HAPC sites within this region) lie in 198 to 319 m, with a maximum height of 120 m. A total of 26 fish taxa were identified from the sinkhole and bioherm sites (Table 4). Species of potential commercial importance included tilefish, sharks, speckled hind, yellow-edge grouper, warsaw grouper, snowy grouper, blackbelly rosefish, red porgy, drum, scorpion fish, amberjack, and phycid hakes. Many different species of Cnidaria were recorded, including Antipatharia black corals, stylasterine hydrocorals, octocorals, and one colonial scleractinian (*Solenosmilia variabilis*) (Table 3).

<u>Tennessee and Alligator Humps, Bioherms #1-4- Pourtalès Terrace (from Reed et al., 2004a)</u>

The Tennessee and Alligator Humps are among dozens of lithoherms that lie in a region called "The Humps" by local fishers, ~14 nm south of the Florida Keys and south of Tennessee and Alligator Reefs (Table 2, Fig. 7). Three dives were made by the PI on Bioherm #3 (*Clelia* 597, 598, 600; Aug. 2001), approximately 8.5 nm NE of Bioherm #2 (Fig. 15). Bioherm #3 consisted of two peaks 1.05 nm apart with a maximum relief of 62 m. The North Peak's minimum depth

Figure 15. Echosounder profile of Pourtalès Terrace, Tennessee Bioherm #2 (depth 212 m at base, relief 85 m). (from Reed et al., 2004a)



was 155 m (submersible DGPS: 24°42.4573'N, 80°31.0513'W) and was 653 m wide at the base, which was 217 m deep at the east base and 183 m at the west side. The minimum depth of South Peak was 160 m and was about 678 m in width E to W at the base. The surrounding habitat adjacent to the mounds was flat sand with about 10% cover of rock pavement. From 213 m to the top, generally on the east flank of the mound, were a series of flat rock pavement terraces at depths of 210, 203, 198, 194, 183, and 171 m and the top plateau was at 165 m. Between each terrace a 30-45° slope consisted of either rock pavement or coarse sand and rubble. Below each terrace was a vertical scarp of 1-2 m where the sediment was eroded away leaving the edge of the terrace exposed as a horizontal, thin rock crust overhang of <1 m and 15-30 cm thick. The top of the bioherm was a broad plateau of rock pavement with 50-100% exposed rock, few ledges or outcrops, and coarse brown sand. Less time was spent on the western side, which was more exposed to the strong bottom currents. The west side of South Peak sloped more gradually than the eastern side, had more sediment, and no ledges were observed.

Fish Communities (from Reed et al., 2004a)

A total of 31 fish taxa, of which 24 were identified to species level, were identified from our submersible videotapes and were associated with the deep-water sinkholes and high-relief bioherms (Table 4). Few studies have directly documented deep-water fish associations with deep-water reef habitats in the western Atlantic. Most of the work has concentrated on the Charleston Bump region of the Blake Plateau off Georgia and South Carolina (Sedberry, 2001). Ross (pers. comm.) reported the following species are common to both the deep-water *Lophelia* reefs on the Blake Plateau off the Carolinas and those of this study: *Chloropthalmus agassizi*, *Helicolenus dactylopterus*, *Hoplostethus* sp., *Laemonema melanurum*, *Nezumia* sp., and *Xiphias gladius*.

Species most common to the high-relief bioherms included deepbody boarfish, blueline tilefish, snowy grouper, and roughtongue bass. Some species were common at both the sinkhole and bioherm sites and included snowy grouper, blackbelly rosefish, and mora. In addition to the moribund swordfish observed in the Jordan Sinkhole, a swordfish was observed from the NR-1 submersible on top of Pourtales Terrace (C. Paull, pers. observation).

Species of potential commercial importance included tilefish, sharks, speckled hind, yellowedge grouper, warsaw grouper, snowy grouper, blackbelly rosefish, red porgy, drum, scorpionfish, amberjack, and phycid hakes. However, the fish densities that we saw at any of the sites were in insufficient numbers to suggest commercial or recreation harvest. In fact, any of the features, both sinkholes and bioherms, could be overfished very easily since only a few individuals of the larger grouper species were present at any one site.

<u>Benthic Communities (from Reed et al., 2004a)</u>

The benthos at the bioherm sites was dominated by sponges, octocorals and stylasterids (Table 3). A total of 21 taxa of Cnidaria were sampled or observed and 16 were identified to species level. These included 3 species of antipatharian black coral, 5 stylasterid hydrocorals, 11 octocorals with one possible new species, and 1 scleractinian (*Solenosmilia variabilis*). Eight species were associated only with the Pourtalès sinkholes and not the bioherms; these included two species of antipatharians; the octocorals *Paramuricea placomus*, *Plumarella pourtalesii*, *Trachimuricea hirta*; and the scleractinian *Solenosmilia variabilis*. Although Gomberg (1976) found evidence of skeletal remains of the colonial scleractinians *Lophelia* and *Madrepora* in sediment samples from the terrace, we did not see any colonies at our dive sites. Sponges identified from collections included 28 taxa. Five species of stylasterine hydrocorals were *Distichopora foliacea*, *Pliobothrus echinatus*, *Stylaster erubescens*, *S. filogranus*, and *S. miniatus*. On the flat pavement adjacent to the base of the mounds, stylasterids and antipatharian black coral bushes were common along with sea urchins and sea stars.

The densities of sponges, stylasterid hydrocorals and octocorals were very high, especially on the plateaus and terraces of the bioherms on the Pourtalès Terrace. Maximum densities of sponges (>5 cm) on the plateaus ranged from 1-80 colonies m^{-2}. Stylasterid coral densities ranged from 9-96 colonies m^{-2} and octocorals 16-48. Densities of sponges (1-2 colonies m^{-2}) and stylasterids (1-20) also dominated the terraces and slopes of the bioherm sites but generally in lower densities than the peak plateaus whereas the octocorals generally had higher densities on the flanks (1-80 colonies m^{-2}).

<u>Region I: Southwest Florida Shelf *Lophelia* Lithoherms (from Reed et al., 2003; Reed et al., 2004 a, b, d)</u>

This region consists of dozens and possibly hundreds of 5-15 m tall lithoherms at depths of 500 m, some of which are capped with thickets of live and dead *Lophelia* coral (Fig. 8). In 1987, Newton et al. described the area from limited dredge and seismic survey. In 2003, Seabeam topographic mapping was conducted by the PI over a small portion of the region (Table 1, Figs. 16,17); ROV dives ground-truthed three of the features: a 36-m tall escarpment and two of the lithoherms (Reed, 2004; Reed et al., 2003; Reed et al., 2004b,d). The lithoherms appeared to consist of rugged black phosphorite-coated limestone boulders and outcrops capped with 0.5-1.0 m tall thickets of *Lophelia pertusa*, which were up to ~10-20% live. Dominant sessile macrofauna included stony corals, octocorals, stylasterid hydrocorals, black corals and sponges (Table 3). The high number of hard bottom lithoherms revealed by the (limited) Seabeam mapping effort indicated tremendous potential for unexplored coral and fish habitat in this region.

Figure 16. Seabeam image of escarpment and lithoherms at Region I off southwest Florida slope. ?= *Innovator* ROV dive sites #6- 8. (from Reed et al., 2004b)

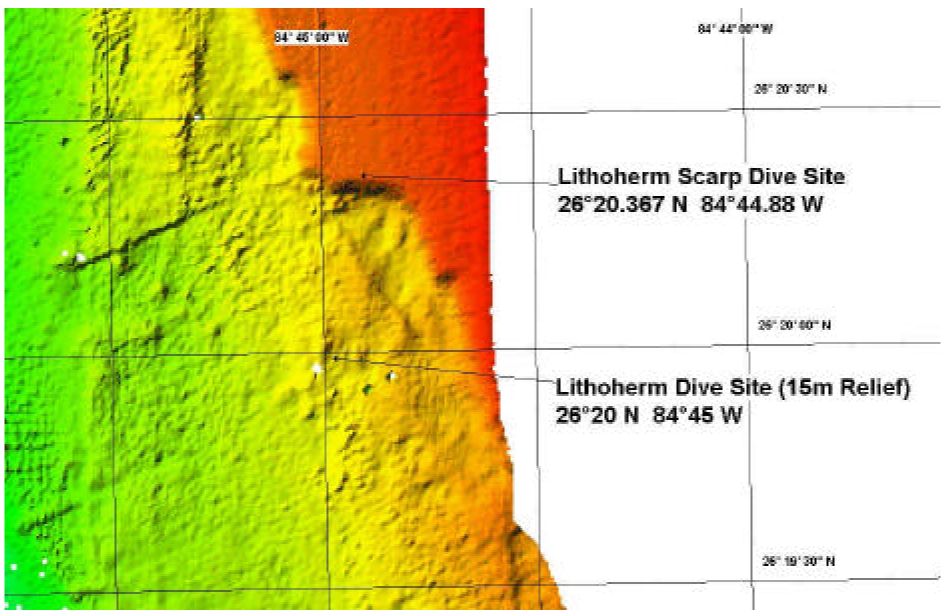
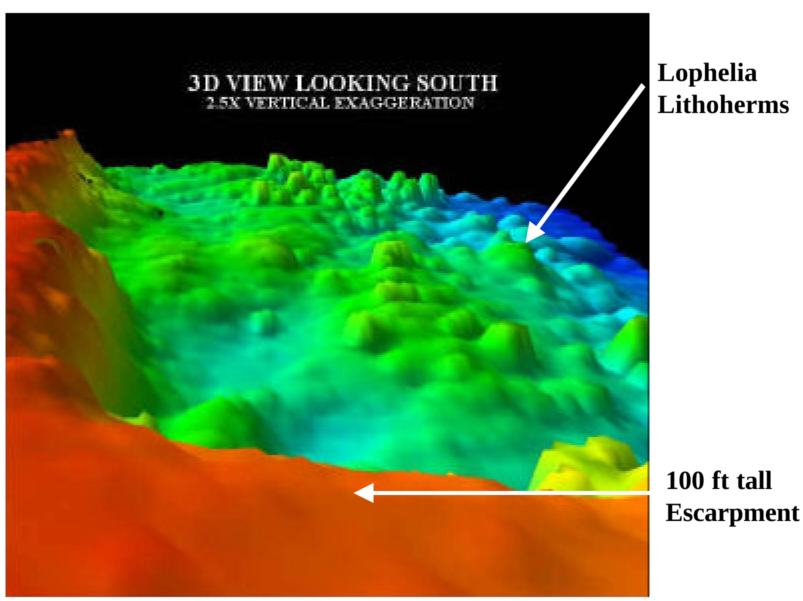


Figure 17. Seabeam image of escarpment and lithoherms at Region I off southwest Florida slope; simulated view from top of escarpment, looking south.. (from Reed et al., 2004b)



An ROV dive by the PI on the 36-m tall escarpment (Fig. 17; top- 412 m, base- 448 m), showed a near vertical wall with a series of narrow ledges, and very rugged topography with crevices and outcrops. Dominant sessile fauna consisted of Antipatharia black coral (30 cm tall), numerous octocoral gorgonacea including Isididae bamboo coral (30-40 cm), and sponges (*Heterotella* sp., *Phakellia* sp., Corallistidae). Pinnacle #4 was a 12 m tall and 60 m wide lithoherm at a depth of 466 m. Eight other lithoherms were apparent on the ROV's sonar within a 100 m radius. A transect up the face of the pinnacle revealed a series of terraces on a rugged 45^o up to 70^o rock slope which consisted of black rock boulders (1-2 m) and outcrops with 1 m crevices. The top ridge was oriented ~NNE. Thickets of live and dead *Lophelia pertusa* were found on some of the slope terraces but primarily on the top ridge. The NE slope face appeared to have more live coral than the NW face. Some of the thickets were ~30-60 cm tall and 60-90 cm diameter. Coral cover was estimated from <5% to over 50% in some areas, and estimated to be 1-20% live. The dominant fauna were similar to the escarpment except for *Lophelia* which was not observed on the escarpment. Common sessile benthic species included Cnidaria: Antipatharia black coral (*Antipathes* sp. and *Cirrhipathes* sp.), *Lophelia pertusa*, gorgonacea octocorals; and sponges: *Heterotella* sp. and other Hexactinellida vase sponges, various plate and vase Demospongiae (Pachastrellidae, Petrosiidae, Choristida). Common motile invertebrates included Mollusca, Holothuroidea, Crinoidea, Decapoda crustaceans (*Chaceon fenneri* and Galatheidae), blackbelly rosefish, and various other benthic fish (fish tapes have not been analyzed yet).

SUMMARY AND RECOMMENDATIONS

The biological and geological characteristics of six regions of deep-water reefs off the southeastern U.S.A. from southwest Florida to South Carolina were summarized in this report based on current data and knowledge compiled primarily from recent submersible and ROV dives. Region A, the *Oculina* Reefs, have been designated an Habitat Area of Particular Concern since 1984 (NOAA, 1982; Reed, 1981d; Reed, 2002b) and portions are a Marine Protected Area for the protection of the coral habitat and snapper/ grouper complex. Even so, extensive areas of the *Oculina* reefs have been severely impacted by legal and illegal bottom trawling since 1984. The six regions outlined in this report (Regions B-D, G-I) are each unique in their own respect. The resource potential of the deep-water habitats in this region is unknown in terms of fisheries and novel compounds yet to be discovered from associated fauna that may be developed as pharmaceutical drugs. Although these habitats are not currently designated as MPAs or HAPCs, they are incredibly diverse and irreplaceable resources. Activities involving bottom trawling, pipelines, or oil/gas production could negatively impact these reefs. This PI strongly recommends that HAPC designation be given to these deep-water reef habitats to provide some protection to these resources. Evidence of potential spawning aggregations of wreckfish (*Polyprion americanus*) and considerable populations of blackbelly rosefish (*Helicolenus dactylopterus*) and other commercially important species could actually threaten the future longevity of these fragile habitats unless bottom trawling in these regions is prohibited or strictly regulated and monitored. These studies summarized in this report are only preliminary and point to the need for additional geological, biological and ecological research. Initially, most of these regions need detailed mapping and habitat characterization studies which will provide data for final determinations of potential HAPC boundaries and future research needs.

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Table 1. Site summary for deep-water coral reefs and lithoherms off SE USA.
In order north to south. Site #1-33 refer to Fig. 4. (from Reed, 2002a; Reed et al., 2004a,b)

*Site Reference	Depth at Base (m)	Depth at Peak (m)	Max. Relief (m); (Width at base)	GPS Coordinates (Peak)
Region D				
1) Stetson's Reefs, Stetson's Pinnacle	780	627	153 (0.8 nm N-S)	32°01.6882'N, 77°39.6648'W
2) Stetson's Reefs, Pinnacle #3, Peak 1-4	694	579 (Peak 1)	114 (2.2 nm N-S)	32°00.6302'N, 77°41.9285'W (Peak 1)
Region C				
3) Savannah Lithoherms, ALVIN site	550	500	54	31°48'N, 79°15'W
4) Savannah Lithoherms, Site 2, Pinnacle #6	549	511	38 (0.4 nm NE-SW)	31°44.3814'N, 79°05.2516'W
5) Savannah Lithoherms, Site 2, Pinnacle #5	549	533	15 (0.3 nm NE-SW)	31°44.0975'N, 79°05.5544'W
6) Savannah Lithoherms, Site 2, Pinnacle #1	537	487	50 (0.53 nm N-S)	31°42.2555'N, 79°07.4831'W
7) Savannah Lithherms	541			31°41.82'N, 79°08.60'W
8) Savannah Lithoherms	532	499	33	31°41.5'N, 79°18.06'W
9) Savannah Lithoherms, Site 1, Pinnacle #4	549	488	61 (0.47 nm N-S)	31°41.4259'N, 79°08.5964'W
10) Savannah Lithoherms	503	490	13	31°41.23'N, 79°17.46'W
Region B				
11) Paull (2000) Lithoherm Site	671 (440-914)	579	91 (150 max)	30°48.2'N 79°38.4'W
12) Jacksonville Lophelia Reef, Pinnacle #204B, Peak 6	701	544	157 max; Peak 6= 107 (3nm N-S; 0.8nm E-W)	30°30.1194'N, 79°39.4743'W
13) Jacksonville Lophelia Reef, Pinnacle #186	866	744	122 (0.9 nm N-S; 0.9 nm E-W)	30°16.8114'N, 79°38.9784'W

14) St. Augustine Lophelia Reef, Pinnacle #3	822	734	88 (0.99 nm N-S)	29°40.2628'N, 79°38.0678'W
15) Cape Canaveral Lophelia Reefs, Pinnacle #113	777	716	61 (0.3 nm N-S; 0.9 nm NW-SE)	28°47.6258'N, 79°37.5859'W
16) Cape Canaveral Lophelia Reefs	793	762	30	28°46.72'N, 79°41.17'W
17) Cape Canaveral Lophelia Reef, Pinnacle #129	791	716	75 (0.53 nm N-S)	28°39.8464'N, 79°37.6735'W
18) Cape Canaveral Lophelia Reef, Pinnacle #TS7 (Near P 135)	762	718	44 (0.78 nm N-S)	28°28.3513'N, 79°37.0064'W
19) Cape Canaveral Lophelia Reefs, Pinnacle #151	758	713	44 (0.3 nm N-S)	28°17.0616'N, 79°36.8306'W
20) Cape Canaveral Lophelia Reefs	838	741	97	28°02.04'N, 79°36.51'W (Loran C)
21) Ft. Pierce Lophelia Reef, Pinnacle #TS4 (near P212)	750	721	29 (0.84 nm N-S)	27°39.4305'N, 79°34.9679'W
22) Stuart Lophelia Reef, Pinnacle #292	723	676	46 (0.95 nm N-S; 0.82 nm E-W)	27°12.5695'N, 79°35.5994'W
23) Jupiter Lophelia Reef, Pinnacle #293	723	685	42 (1.66 nm N-S; 1.0 nm E-W)	27°01.3474'N, 79°35.3889'W
Region A *Oculina* Reefs (Reed, 1980, 2002a,b)	70-100		24	27°32.8'N, 79°56.2'W to 28°59.2'N, 80°06.6'W
Region E (Mullins et al., 1981; Reed, 2002a)	1000-1300		40	27°40'N, 78°15'W to 27°10'N, 77°30'W
Region F (Neumann et al., 1977; Messing et al., 1990; Reed, 2002a)	610- 675		50	26°56.72'N, 79°16.02'W to 27°25'N, 79°20'W
Region G 24) Miami Terrace, East Ridge, W. Face, Site #BU4	375	279	95	26°05.7066'N, 79°50.3634'W (ridge top)

25) Miami Terrace, East Ridge, E. Face, Site #BU4	335	284	51	26°05.6902'N, 79°50.2540'W (base of escarptment)
26) Miami Terrace, West Ridge, East Face, Site #BU6	437	310	126	26°01.2885'N, 79°49.3258'W (base of escarpment)
27) Miami Terrace, East Ridge, E. Face, Site #BU2	573	399	174	25°41.9970'N, 79°51.0510'W (base of escarpment)
28) Miami Terrace, West Ridge, E. Face, Site #BU2	391	321	70	25°41.9959'N, 79°51.8924'W (base of escarpment)
29) Miami Terrace, West Ridge, Base E. Face, Site BU1b	549	393	155	25°35.9963'N, 79°52.9368'W (base of escarpment)
30) Miami Terrace, West Ridge, W. Face, Site #BU1b	430	322	112	25°35.9864'N, 79°54.2491'W
Region H				
*Pourtales Terrace Sites (Reed et al., 2004)	198- 461		12-180	24°15.33'N, 80°54.27'W to 24°44.71'N, 80°27.59'W
Region I				
31) SW Fla. Lithoherms, Pinnacle #1	558	554	4	26°19.9094'N, 84°45.8639'W
32) SW Fla. Lithoherms, Site 2 Escarpment	448	412	36 escarp-ment	26°20.3915'N, 84°44.8733'W
33) SW Fla. Lithoherms, Pinnacle #4	466	454	12	26°20.0133'N, 84°45.0030'W (base)

Regions A-H: Southeast USA; Region I: Eastern Gulf of Mexico; *= Region I, Pourtales Terrace Sites- see separate table; dive number: JSL I, II= HBOI's *Johnson-Sea-Link I* and *II* manned submersibles, CORD= HBOI's *Cord* Remotely Operated Vehicle (ROV), ROV= Sonsub *Innovator* ROV, ALVIN= WHOI's *Alvin* submersible; depth= at base, peak, maximum relief, and maximum width at base of bioherm; coordinates are submersible/ROV GPS location at peak of bioherm (or as indictated).

Table 2. Site summary for deep-water sinkholes and bioherms off south Florida, Pourtalès Terrace. (from Reed et al., 2004a)

*Site Reference	Depth (m)	Max. Relief (m)	Width (m)	GPS Coordinates
Naples Sinkhole	175	-55	152	26°05.1791'N 84°13.4678'W
Jordan Sinkhole	366	-180	229	24°16.4241'N, 81°02.1846'W
Marathon Sinkhole	461	-61	610	24°15.3289'N, 80°54.2705'W
Key West Bioherm	198	12	422	24°21.8038'N, 81°50.7397'W
Tennessee Bioherm #1	319	120	574	24°30.1670'N, 80°40.1880'W
Tennessee Bioherm #2	213	85	1613	24°35.2676'N, 80°35.3345'W
Alligator Bioherm #3	217	62	678	24°42.4573'N, 80°31.0513'W
Alligator Bioherm #4	213	48	1778	24°44.71'N, 80°27.59'W

Depth and width at base of bioherm or top of sinkhole; coordinates are submersible GPS location at peak of bioherm or base of sinkhole.

Table 3. Species list of macroinvertebrates associated with deep-water reefs off southeastern U.S.A. (Phyla: ART= Arthropoda, BRY= Bryozoa, CNI= Cnidaria, ECH= Echinodermata, MOL= Mollusca, POR= Porifera, VES= Vestimetifera; Sites: SC= Stetson's Reefs, South Carolina; GA= Savannah Lithoherms, Georgia; FL-E= East Coast Florida *Lophelia* Reefs; MT= Miami Terrace Escarpment; PT= Pourtalès Terrace Sinkholes and Bioherms; FL-W= SW Florida Lithoherms; VK= Viosca Knoll). (from Reed et al., 2004a,b)

Phylum	Taxonomy	Min Depth (m)	Max Depth (m)	SC	GA	FL-E	MT	PT	FL-W	VK
ART	Chaceon fenneri (golden crab)	509	509		X					
BRY	Membranipora? sp. Blainville, 1830	631	631	X						
CNI	Muriceides sp. (not hirta, not kukenthali) Studer, 1887	191	191					X		
CNI	Stylaster erubescens Pourtales, 1868	175	186					X		
CNI	Swiftia casta (Verrill, 1883)	525	525					X		
CNI	Swiftia new sp.? Duchassaing & Michelotti, 1864	497	497					X		
CNI	Solenosmilia variabilis Duncan, 1873	470	470					X		
CNI	Trachymuricea hirta (Pourtales, 1867)	462	468					X		
CNI	Paramuricea placomus (Linnaeus, 1924)	462	470					X		
CNI	Antipathes rigida? Pourtales, 1868	319	319					X		
CNI	Placogorgia mirabilis Deichmann, 1936	172	212					X		
CNI	Thesea parviflora Deichmann, 1936	183	183					X		
CNI	Hydroida	202	656	X				X		
CNI	Stylaster miniatus (Pourtales, 1868)	175	200					X		
CNI	Stylaster filogranus Pourtales, 1871	175	200					X		
CNI	Distichopora foliacea Pourtales, 1868	175	175					X		
CNI	Pliobrothus echinatus Cairns, 1986	175	175					X		
CNI	Bathypsammia? sp. Marenzeller, 1907	418	640	X					X	
CNI	Clavularia new sp.? Quoy & Gaimard, 1834	648	648	X						
CNI	Eunephthya nigra (Pourtales, 1868)	648	768	X						
CNI	Octocorallia, unid. spp.	501	671	X	X					
CNI	Lophelia pertusa (Linnaeus, 1758)	284	815	X	X	X	X		X	X
CNI	Scleractinia, unid. spp.	582	632	X		X				
CNI	Enallopsammia profunda (Pourtales, 1867)	305	742	X	X	X	X			
CNI	Ifalukellidae, new sp.? Bayer, 1955 (ye morph)	502	649	X	X					
CNI	Eunicella modesta (Verrill, 1883)	518	732		X	X				
CNI	Keratoisis flexibilis (Pourtales, 1868) (wh morph)	378	816	X	X	X		X		
CNI	Ifalukellidae, new sp.? Bayer, 1955 (or morph)	519	656	X	X					
CNI	Actiniaria	565	751			X				
CNI	Placogorgia? sp.1 Wright & Studer, 1889	565	579			X				
CNI	Chrysogorgia squamata (Verrill, 1883)	581	581			X				
CNI	Bathypathes alternata Brook, 1889	466	716			X			X	
CNI	Pterostenella? new sp.? Versluys, 1906	754	754			X				
CNI	Zoanthidea, unid. sp.2	734	734			X				
CNI	Stylaster unid. sp.1	557	557						X	
CNI	Placogorgia tenuis? (Verrill, 1883)	457	557						X	
CNI	Callogorgia verticillata (Pallas)	511	511							X
CNI	Isidella sp.1 Gray, 1857	744	762			X				
CNI	Paramuricea sp.2 Kölliker, 1865	573	573			X				

CNI	Madrepora oculata Linnaeus, 1758	322	763		X	X	X			
CNI	Paramuricea sp.4 Kölliker, 1865	762	762			X				
CNI	Plumarella pourtalessi (Verrill, 1883)	171	753	X	X	X	X	X		
CNI	Keratoisis flexibilis (Pourtales, 1868) (pi morph)	374	734			X	X			
CNI	Actiniaria, unid. sp.1 (Venus fly trap)	284	734			X	X			
CNI	Candidella imbricata (Johnson, 1862) + Thouarella? sp. Gray, 1870	732	732			X				
CNI	Paramuricea sp.3 Kölliker, 1865	558	732			X				
CNI	Anthomastus nr. agassizzi Verrill, 1922	420	753			X			X	
CNI	Telestula? sp.2 Madsen, 1944	734	784			X				
CNI	Paramuricea sp.5 Kölliker, 1865	743	744			X				
CNI	Paramuricea sp.1 Kölliker, 1865	590	744			X				
CNI	Paramuricea sp.6 Kölliker, 1865	328	727			X	X			
CNI	Paramuricea sp.7 Kölliker, 1865	711	711			X				
CNI	Paramuricea sp.8 Kölliker, 1865	701	716			X				
CNI	Capnella nigra (Pourtales, 1868)	325	762			X	X			
CNI	Paramuricea multispina Deichmann, 1936	189	715			X		X		
CNI	Plexauridae, unid. sp.1 Gray, 1859	579	716	X		X				
CNI	Muriceides hirta? (=Trachymuricea) (Pourtales, 1867)	681	716			X				
CNI	Paramuriceidae sp.2 (nr. Paramuricea echinata Deichmann, 1936)	716	716			X				
CNI	Paramuriceidae sp.4 (nr. Paramuricea placomus (Linnaeus))	296	296				X			
CNI	Antipatharia, unid. sp.1 (re-or morph)	283	767	X		X	X	X		X
CNI	Paramuriceidae sp.3 (nr. Paramuricea placomus (Linnaeus))	283	304				X			
CNI	Antipatharia, unid. sp.2 (wh-pi morph)	328	515		X		X	X	X	
CNI	Paramuriceidae sp.5 (nr. Echinomuricea atlantica (Johnson, 1862))	284	284				X			
CNI	Zoanthidea, unid. sp.1	419	699			X	X			
CNI	Paramuricea sp.9 Kölliker, 1865	326	336				X			
CNI	Paramuriceidae sp.6 (nr. Paramuricea placomus (Linnaeus))	326	326				X			
CNI	Paramuriceidae sp.7 (nr. Paramuricea multispina Deichmann, 1936)	323	323				X			
CNI	Zoanthidea, unid. sp.3	328	328				X			
CNI	Villogorgia nr. nigrescens Duchassaing & Michelotti, 1860	215	215					X		
CNI	Paramuricea sp.10 Kölliker, 1865	403	403				X			
CNI	Paramuricea sp.11 Kölliker, 1865	322	358				X			
CNI	Paramuricea sp.12 Kölliker, 1865	366	366				X			
CNI	Stylasteridae, unid. sp.	173	742		X	X	X	X		
CNI	Paramuriceidae sp.8 (nr. Echinomuricea atlantica (Johnson, 1862))	323	323				X			
CNI	Paramuricea sp.13 Kölliker, 1865	323	323				X			
CNI	Hydroida, unid. sp.1	284	322				X			
ECH	Holothuroidea	181	181					X		
ECH	Tamaria? sp.	653	653	X						
ECH	Solaster sp.	653	653	X						
ECH	Asteroidea + Cidaroidea	516	516		X					
ECH	Asteroidea, 2 unid. spp.	518	518		X					
ECH	Asteroidea, unid. sp.1	454	454						X	
ECH	Asteroporpa? sp.	304	304				X			

MOL	Calliostoma pulchrum (C.B. Adams, 1850)	187	187					X		
MOL	Hyalina albolineata (Orbigny, 1842)	187	187					X		
MOL	Scaphella gouldiana (Dall, 1887)	187	188					X		
MOL	Bivalvia, unid. sp.1	445	445							X
MOL	Bursa tenuisculpta (Dautzenberg & Fischer, 1906)	187	283				X	X		
MOL	Perotrochus amabilis (F.M. Bayer, 1963)	181	265					X		
MOL	Conus villepini Fisher and Bernardi, 1857	171	188					X		
MOL	Murex beauii Fischer & Bernardi, 1857	188	188					X		
MOL	Entemnotrochus adansonianus (Crosse & Fischer, 1861)	180	265					X		
MOL	Perotrochus midas F.M. Bayer, 1965	262	393					X		
POR	Haplosclerida?	171	184					X		
POR	Aka sp. de Laubenfels, 1934 or Spongosorites sp. Topsent, 1896 + Haplosclerida	543	543					X		
POR	Haplosclerida + Siphonodictyon sp. Bergquist, 1965 or Spongosorites sp. Topsent, 1896	187	543					X		
POR	Theonellidae	470	472					X		
POR	Pachastrella sp. Schmidt, 1868 or Poecillastra sp. Sollas, 1888	467	467					X		
POR	Stellettidae?	312	312					X		
POR	Erylus transiens (Weltner, 1882)	262	262					X		
POR	Halichondrida	260	260					X		
POR	Theonellidae, new genus, new sp.	199	208					X		
POR	Mycalidae	284	312					X		
POR	Chondrosia? sp. Nardo, 1847	297	300					X		
POR	Halichondriidae	237	648	X				X		
POR	Plakortis sp. Schulze, 1880	220	312					X		
POR	Petrosiidae	178	750	X		X	X	X	X	
POR	Porifera, unid. sp.	192	297					X		
POR	Corallistes sp. Schmidt, 1870 or Callipelta sp. Sollas, 1888	206	206					X		
POR	Spirophorida	183	183					X		
POR	Lithistida	185	310					X		
POR	Geodiidae	180	816			X		X		
POR	Poecilosclerida	132	717			X		X		
POR	Epipolasis sp. de Laubenfels, 1936	211	211					X		
POR	Axinellida + Plakortis? sp. Schulze, 1880	210	210					X		
POR	Axinellidae	168	183					X		
POR	Characella? sp. Sollas, 1886	198	198					X		
POR	Stellettinopsis? sp. Carter, 1879	198	198					X		
POR	Echinodictyum sp. Ridley, 1881	171	172					X		
POR	Phakellia new sp.1 Bowerbank, 1862	171	171					X		
POR	Auletta sp. Schmidt, 1870	171	207					X		
POR	Phakellia new sp.2 Bowerbank, 1862	174	174					X		
POR	Phakellia new sp.3 Bowerbank, 1862	174	174					X		
POR	Dictyoceratida?	172	172					X		
POR	Pachastrellidae	166	811	X	X	X	X	X		X
POR	Lychniscosida	649	662	X						
POR	Lyssacinosida	628	757	X		X				
POR	Phakellia sp. Bowerbank, 1862	171	756	X	X	X	X	X	X	
POR	Corallistes sp. Schmidt, 1870	226	689	X				X		
POR	Oceanapia sp. Norman, 1869	172	652	X				X		

POR	Plakinidae	638	660	X						
POR	Aka (Siphonodictyon) sp.de Laubenfels, 1934	183	648	X				X		
POR	Ancorina? sp. Schmidt, 1862	641	641	X						
POR	Phakellia sp.2 Bowerbank, 1862	509	509		X					
POR	Hexasterophora	517	761	X	X	X				
POR	Axinellida	201	499		X			X		
POR	Biemnidae	512	628	X	X					
POR	Pachastrellidae (different)	527	527		X					
POR	Ircinia new sp.? Nardo, 1833	500	500		X					
POR	Choristida, new sp.?	520	520		X					
POR	Raspailiidae	321	763		X	X	X	X		
POR	Hexactinellida	186	800	X	X	X	X	X		
POR	Heterotella sp. Gray, 1867	418	762		X	X			X	
POR	Stylocordyla sp. Thomson, 1873	515	515		X					
POR	Phakellia sp.3 Bowerbank, 1862	515	515		X					
POR	Aka sp. de Laubenfels, 1934 + Hadromerida	456	456						X	
POR	Myxillina? sp. Hajdu, Van Soest & Hooper, 1994	442	442							X
POR	Dendroceratida	448	448							X
POR	Hyalonematidae? + Zoanthidea	737	737			X				
POR	Oceanapiidae	758	758			X				
POR	Calthropellidae	757	757			X				
POR	Ancorinidae?	586	586			X				
POR	Dercitus cf. bucklandi (Bowerbank, 1858)	809	809			X				
POR	Aphrocallistes sp. Gray, 1858	587	800			X				
POR	Polymastia sp. Bowerbank, 1864	726	726			X				
POR	Phakellia sp. (different) Bowerbank, 1862	735	735			X				
POR	Corallistidae	186	767	X			X	X		
POR	Asterophorida	431	431				X			
POR	Leiodermatium sp. Schmidt, 1870	172	754	X			X	X		
POR	Spongosorites sp. Topsent, 1896	171	671	X		X	X	X		
POR	Geodia sp. Lamarck, 1815	174	767	X			X	X		
POR	Hexactinellida + Zoanthidea	328	411				X			
POR	Poecillastra? sp. Sollas, 1888	323	427				X		X	
POR	Choristida	173	509		X		X	X		
POR	Choristidae?	323	323				X			
POR	Oceanapiidae or Topsentia sp. Berg, 1899	173	173					X		
POR	Hymedesmia sp.1 Bowerbank, 1864 (blue morph)	172	179					X		
POR	Hymedesmia sp.2 Bowerbank, 1864 (ye morph)	172	179					X		
POR	Demospongiae	170	541				X	X		
POR	Discodermia sp. du Bacage, 1869	180	269					X		
POR	Choristida or Petrosida	258	258					X		
POR	Zyzzya sp. de Laubenfels, 1936	222	222					X		
POR	Smenospongia sp. Wiedenmayer, 1977 or Ircinia sp. Nardo 1833	222	222					X		
POR	Petrosida or Halichondrida	183	183					X		
POR	Vetulina sp. Schmidt, 1879 or Leiodermatium sp. Schmidt, 1870	415	415				X			
POR	Erylus sp. Gray, 1867	216	356				X	X		
VES	Vestimentifera, unid. sp.	443	443							X

Table 4. Species list of fish associated with deep-water reefs off Florida (Sites: FL= Florida East Coast *Lophelia* Reefs; MT= Miami Terrace Escarpment; PT= Pourtalès Terrace). (from Reed et al., 2004a,b)

Taxonomy	Common Name	Max Depth (m)	Min Depth (m)	FL	MT	PT
Anthias nicholsi Firth, 1933	yellowfin bass	283	179		X	X
Antigonia capros Lowe, 1843	deepbody boarfish	219	174			X
Beryx dacadactylus?	alphonsino?	287			X	
Brotulidae	cusk-eel	469	322		X	X
Carcharhinus falciformis (Müller & Henle, 1839)	silky shark	522	335			X
Caulolatilus microps Goode and Bean, 1878	blueline tilefish	223	172			X
Chaetodon aya	bank butterflyfish	179				X
Chlorophthalmidae	greeneye	296			X	
Chlorophthalmus agassizi Bonaparte, 1840	shortnose greeneye	522	396		X	X
Conger conger?	conger eel	296	0		X	
Congridae	conger eel	381	0			X
Cookeolus japonicus (Cuvier, 1829)	longfinned bulleye	198	171			X
Epinephelus drummondhayi Goode and Bean, 1878	speckled hind	183				
Epinephelus flavolimbatus Poey, 1865	yellowedge grouper	174				
Epinephelus nigritus (Holbrook, 1855)	Warsaw grouper	198	180			X
Epinephelus niveatus (Valenciennes, 1828)	snowy grouper	308	174			X
Epinephelus sp. (misty grouper?)	misty grouper?	287				X
Galeus arae (Nichols, 1927)	roughtail catshark	518				X
Gephyroberyx darwinii (Johnson, 1866)	big roughy	518	392			X
Gymnothorax sp. (cf. funebris Ranzani, 1840)	green moray	187	174			
Gymnothorax sp. (new moray?)	new moray	179				X
Helicolenus dactylopterus (Delaroche, 1809)	blackbelly rosefish	497	179		X	X
Hemanthias sp.	seabass	194	174			X
Hemanthias vivanus (Jordan & Swain, 1885)	red barbier	191	168			X
Hoplostethus mediterraneus Cuvier, 1829	silver roughy	461				X
Hoplostethus sp.	roughies	496	189			X
Hydrolagus sp.	spotted ratfish	762	714	X		
Hyperoglyphe sp.	barrelfish	287	284		X	
Laemonema melanurum Goode and Bean, 1896	mora	546	186	X	X	X
Mola mola	ocean sunfish	180				X
Mustelidae?	dogfish	586		X		
Mustelus sp.	dogfish	369			X	
Myctophidae	laternfish	500	296	X	X	
*Nezumia sp. (*3 spp.- *N. bairdii, N. aequalis, or N. atlantica)*	grenadier, rattail	726	322	X	X	X
Ostichthys trachypoma (Günther, 1859)	bigeye soldierfish	180				
Pagrus pagrus (Linnaeus, 1758)	red porgy	175				
Pareques iwamotoi Miller and Woods, 1988	blackbar drum	183				
Peristidion sp.	armored sea robin	438			X	
Plectranthias garrupellus Robins and Starck, 1961	apricot bass	172				X
Polyprion americanus	wreckfish	693	283	X	X	
Pronotogrammus martinicensis (Guichenot, 1868)	roughtongue bass	212	168			X

*Raja s*p.	skate	738	339	X	X	
Scorpaenidae	scorpionfish	296	186		X	X
Scyliorhinidae?	catshark?	326			X	
Seriola dumerili (Risso, 1810)	greater amberjack	187	175			X
Seriola rivoliana	Almaco jack	179				X
Squalidae	dogfish	399	322		X	
Synaphobranchidae?	cutthroat eel	762	714	X		
Unid.- silver body, barbels		336			X	
Urophycis sp.	phycid hake	297				X
Xeiidae?	red dory?	376			X	
Xiphias gladius Linnaeus, 1758	swordfish	518				X

FIGURE CAPTIONS

Figure 1. Coral colony and branch tip: top- *Oculina varicosa* (80m); middle- *Lophelia pertusa* (490m); bottom- *Enallopsammia profunda* (585m). (scale lines = 1 cm; top left fig. Scale = 5 cm) (from Reed, 2002a; Hydrobiologia 471: 57-69)

Figure 2. Depth range and maximum relief of deep-water coral reefs off southeastern U.S.A. Dominant colonial coral listed for each site (see Figure 3 for site locations). (from Reed, 2002a; Hydrobiologia 471: 57-69)

Figure 3. Deep-water coral reef regions off southeastern U.S.A. (see Table 1 for locations). ?= *Johnson-Sea-Link* I and II submersible dive sites; Regions: A=*Oculina* Coral Reefs, B= East Florida *Lophelia* Reefs, C= Savannah *Lophelia* Lithoherms, D= Stetson's Reefs (D1= region of dense pinnacles), E= *Enallopsammia* Reefs (Mullins et al., 1981), F= Bahama Lithoherms (Neumann et al., 1977), G= Miami Terrace Escarpment. (from Reed et al., 2004a; chart from NOAA, NOS, 1986)

Figure 4. Submersible dive sites and echosounder sites on deep-water reefs off southeastern U.S.A. (see Table 1 for locations). ?# = *Johnson-Sea-Link* I and II submersible dive sites, F# = high-relief pinnacles from echosounder transect. (from Reed et al., 2004a; chart from NOAA, NOS, 1986)

Figure 5. Detailed chart of high-relief region with *Lophelia* coral mounds on Charleston Bump, Blake Plateau (from Popenoe and Manheim, 2001; American Fisheries Society Symposium 25: 43-94)

Figure 6. Bathymetry and submersible dive sites on Miami Terrace Escarpment at Region G. (see Table 1 for locations). ?= *Johnson-Sea-Link* I submersible dive sites. (from Reed et al., 2004a; chart from Ballard and Uchupi, 1971; MTS Journal 5: 43-48)

Figure 7. Bathymetry and submersible dive sites on Pourtalès Terrace at Region H. (see Table 2 for locations). ?= *Johnson-Sea-Link* and *Clelia* submersible dive sites; JS= Jordan Sinkhole, MS= Marathon Sinkhole, T1= Tennessee Humps Bioherm #1, T2= Tennessee Humps Bioherm #2, A3= Alligator Humps Bioherm #3, A4= Alligator Humps Bioherm #4. (from Reed et al., 2004b; chart from Malloy and Hurley, 1970; Geol. Soc. Amer. Bull. 81: 1947-1972)

Figure 8. Deep-water coral lithoherms and ROV dive sites at Region I off southwest Florida slope (see Table 1 for locations). ?= *Innovator* ROV dive sites. (from Reed et al., 2004a; chart from NOAA, NOS, 1986)

Figure 9. Echosounder profile of Stetson's Pinnacle (depth 780 m, relief 153 m). (from Reed et al., 2004b)

Figure 10. Echosounder profile of Savannah Lithoherm, Pinnacle #1 (depth 537 m, relief 50 m). (from Reed et al., 2004b)

Figure 11. Height of *Lophelia* pinnacles and lithoherms on echosounder transects from Jacksonville to Jupiter, Florida at depths of 600 to 800 m. (from Reed et al., 2004b)

Figure 12. Echosounder profile of Jacksonville Lithoherm, Pinnacle #204B (depth 701 m, relief 157 m). (from Reed et al., 2004a)

Figure 13. Echosounder profile of Cape Canaveral Lophelia Reef, Pinnacle #113 (depth 777 m, relief 61 m). (from Reed et al., 2004a)

Figure 14. Echosounder profile of Miami Terrace Escarpment, Site #BU1b, west ridge (depth 549 m at base, relief 155 m). (from Reed et al., 2004a)

Figure 15. Echosounder profile of Pourtalès Terrace, Tennessee Bioherm #2 (depth 213 m at base, relief 85 m). (from Reed et al., 2004b)

Figure 16. Seabeam image of escarpment and lithoherms at Region I off southwest Florida slope. ?= *Innovator* ROV dive sites #6 and 7. (from Reed et al., 2004b)

Figure 17. Seabeam image of escarpment and lithoherms at Region I off southwest Florida slope, simulated view from top of escarpment. ?= *Innovator* ROV dive sites #6 and 7. (from Reed et al., 2004b)

REFERENCES

Deep-Water Reefs - Habitat, Biological, and Geological References
Part 1: Western Atlantic- North Carolina to Florida
Part 2: Gulf of Mexico (p.64)
Part 3: Eastern Atlantic and General Deep Sea Reefs (p.68)

Compiled by John Reed, October 20, 2004
[*- Reference SEAMAP Deep-water Florida Data Set]

PART I- Southeastern USA, Blake Plateau, and Straits of Florida:

*AES Ocean Express. 2002. Application of AES Ocean Express LLC for a natural gas pipeline right-of-way on the outer continental shelf off the coast of Broward County, Florida. Application to MMS. AES Ocean Express.

Agassiz, A. 1869. Preliminary report on the Echini and star-fishes dredged in deep water between Cuba and the Florida Reef, by L. F. de Pourtales, Assist. U.S. Coast Survey. Bull. Mus. Comp. Zool. Harvard 1(9): 253-308.

*Agassiz, L. 1869. Report upon deep-sea dredgings in the Gulf Stream, during the third cruise of the U.S. Steamer BIBB, addressed to Professor Benjamin Pierce, Superintendent U.S. Coast Survey. Bull. Mus. Comp. Zool. Harvard 1(13): 363-386.

*Agassiz, A. 1888. Three cruises of the United States Coast and Geodetic Survey Steamer "Blake", 1. Bull. Mus. Comp. Zool. Harvard 14: 1-314.

*Anselmetti, F. S., G. Eberli, and Z. Ding. 2000. From the Great Bahama Bank into the Straits of Florida: a margin architecture controlled by sea-level fluctuations and ocean currents. Geological Society of America Bulletin 112: 829-844.

Arendt, M., C. Barans, G. Sedberry, R. Van Dolah, J. Reed, and S. Ross. 2003. Summary of Seafloor Mapping and Benthic Sampling in 200-2000m from North Carolina through Florida, Final Report, Deep-water Habitat Mapping Project, Phase II. South Carolina Dept. of Natural Resources, Charleston, S.C., 156 pp.

*Avent, R.M. and F.G. Stanton. 1975. Submersible reconnaissance and research program. Harbor Branch Foundation, 1975 Annual Report.

*Avent, R.M. and F.G. Stanton. 1979. Observations from research submersible of megafaunal distribution on the continental margin off central eastern Florida, Harnor Branch Foundation Technical Report #25, 40 pp.

*Avent, R.M., F.G. Stanton, and J.K. Reed. 1976. Submersible reconnaissance and research program. Harbor Branch Foundation, Annual Report, 52 pp.

*Avent, R., M. King, and R. Gore. 1977. Topographic and faunal studies of shelf-edge prominences off the central eastern Florida coast. Int. Revue ges. Hydrobiol. 62: 185-208.

Ayers, and Pilkey. Piston core and surficial investigations of the Florida-Hatteras slope and inner Blake Plateau. [chapter on corals on Blake Plateau]

*Bailey, Norman and K. Kent. 1982. High-resolution seismic-reflection profiles collected aboard R/V Eastward, cruise ESTW 80-8, over Blake Escarpment. U.S. Geological Survey Open-File Report 82-940. (3 sites east of Florida, 7,170 kn of data; microfilm data available)

Ball, M.M., Popenoe, P., Vazzana, M.E., Coward, E.L., Dillon, W.P., Durden, T., Hampson, J.C., and Paull, C.K. l980. South Atlantic Outer Continental Shelf hazards. In Popenoe, P., ed., l980, Final Report --Environmental studies, southeastern United States Atlantic Outer Continental Shelf, l977. U.S. Geological Survey Open-File Report 80-l46, p. 11-1 to 11-16.

*Ballard, R. and E. Uchupi. 1971. Geological observations of the Miami Terrace from the submersible Ben Franklin. Marine Tech. Society Journal 5: 43-48.

Bayer, F.M. and M. Grasshoff. 1995. Two new species of the Gorgonacean genus Ctenocella from deep reefs in the Western Atlantic. Bull. Mar. Sci. 56(2): 625-652.

Barnes, R. and E. Goldberg. 1976. Methane production and consumption in anoxic marine sediments. Geology 4: 297-300.

*Bayer, F.M. 1966. Dredging and trawling records of R/V John Elliott Pillsbury from 1964 and 1965. Stud. Tropical Oceanogr., Miami 4(1): 82-105. [some sites in Florida Straits with notes on coordinates for start and end, depth, gear, and catch remarks]

“Blake”. VI. Report on the corals and antipatharia. Bulletin of the Museum of Comparative Zoology, p. 95-120.

Blake, J.A., B. Hecker, J. Grassle, B. Brown, M. Wade, P. Boehm, E. Baptiste, B. Hilbig, N. Maciolek, R. Petrecca, R. Ruff, V. Starczak, and L. Watling. 1987. Study of biological processes on the U.S. South Atlanic slope and rise. Phase 2. Batelle New England Marine Research Laboratory, WHOI, Lamont-Doherty Geological Observatory, and Ira C. Darling Center, OCS Study, MMS 86-0096 (Contract No. 14-12-0001-30064). [North and South Carolina] [Parts zeroxed]

Blake, J.A., B. Hecker, J. Grassle, N. Maciolek-Blake, B. Brown, M. Curran, B. Dade, S. Frieitas, and R. Ruff. 1985. Study of biological processes on the U.S. South Atlantic Slope and Rise. Phase 1. Benthic characterization study. Batelle New England Marine Research Laboratory, WHOI, and Lamont-Doherty Geological Observatory, Minerals Management Service Cont. No. 14-12-0001-30064, 2 vol. [North Carolina]

*BLM. 1979. South Atlantic OCS Benchmark Program, Outer Continental Shelf Environmental Studies. BLM Contract No. AA550-CT7-2. Texas Instruments Inc. [Cape Fear to Daytona, to 285 m] [Executive summary zeroxed only]

BLM. 1981. Final report South Atlantic OCS area living marine sources study. BLM Contract No. AA551-CY9-27. 297 pp. [Charleston to Jacksonville, 19-100 m depths]

Bogle, M.A. 1975. A review and preliminary revision of the Aglaopheniinae (Hydroida: Plumulariidae) of the tropical western Atlantic. Unpublished M.S. Thesis, University of Miami.

Brooke, S. D. 1998. Reproduction and larval biology of the ivory tree coral Oculina varicosa, American Zoologist 38, 100a.

Brooke, S.D. 2002. Reproductive ecology of a deep-water scleractinian coral, Oculina varicosa from the South East Florida Shelf. Dissertation, Southampton Oceanography Centre, Southampton.

Brooke S.D. and C.M. Young. 2003. Reproductive ecology of a deep-water scleractinian coral, Oculina varicosa from the South East Florida Shelf. Cont Shelf Research 23: 847-858.

Buffler, R.T., Watkins, J.S. and Dillon, W.P. 1979. Geology of the offshore Southeast Georgia Embayment U.S. Atlantic Continental Margin, based on multichannel seismic reflection profiles. In Watkins, J.S., Montadert, L. and Dickerson, P.W., eds., Geological and Geophysical Investigations of Continental Margins. American Association Petroleum Geologists Memoir 29, p. 11-25.

*Bush, J. 1951. Rock from the Straits of Florida. Bull. Amer. Assoc. Petroleum Geologists 35: 102-107.

*Cairns, S.D. 1976. Review of the deep-water ahermatypic corals (Scleractinia) of the tropical Western Atlantic. Ph.D. Thesis, Univ. Miami, Fl., 316 pp.

*Cairns, S.D. 1979. The deep-water Scleractinia of the Caribbean Sea and Adjacent Waters. Studies of the Fauna of Curacao and Other Caribbean Islands, No. 180, 341 pp.

*Cairns, S.D. 1986. A revision of the northwest Atlantic Stylasteridae (Coelenterata: Hydrozoa). Smithsonian Cont. to Zoology, No. 418, 131 pp.

*Cairns, S.D. 2000. A revision of the shallow-water azooxanthellate scleractinia of the Western Atlantic. Studies of the Natural History of the Caribbean Region, Vol. 75, 240 pp.

Cairns S.D. and R.E. Chapman. 2002. Biogeographic affinities of the North Atlantic deep-water Scleractinia. In Willison, JHM et al. (eds.), Proc. First Intern. Symp. Deep-Sea Corals. Ecology Action Centre and Nova Scotia Museum, Halifax, pp. 30-57.

*Calypso Pipeline. 2001. Geohazards assessment, proposed 24" gas pipeline route, Freeport, Grand Bahama Island to Port Everglades, Florida. Report submitted to Calypso Pipeline LLC, project no. 0401-397. Williamson and Associates, Inc, Seattle, WA and Geoscience Earth and Marine Services, Inc, Houston, TX

Cashman, K.V. and P. Popenoe. 1985. Slumping and shallow faulting related to the presence of salt on the continental slope off North Carolina. Marine and Petroleum Geology 2: 260-?

Cerame-Vivas, M., and I. Gray. 1966. The distributional pattern of benthic invertebrates of the continental shelf off North Carolina. Ecology 47: 260-270.

Child, C. A. 1998. Nymphon torulum, new species and other Pycnogonida associated with the coral Oculina varicosa on the east coast of Florida, Bulletin of Marine Science 63, 595-604.

Clark, M., John Reed, and A. Hunter. 2000. Sea Profiles: An Interactive Journey of Ocean Exploration. Educational 2 CD ROM set. The Media Lab, HBOI (International TV Association Gold Medal for New Media).

Colquhoun, D.J., Arthur, M.A., Dillon, W.P., Hatcher, R.D., Huddlestun, P.F., Poag, C.W., Valentine, P.C., and Popenoe, P. 1991. Southeastern Atlantic Regional Coast Cross-Section, American Association of Petroleum Geologists, Tulsa.

Continental Shelf Associates. 1979. South Atlantic hard bottom survey. BLM Contract No. AA551-CT8-25, 356 pp. [Charleston to Jacksonville, 44- 194 m depths]

*De Silva, D. 1955. The mystery of the tilefish. Sea Frontiers, May Issue, p. 4-8.

Dillon, W.P. 1981. Regional geology. In Dillon, W. P., ed., Summary report on the regional geology environmental considerations for development, petroleum potential and estimates of undiscovered recoverable oil and gas resources of the United States southern Atlantic continental margin in the area of the proposed Oil and Gas Lease Sale No. 78. U.S. Geological Survey Open-File Report 81-749, p. 6-58e.

Dillon, W.P. (ed.) 1981. Summary report on the regional geology, environmental considerations for development, petroleum potential, and estimates of undiscovered recoverable oil and gas resources of the United States southern Atlantic continental margin in the area of proposed Oil and Gas Lease Sale No. 78. U.S. Geological Survey Open File Report 81-749, 108p.

Dillon, W.P. (ed.). l982. Summary of regional geology, petroleum potential, resource assessment and environmental considerations for oil and gas lease sale area #56: U.S. Geological Survey Open-File Report 82-398, 63 pp.

Dillon, W. P. (ed.). l983. Geology report for proposed oil and gas lease sale no. 90; continental margin off the southeastern United States. U.S. Geological Survey Open-File Report 83-186, 125 p., 2 plates.

Dillon, W. P. 1983. Regional geology and petroleum potential. In Dillon, W. P., ed., Geology report for proposed oil and gas lease sale no. 90; continental margin off the southeastern United States. U.S. Geological Survey Open-File Report 83-186, p. 6-84.

Dillon, W. P. 1984. Mineral resources of the Atlantic Exclusive Economic Zone. In Conference Record, Oceans '84, Marine Technology Society and IEEE Ocean Engineering Society, p. 431-437. Reprinted in Champ, M.A., Chmn, 1984, Exclusive Economic Zone Papers, MTS/IEEE, p 72-78.

Dillon, W.P. and Kvenvolden, K.A. ?. Gas hydrates in sea floor sediments off southeastern U.S.: Evidence from seismic reflection and drilling data, Alternative energy source. Methane Hydrates Workshop, Technical Proceedings, Department of Energy, Morgantown, W.Va., DOE-METC 82-49, p. 78-81.

Dillon, W.P. and Max M.D. 2000. Oceanic gas hydrate. In Max, M..D., ed., Natural Gas Hydrate in Oceanic and Polar Environments, p. 61-76, Kluwer Academic Publishers, Dordrecht.

Dillon, W.P. and Max M.D. 2000. The U.S. Atlantic continental margin; the best-known gas hydrate locality, Chapter 13. p. 157-170, In Max, M.D. ed., Natural GasHydrate in Oceanic and Polar Environments, Kluwer Academic Publishers, Dordrecht.

Dillon, W.P. and McGinnis, L.D. 1983. Basement structures indicated by seismic-refraction measurements offshore from South Carolina and adjacent areas. In Gohn, G., ed., U.S. Geological Survey Professional Paper 1313, p. O1-O7.

Dillon, W.P. and Paull, C.K. 1978. Interpretation of multichannel seismic-reflection profiles of the Atlantic continental margin of the coasts of South Carolina and Georgia. U.S.Geological Survey Miscellaneous Field Investigations Map MF-936.

Dillon, W.P. and Paull, C.K. 1980. Summary of development of the continental margin off Georgia based on multichannel and single channel seismic reflection profiling and stratigraphic well data. In Arden, D.D. and Beck, B.F., eds., Symposium on Southeastern Coastal Plain Geology, vol.1, 10 p., 3 fig.

Dillon W.P. and Paull, C.K. 1983. Marine gas hydrates - II: Geophysical evidence. In Cox, J. L. (ed.), Natural Gas Hydrates: Properties, Occurrences and Recovery. Boston, Butterworth Publishers, p. 73-90.

*Dillon, William and P. Popenoe. 1988. The Blake Plateau basin and Carolina trough. Chapter 14. pp. 291- 328, In: R. Sheridan and J. Grow (eds.), The Geology of North America, The Atlantic Continental Margin, U.S. Geological Soc. Am., The Geology of North America, 2 vol.

Dillon, W.P., et al. 1975. Sediments, structural framework, petroleum potential, environmental considerations and operational considerations of the United States South Atlantic outer continental shelf. U.S. Geological Survey Open-File Report 75-411, 262 p., l plate.

Dillon, W.P., Sheridan, R.E., and Fail, J.P. 1976. Structure of the Western Blake Bahama Basin as shown by 24 channel CDP profiling. Geology 4: 459-462.

Dillon, W.P., Folger, D.W., Ball, M.M., Powers, R, and Wood, G., Jr. 1978. Summary report of the sediments, structural framework, petroleum potential environmental conditions and operational considerations of the United States South Atlantic continental margin. Prepared for Bureau of Land Management for proposed oil and gas lease sale #54. U.S.Geological Survey Open-File Report 78-594, 39 p.

Dillon, W.P., Klitgord, K.D., and Paull, C.K. 1979. Geologic setting of the COST GE-1 drillsite. In Scholle, P.A., ed., Geological studies of the COST GE-1 well, United States South Atlantic Outer Continental Shelf area. U.S. Geological Survey Circular 800, p. 4-6.

Dillon, W.P., Paull, C.K., Buffler, R.T., and Fail, J.P. 1979. Structure and development of the Southeast Georgia Embayment and northern Blake Plateau: Preliminary analysis. In Watkins, J. S., Montadert, L., and Dickerson, P.W., eds., Geological and Geophysical Investigations of Continental Margins: American Association of Petroleum Geologists Memoir 29, p. 27-41.

Dillon, W.P., Paull, C.K., Dahl, A.G., Patterson, W.C. 1979. Structure of the continental margin near the COST GE-1 well site from a common depth point seismic reflection profile. In Scholle, P.A., ed., Geological studies of the COST GE-1 well, United States South-Atlantic Outer Continental Shelf area: U.S. Geological Survey Circular 800, p.97-107.

*Dillon, W.P., Poag, C.W., Valentine, P.C., and Paull, C.K. 1979. Structure, biostratigraphy and seismic stratigraphy along a CDP seismic profile through 3 drill sites on the continental margin off Jacksonville, Florida. U.S. Geological Survey, Miscellaneous Field Investigation Map MF-1090.

Dillon, W.P., Grow, J.A., and Paull, C.K. 1980. Unconventional gas hydrate seals may trap gas off southeast United States. Oil and Gas Journal, v. 78, no. 1, p. 124, 126, 129-130.

Dillon, W.P., Klitgord, K.D., Paull C.K. and Grow, J.A. 1982. Summary of regional geology. In Dillon, W.P., ed., Summary of regional geology petroleum potential, resource assessment and environmental considerations for oil and gas lease sale area #56: U.S. Geological Survey Open-File Report 82-398, p. 5-20.

Dillon, W.P., Klitgord, K.D., and Paull, C.K. 1983. Mesozoic development and structure of the continental margin off South Carolina. In Gohn, G., ed., U.S. Geological Survey Professional Paper 1313, p. N1-N16.

Dillon, W.P., Popenoe, P., Grow. J.A., Klitgord, K.D., Swift, B.A., Paull, C.K. and Cashman, K.V. 1983. Growth faulting and salt diapirism: Their relationship and control in the Carolina Trough, eastern North America. In Watkins, J.S. and Drake, C.L., eds., Studies in Continental Margin Geology, American Association of Petroleum Geologists Memoir No. 34, p. 21-46.

*Dillon, W. P., Paull, C. K., and Gilbert, L. E. 1985. History of the Atlantic continental margin off Florida: The Blake Plateau Basin. In Poag, C. W., ed., Geologic Evolution of the United States Atlantic Margin, Van Nostrand, Reinhold, New York, p. 189-215.

Dillon, W.P., Manheim, F.T., Jansa, L.F., Palmason, G. Tucholke, B.E. and Landrum, R.S. 1986. Resource potential of the western North Atlantic Basin. In Vogt, P.R., and Tucholke, B.E., eds., The Geology of North America, volume M, The Western North Atlantic Regions, Geological Society of America, p 661-676.

Dillon, W. P., Valentine, P. C., and Paull, C. K. 1987. Geology of the Blake Escarpment. NOAA Symposium Series for Undersea Research, vol. 2, no. 2, P 177-190.

Dillon, W.P., P. Valentine, and C. Paull. 1987. The Blake Escarpment- a product of erosional processes in the deep ocean. Symp. Ser. For Undersea Research, NOAA's Undersea Research Program 2: 177-190.

Dillon, W.P., Schlee, J.S. and Klitgord, K.D. 1988. The development of the continental margin of eastern North America - conjugate continental margin to West Africa. Journal of African Earth Sciences, vol. 7, no. 2, p. 361-367.

Dillon, W.P., Trehu, A.M., Valentine, P.C., and Ball, M.M. 1988. Eroded carbonate platform margin - the Blake Escarpment off southeastern United States. In Bally, A.W., ed, Atlas of Seismic Stratigraphy, American Assoc. Petroleum Geologists Studies in Geology Series, No. 27, vol. 2, p. 40-47.

*Dillon, W.P., Risch, J.S., Scanlon, K.M., Valentine, P.C., and Huggett, Q.J. 1993. Ancient crustal fractures control the location and size of collapsed blocks at the Blake Escarpment, east of Florida. In Schwab, W.C., Lee, H.J. and Twichell, D.C., eds., Submarine Landslides: Selected Studies in the U.S. Exclusive Economic Zone, U.S. Geological Survey Bulletin 2002, p. 54-59.

Dillon, W.P., Fehlhaber, Kristen, Coleman, D.F., Lee, M.W., and Hutchinson, D.R. 1995. Maps showing gas hydrate distribution off the east coast of the United States. U.S. Geological Survey Miscellaneous Field Investigations Map, MF 2268, 2 sheets, 1:1,000,000.

Dillon, W., Hutchinson, D., and Drury, R. 1996. Seismic reflection profiles on the Blake Ridge near Sites 994, 995 and 997. Proceeding of the Ocean Drilling Program, Initial reports, v. 164, p. 47-56

Dillon, W., Holbrook, W.S., Drury, R., Gettrust, J., Hutchinson, D., Booth, J. and Taylor, M. 1997. Faulting of Gas-Hydrate-Bearing Marine Sediments ? Contribution to Permeability. Proceedings of the Offshore Technology Conference, p. 201-209.

Dillon, W.P., Danforth, W.W., Hutchinson, D.R., R.M., Drury, Taylor, M.H., Booth, J.S. 1998. Evidence for faulting related to dissociation of gas hydrate and release of methane off the southeastern United States. In Henriet, J.P. and Mienert, J, eds., Gas Hydrates: Relevance to World Margin Stability and Climate Change, Geological Society, London, Spec. Publication 137, p.293-302.

Dillon, W.P., Nealon, J.W., Taylor, M.H., Lee, M.W., Drury, R.M., and Anton, C.H. 2001. Seafloor collapse and methane venting associated with gas hydrate on the Blake Ridge ? causes and implications to seafloor stability and methane release. In C.K. Paull and W.P. Dillon, eds., Natural Gas Hydrates: Occurrence, Distribution, and Detection, American Geophysical Union, Geophysical Monograph 124, p. 211-233.

Doyle, L.J., O. Pilkey, and C. Woo. 1979. Sedimentation on the eastern United States continental margin. SEPM Special Publication No. 27: 119-129.

Drake, C.L., J. Ewing, and H. Stockard. 1968. The continental margin of the eastern United States. Canadian Jour. Earth Sciences 5: 993-1010.

*Edsall, Douglas. 1978. Southeast Georgia embayment, high-resolution seismic-reflection survey. U.S. Geological Survey, Open File Report 78-800. [Georgia and North Florida]

*EEZ-Scan 87. 1991. Atlas of the U.S. Exclusive Economic Zone, Atlantic continental margin. U.S. Geological Survey, Miscellaneous Investigations Series I-2054, 174p. (portion of N. Florida to 2400')

*Emery, K. 1966. The Atlantic continental shelf and slope of the United States. United States Geological Survery Professional Papers 529-A: A1-A23.

*Emery, K.O. and E. Uchupi. 1972. Western North Atlantic Ocean: topography, rocks, structure, water, life, and sediments. Amer. Assoc. Petroleum Geologists Mem. 17.

Emery, K.O., R. Ballard, and R. Wigley. 1970. A dive aboard "Ben Franklin" off West Palm Beach Florida. Marine Technology Society Journal 4(2): 7-16. [All stations less than 200 m; no coordinates listed]

Emiliani, C., J. Hudson, E. Shinn, and R. George. 1978. Oxygen and carbon isotopic growth record in a reef coral from the Florida Keys and a deep-sea coral from Blake Plateau. Science 202: 627-629.

*Ewing, John M. Ewing, and R. Leyden. 1966. Seismic-profiler survey of Blake Plateau. Bull. Amer. Assoc. Petroleum Geologists 50: 1948-1971. (includes Florida)

Fluke, L.A. 1994. Recent Atlantic shelf sedimentation within a siliciclastic-carbonate transition, Florida, USA. M.S. Thesis, Florida Institute Technology, Melbourne, Florida, 78 p.

Folger, D.W., Dillon, W.P., Grow, J.A., Klitgord, K.D., and Schlee, J.S. 1979. Evolution of the Atlantic Continental Margin of the United States. In Talwani M., Hay, W. and Ryan, W.B.F., eds., Deep drilling results in the Atlantic Ocean: Continental Margins and Paleoenvironment. American Geophysical Union, Maurice Ewing Series 3, p 87-108.

Genin, A., Paull, C.K., and Dillon, W.P. 1992. Anomalous abundances of deep-sea fauna on rocky bottom exposed to strong currents. Deep Sea Research, vol. 39, no. 2, p. 293-302.

George, R.Y. 2002. Ben Franklin temperate reef and deep sea "Agassiz Coral Hills" in the Blake Plateau off North Carolina. Hydrobiologia 471: 71-81.

George, R.Y. and R. Menzies. 1972. Deep-sea faunal zonation of benthos along Beaufort-Bermuda transect in the North-western Atlantic. Proc. Royal Society of Edinburgh 73, 19, 1971/1972: 183-194.

Gilbert, L.E., and Dillon, W.P. 1981. Multichannel seismic profiles collected by the Teledyne Exploration Company in l977 south of Cape Hatteras, North Carolina. U.S. Geological Survey Open File Report 81-726, 2 p., 1 fig.

Gilbert, L.E. and Dillon, W.P. l98l. Bathymetric map of the Blake Escarpment. U.S. Geological Survey Field Studies Map MF-l362.

Gilmore, R. G. and R. S. Jones. 1992. Color variation and associated behavior in the epinepheline groupers, Mycteroperca microlepis (Goode and Bean) and M. phenax Jordan and Swain, Bulletin of Marine Science 51, 83-103.

Ginsburg, R., R. Michael Lloyd, K. Stockman, and J. McCallum. 1961. Shallow-water carbonate sediments. Pp. 554- 581, in M. Hill (ed.), The Sea, Vol. 3 The Earth Beneath the Sea History. Interscience Publ., N.Y.

*Gomberg, D. 1976. Geology of the Pourtales Terrace, Straits of Florida. Ph.D. Dissertation, Univ. Miami, Fl.

*Gorsline, Donn. 1963. Bottom sediments of the Atlantic shelf and slope off the southern United States. Jour. Geology 71: 422-440.

*Gorsline, D.S. and D. Milligan. 1963. Phosphatic deposits along the margin of the Pourtales Terrace, Florida. Deep-Sea Research 10: 259-262.

Grassle, J., H. Sanders, R. Hessler, G. Rowe, and T. McLellan. 1975. Pattern and zonation: a study of the bathyal megafauna using research submersible ALVIN. Deep-sea Research 22: 457-481.

Grim, M.S., Dillon, W.P., and Mattick, R.E. 1980. Seismic refraction and gravity measurements from the Continental Shelf offshore from North and South Carolina. Southeastern Geology, vol. 21, p. 239-249.

Grimes, C., C. Manooch, and G. Huntsman. 1982. Reef and rock outcropping fishes of the outer-continental shelf of North Carolina and South Carolina and ecological notes on the red porgy and vermillion snapper. Bull. Mar. Sci. 32(1): 277-289.

Grow, J. A., Hutchinson, D. R., Klitgord, K. D., Dillon, W. P., and Schlee, J. S. ?. Representative multichannel seismic reflection profiles over the U.S. Atlantic continental margin. In Bally, A. W., (ed.), Seismic Expression of Structural Styles: American Association of Petroleum Geologists, Studies in Geology Series, Number 15, p. 2.2.3-1 to 2.2.3-19.

Grow, J.A., Schlee, J.S., and Dillon, W. P. l980. Multichannel seismic-reflection profiles collected along the U.S. Continental Margin in l978. U.S. Geological Survey Open File Report 80-834, 2pp, 1 map.

Grow, J.A., Klitgord, K.D., Schlee, J.S. and Dillon, W.P. 1988. Representative seismic profiles. In Sheridan, R.E., and Grow, J.A., eds., The Atlantic Continental Margin: US, The Geology of North America, vol. I-2, Geological Society of America, Boulder, CO, plate 4.

Halpern, J.A. 1970. Goniasteridae (Echinodermata: Asteroidea) of the Straits of Florida. Bull. Mar. Sci. 20(1): 193-286.

Hatcher, R.D., Jr., Colquhoun, D.J., Secor, D.T., Cook, F.A., Dillon, W. P., Klitgord, Kim, Popenoe, Peter, Merschat, C.E., Wiener, L.S., Milici, R.C., Nelson, A.E., Sheridan, R. E., and Snoke, A.W. 1994. Centennial Continent/Ocean Transect #18, E-5 - Cumberland Plateau to Blake Plateau. Geological Society of America, Boulder, CO, two maps and text (56 p.).

*Hathaway, John, C. Wylie Poag, P. Valentine, R. Miller, D. Schultz, F. Manheim, F. Kohout, M. Bothner, and D. Sangrey. 1979. U. S. Geological Survey core drilling on the Atlantic shelf. Science 206 (4418): 513- ?

*Harbor Branch Oceanographic Foundation. 1978. R/V GOSNOLD cruise records 1973-1977. Harbor Branch Oceanographic Institution Library. [East coast Florida, dredge, trawl and grab; dates, time, coordinates start and end, depth, collection notes]

*Henry, Vernon. 1978. Distribution and occurrence of reefs and hardgrounds in the Georgia Bight. Final Report to U.S. Geol. Surv., Woods Hole, Ma, Open File Rept. 80-146.

*Henry, V.J. and R. Giles. 1976? Distribution and occurrence of reefs and hardgrounds in the Georgia Bight. Pp. 8-1 – 8-36, In Chapter 8, BLM Mem. Understanding No. AA550-MU6-56.

*Holmes, C.W. 1981. Late Neogene and Quaternary geology of the southeastern Florida shelf and slope. U.S. Geological Survey Open-file Rept. 81-1029.

Holthuis, L.B. 1971. The Atlantic shrimps of the deep-sea genus Glyphocrangon A. Milne Edwards, 1881. Bull. Mar. Sci. 21(1): 267-373.

Holthuis, L.B. 1974. The lobsters of the superfamily Nephropidea of the Atlantic Ocean (Crustacea: Decapoda). Bull. Mar. Sci. 24(4): 723-871.

Hoskin, C.M., J.C. Geier, and J.K. Reed. 1983. Sediment produced from abrasion of the branching stony coral Oculina varicosa. Journal of Sedimentary Petrology 53: 779-786.

Hoskin, C.M., J.K. Reed, and D.H. Mook. 1987. Sediments from a living shelf-edge reef and adjacent area off central eastern Florida. Pp. 42-57, In F. JMR. Maurrasse (ed.), Symposium on south Florida geology, Miami Geological Society Memoirs 3.

Hubbard, D.K., A. Hine, D. Breese, and G. Rezak. 1974. Preliminary seismic reflection investigation of Ft. Pierce Inlet and offshore continental shelf. Submitted to Nat Harrison, Ashland Oil, 40 p.

*Hurley, R. 1964. Bathymetry of the Straits of Florida and the Bahama Islands. Part III. Southern Straits of Florida. Bulletin of Marine Science of the Gulf and Caribbean 14: 373-380. [missing chart of survey]

*Hurley, R., V. Siegler, and K. Fink, Jr. 1962. Bathymetry of the Straits of Florida and the Bahama Islands. Bulletin of Marine Science of the Gulf and Caribbean 12: 313-321. [missing chart of survey]

*Jordan, G. 1954. Large sink holes in Straits of Florida. Bulletin of American Association of Petroleum Geologists 38: 1810-1817.

*Jordan, G. and H. Stewart Jr. 1961. Submarine topography of western straits of Florida. Bulletin Geological Society of America 72: 1051- 1058.

*Jordon, G. , R. Malloy, and J. Kofoed, 1964. Bathymetry and geology of Pourtales Terrace. Marine Geology 1: 259-287.

Klitgord, K.D., Dillon, W.P. and Popenoe, P. 1983. Mesozoic tectonics of the southeastern United States coastal plain and continental margin. In Gohn, G., ed., U.S. Geological Survey Professional Paper 1313, p. P1-P15.

Knott, David and P. Wendt. 1985. Special literature analysis study: final report on benthic communities in certain slope areas of the South Atlantic Bight. OCS Study, MMS 85-0051, 75 p. [North Carolina to Georgia]

Koenig, C. C., F. C. Coleman, C. Grimes, G. Fitzhugh, K. Scanlon, C. Gledhill, and M. Grace. 2000. Protection of fish spawning habitat for the conservation of warm-temperate reef-fish fisheries of shelf-edge reefs of Florida. Bulletin of Marine Science 66: 593-616.

Koenig, C. C., A. N. Shepard, J. K. Reed, R. G. Gilmore, F. C. Coleman, S. Brooke, J. Brusher, M. Barnette, A. W. David, K. Scanlon 2002. Florida Oculina Banks Marine Protected Area: habitat, fish populations, restoration, and enforcement. National Undersea Research Program, 2nd Quarter Milestone.

Koenig, C., A. Shepard, J. Reed, G. Gilmore, F. Coleman, S. Brooke, J. Brusher, M. Barnette, A. David, and K. Scanlon. 2002 (In press). Florida Oculina coral banks: habitat, fish populations, restoration, and enforcement. Benthic Symposium, Tampa, Florida, 2002. Abstract.

Koenig, C., A. Shepard, J. Reed, R. Gilmore, F. Coleman, S. Brooke, K. Scanlon, M. Barnette, J. Brusher, and A. David. 2004 (in press). A deep-water Oculina coral ecosystem in the western Atlantic: habitat, fish populations, restoration, and enforcement. Benthic Habitat American Fishery Society Meeting, Special Publication.

*Kofoed, J. and R. Malloy. 1965. Bathymetry of the Miami Terrace. Southeastern Geology 6: 159-165.

*Kornicker, L.S. and D. Squires. 1962. Floating corals: a possible source of erroneous distribution data. Limnology and Oceanography 7: 447-452. [Colpophyllia collected at 400 fathoms on Blake Plateau among deep water corals]

*Land, L. and C. Paull. 2000. Submarine karst belt rimming the continental slope in the Straits of Florida. Geo-Marine Letters 20: 123-132.

*Land, L., C. Paull, and B. Hobson. Genesis of a submarine sinkhole without subaerial exposure: Straits of Florida. Geology 23(10): 949-951.

Lyman, Theodore. 1869. Preliminary report on the Ophiuridae and Astrophytidae dredged in deep water between Cuba and the Florida Reef, by L. F. de Pourtales, Assist. U.S. Coast Survey. Bull. Mus. Comp. Zool. Harvard 1(10): 309-354.

*Macintyre, I. and J. Milliman. 1970. Physiographic features on the outer shelf and upper slope, Atlantic continental margin, southeastern United States. Bulletin Geological Society of America 81: 2577-2598.

*Macintyre, I. And J. Milliman. ?. Limestones from the outer shelf and upper slope continental margin, southeastern U.S. Contribution No. 2488 WHOI.

Mallinson, D. 2000. Scientific diving and geological investigations of Tortugas Bank, southwest Florida margin. Proceedings of American Academy of Underwater Sciences 20th Annual Symposium, St. Petersburg, Florida, October 2000.

*Malloy, R.J. and R. Hurley. 1970. Geomorphology and geologic structure: Straits of Florida. Geological Society of America Bulletin, vol. 81: 1947-1972. [map of Florida Straits]

Meisburger, E.P. and D. Duane. 1969. Shallow structural characteristics of Florida Atlantic shelf as revealed by seismic reflection profiles. U.S. Army Corps of Engineers, Transactions Gulf Coast Association of Geological Societies 19: 207-215.

Meisburger, E.P. and D. Duane. 1971. Geomorphology and sediments of the inner continental shelf, Palm Beach to Cape Kennedy, Florida. U.S. Army Corps of Engineers, Technical Memorandum No. 34, 111 p.

Menzies, R.J., O. Pilkey, B. Blackwelder, D. Dexter, P. Huling, and L. McCloskey. 1966. A submerged reef off North Carolina. Int. Revue ges. Hydrobiol. 51(3): 393-431.

Messing, C. 1978. Pentametrocrinus atlanticus (Perrier) (Crinoidea: Echinodermata): a review. Journal of Natural History 12: 699-708.

*Messing, C., A. Neumann, and J. Lang. 1990. Biozonation of deep-water lithoherms and associated hardgrounds in the northeastern Straits of Florida. Palaios 5: 15-33.

Meyer D.L., C. Messing, D. Macurda Jr. 1978. Zoogeography of tropical western Atlantic Crinoidea. Bull. Mar. Sci. 28: 412-441.

Miller, J. E. and D.L. Pawson. 1979. A new subspecies of Holothuria lentigenosa Marenzeller from the western Atlantic Ocean, Proceedings of Biological Society of Washington 91, 912-922.

*Milligan, D.B. 1962. Marine geology of the Florida Straits. M.S. Thesis, Florida State University, 120 pp.

Milliman, J.D. 1974. Marine Carbonates. Springer-Verlag, New York.

Milliman, J.D. and K.O. Emery. 1968. Sea levels during the past 35,000 years. Science 162: 1121-1123.

Milliman, J.D., F. Manheim, R. Pratt, and E. Zarudski. 1967. ALVIN dives on the continental margin off the southeastern United States, July 2-13, 1967. WHOI Reference No. 67-80, 48p. + figs. (South Carolina)

Milliman, J.D., O. Pilkey, and B. Blackwelder. ?. Carbonate sediments on the continental shelf, Cape Hatteras to Cape Romain. Cont. No. 2137 WHOI, pp. 245-267.

*Milliman, J.D., O. Pilkey, and D. Ross. 1972. Sediments of the continental margin off the Eastern United States. Geol. Soc. Amer. Bull. 83: 1315-1334.

Minerals Management Service MMS. 1982. Final report South Atlantic OCS area living marine resources study, year II. MMS Contract No. AA551-CT1-18, 3 vol. [Charleston to Jacksonville, 19-100 m depths]

*Minter, Larry, G. Keller, and T. Pyle. 1975. Morphology and sedimentary processes in and around Tortugas and Agassiz Sea Valleys, southern Straits of Florida. Marine Geology 18: 47-69.

*Moe, M. 1963. A survey of offshore fishing in Florida. Professional Paper Series No. 4, Florida State Board of Conservation Marine Laboratory, St. Petersburg, Fl., 117 pp. [parts zeroxed]

*Mullins, H. and C. Neumann. 1979. Geology of the Miami Terrace and its paleoceanographic implications. Marine Geology 30: 205-232.

*Mullins, H., C. Neumann, R. Jude Wilber, A. Hine, and S. Chinburg. 1980. Carbonate sediment drifts in nothern Straits of Florida. Am. Assoc. Petroleum Geologists Bull. 64 (10): 1701-1717.

*Mullins, H.T., C. Newton, H. Kathryn, and H. van Buren. 1981. Modern deep-water coral mounds north of Little Bahama Bank: criteria for recognition of deep-water coral bioherms in the rock record. Journal of Sedimentary Petrology 51: 999-1013.

*Neumann, C. and M. Ball, 1970. Submersible observations in the Straits of Florida: geology and bottom currents. Bulletin Geological Society of America. 81: 2861-2874.

*Neumann, A., J. Kofoed, and G. Keller. 1977. Lithoherms in the Straits of Florida. Geology 5: 4-10.

NOAA. 1981. Key Largo Coral Reef National Marine Sanctuary deep water resource survey. NOAA Tech. Rept. CZ/SP-1, 144 pp.

NOAA. 1982. Fishery Management Plan for Coral and Coral Reefs of the Gulf of Mexico and South Atlantic, Gulf of Mexico and South Atlantic Fishery Management Councils, National Oceanographic and Atmospheric Administration.

NOAA. 1983. Announcement of Proposed National Marine Sanctuary Program Site Evaluation List. Federal Register, Vol. 48, No. 41, March 1, 1983.

NOAA. 1998. Oculina bank HAPC expanded northward. South Atlantic Update, The South Atlantic Fishery Management Council, National Oceanographic and Atmospheric Administration, South Atlantic Fisheries Management Commission.

NOAA. 2000. Final rule, Amendment 4 to the Fishery Management Plan for Coral, Coral Reefs, and Live/Hard Bottom Habitats of the South Atlantic Regions (Coral FMP). Federal Register, Vol. 65, No. 115, June 14, 2000.

Parker, R., D. Colby, and T. Wills. 1983. Estimated amount of reef habitat on a portion of the U.S. South Atlantic and Gulf of Mexico continental shelf. Bulletin of Marine Science 33: 935-940.

Paull, C.K. and Dillon, W.P. 1979. The subsurface geology of the Florida-Hatteras slope and inner Blake Plateau. U.S. Geological Survey Open-File Report 79-448, 94 pp.

Paull, C.K. and Dillon, W. P. l980. Erosional origin of the Blake Escarpment: An alternative hypothesis. Geology, v. 8, p. 538-542.

Paull, C.K. and Dillon, W.P. 1980. The appearance and distribution of the gas hydrate reflector off the southeastern United States. U.S. Geological Survey Open-File Report 80-88, 24 p.

*Paull, C.K. and Dillon, W.P. 1980. Structure, stratigraphy, and geologic history of the Florida-Hatteras shelf and inner Blake Plateau. American Association of Petroleum Geologists Bulletin 64(3): 339-358.

*Paull, C.K. and Dillon, W.P. 1980. The stratigraphy of the Florida-Hatteras shelf and slope and its relationship to the offshore extension of the principal artesian aquifer. In Arden, D.D. and Beck, B.F., eds., Symposium on Southeastern Coastal Plain Geology, Vol. 1, 6 ms pages, 2 figs.

Paull, C.K., and Dillon, W.P. 1981. Erosional origin of the Blake Escarpment. An alternative hypothesis – Reply. Geology, v. 9, p. 339-341.

Paull, C.K. and Dillon, W.P. 1981. Appearance and distribution of the gas hydrate reflection in the Blake Ridge region, offshore southeastern United States. USGS Miscellaneous Field Studies Map, MF-1252.

Paull, C.K. and Dillon, W.P. 1982. Carolina Trough structure contour maps. U.S. Geological Survey Miscellaneous Field Studies Map, MF-1042, 4 sheets.

Paull, C.K. and C. Neumann. ? Continental margin brine seeps: their geological consequences. Geology 15: 545-548.

Paull, C.K., Popenoe, P., Dillon, W.P., and McCarthy, S.M. 1980. Geologic subcrop map of the Florida-Hatteras shelf, slope, and inner Blake Plateau. U.S. Geological Survey Miscellaneous Field Studies Map MF-1171, scale 1:500,000.

Paull, C.K., Matsumoto, R, Wallace, P.J., and Dillon, W.P. 2000. Proceedings of the Ocean Drilling Program, Scientific Results volume 164, College Station TX (Ocean Drilling Program), 459p.

*Paull, C. K., A. Neumann, B. am Ende, W. Ussler, N. Rodriguez. 2000. Lithoherms on the Florida-Hatteras slope. Marine Geology 166: 83-101.

Perkins, T.H., ..., J.K. Reed...1997. Distribution of hard-bottom habitats on the continental shelf off the northern and central east coast of Florida. Southeast Area Monitoring and Assessment Program, National Marine Fisheries Service.

*Pilkey, O.H. and R. Giles. ?. Bottom topography of the Georgia continental shelf. Univ. Georgia Marine Institute Contribution Number 95.

*Pilkey, O.H., D. Schnitker, and D. Pevear. 1966. Oolites on the Georgia continental shelf edge. J. Sedimentary Petrology 36(2): 462-467.

Pilkey, Orrin, I. Macintyre, and E. Uchupi. 1971. Shallow structures: shelf edge of continental margin between Cape Hatteras and Cape Fear, North Carolina. American Association of Petroleum Geologists ??

Pilkey, Orrin B. Blackwelder, H. Knebel, and M. Ayers. 1981. The Georgia Embayment continental shelf: stratigraphy of a submergence. Geological Soc. Of Amer. Bull., Part 1, vol. 92: 52-63.

*Pillsbury, J.E. 1890. The Gulf Stream, a description of the methods employed in the investigation, and the results of the research. Appendix No. 10- 1890. Superintendant U.S. Coast and Geodetic Survey, for year ending June 1890, pp. 459-620. [parts zeroxed- current measurements from Blake while anchored in the Stream to depths of 2000 fathoms]

Pinet, Paul and P. Popenoe. 1982. Blake Plateau: control of Miocene sedimentation patterns by large scale shifts of the Gulf Stream axis. Geology 10: 257-259.

*Pinet, Paul and P. Popenoe. 1985. Shallow seismic stratigraphy and post-Albian geologic history of the northern and central Blake Plateau. Geol. Soc. Am. Bull. 96: 627-638.

*Poag, C. Wylie. 1978. Stratigraphy of the Atlantic continental shelf and slope of the United States. Ann. Rev. Earth Planet Sci. 6: 251-280.

Poag, C. Wylie. 1984. Neogene stratigraphy of the submerged U.S. Atlantic margin. Paleogeography, Paleoclimatology, Paleoecology 47: 103-127.

Pomponi, S. A. and J. K. Reed. 2000. Sustainable Use of Deep-sea Organisms Collected for Biomedical Research. Marcuba 2000, 5th Congress on Marine Sciences, December 4-8, 2000, Havana, Cuba.

Pomponi, S., M. Kelly, J. Reed, and A. Wright. 2001. Diversity and bathymetric distribution of lithistid sponges in the tropical western Atlantic region. Bulletin of the Biological Society of Washington 10: 344-353.

Pomponi, S., A. Wright, and J. Reed. 2003. Exploration in the South Atlantic Bight: discovery of new resources with pharmaceutical potential. Oceans 2003.

Popenoe, Peter. 1985. Cenozoic depositional and structural history of the North Carolina margin from seismic-stratigraphic analyses. Pp. 125-186, in: C. Poag (ed.), Stratigraphy and Depositional History of the U.S. Atlantic Margin, Van Nostrand Reinhold Pub. Co.

Popenoe, Peter. 1994. Bottom characteristics of the northern Blake Plateau. U.S. Geol. Survey, Open File Rep. 93-724, 16 p. + figs.

*Popenoe, Peter and Dillon, W.P. 1996. Characteristics of the continental slope and rise off North Carolina from GLORIA and seismic-reflection data: The interaction of downslope and contour current processes, Chapt. 4. In Gardner, J.V. Field, M.E., and Twichell, D.C., eds., Geology of the United States' Seafloor: The View from GLORIA, Cambridge University Press, Cambridge, U.K., p. 59-79.

Popenoe, P. and F. Manheim. 2001. Origin and history of the Charleston Bump- geological formations, currents, bottom conditions, and their relationship to wreckfish habitats on the Blake Plateau. American Fisheries Society Symposium 25: 43-94.

Popenoe, P., Ball, M.M., Vazzana, M.E., Paull, C.K., Coward, E.L., Dillon, W.P., Hampson, J.C., and Durden, T. 1980. Southeastern U.S. Atlantic Outer Continental Shelf, geologic hazards or constraints to petroleum development. In Popenoe, P., ed., Final report--Environmental studies, southeastern United States Atlantic Outer Continental Shelf, l977: U.S. Geological Survey Open-file Report 80-l46, map scale 1:500,000.

Popenoe, P., Dillon, W.P., Paull, C.K. and Robb, J.M. l982. Environmental considerations. In Dillon W.P., ed., Summary of regional geology, petroleum potential, resource assessment and environmental considerations for oil and gas lease sale area #56: U.S. Geological Survey Open-File Report 82-398, p. 35-54.

*Popenoe, Peter, V. Henry, and F. Idris. 1987. Gulf trough- The Atlantic connection. Geology 15: 327-332.

Popenoe, Peter, Schmuck, E.A., and Dillon, W.P. 1993. The Cape Fear Landslide: Slope failure associated with salt diapirism and gas hydrate decomposition. In Schwab, W.C., Lee, H.J. and Twichell, D.C. eds., Submarine landslides: Selected Studies in the U.S. Exclusive Economic Zone, U.S. Geological Survey Bulletin 2002, p. 40-53.

Popenoe, Peter, E. Schmuck, and W. Dillon. 2002. The Cape Fear landslide: slope failure associated with salt dispirism and gas hydrat decomposition. In: Submarine Landslides: Selected Studies in the U.S. Exclusive Economic Zone. U.S. Geol. Survey Bull. 2002: 40-53.

Poppe, L.J., and Dillon, W.P. 1989. Petrology of some Lower Ordovician-Silurian sedimentary strata from the Southeast Georgia Embayment, U.S. outer continental shelf. Southeastern Geology, vol. 29, no. 3, p. 169-194.

Popp, L.J. and Polloni. 2000. USGS East-coast sediment analysis: procedures, database, and georeferenced displays. OFR 00-358.

Poppe, L.J., J.C. Hathaway, R.E. Hall, and R.F. Commeau. 1986. Formation of the shelf-edge Cretaceous-Tertiary contact off the Southeastern U.S. coast. Paleogeography, Paleoclimatology, Paleoecology 57: 117-135.

Pourtales, L.F. de 1867. No. 6- Contributions to the fauna of the Gulf Stream at great depths. Bulletin of the Museum of Comparative Zoology, 1(6): 103-120.

Pourtales, L.F. de 1868. No. 7- Contributions to the fauna of the Gulf Stream at great depths. Bulletin of the Museum of Comparative Zoology, Harvard 1(7): 121-142.

Pourtales, L.F. de 1869. List of the Crinoids obtained on the coasts of Florida and Cuba, by the United States Coast Survey Gulf Stream Expeditions, in 1867, 1868, 1869. Bulletin of the Museum of Comparative Zoology, Harvard 1(11): 355-361.

Pourtales, L. 1880. No.4- Reports on the results of dredging, under the supervision of Alexander Agassiz, in the Caribbean Sea, 1878-1879, by the United States Coast Steamer "Blake", Part VI. Report on the corals and antipatharia. Bulletin of the Museum of Comparative Zoology 1:7: 95-120.

*Pratt, R.M. 1968. Map showing deep-sea topography off the Atlantic coast of the United States. Geological Survey, Professonal Paper: 529-B. Cont. No. 1820 WHOI.

Presley, R.F. 1970. Larval snowy grouper Epinephelus niveatus from the Florida Straits. Fla. Dept. Nat. Resour. Mar. Res. Lab. Leafl. Ser. Vol 4, Pt. 1, No. 18, 6 pp.

Rankin, D.W., Dillon, W.P., Black, D.F., Boyer, S.E., Daniels, D.L., Goldsmith, R., Grow, J.A., Horton, J.W., Jr., Hutchinson, D.R., Klitgord, K.D., McDowell, R.C., Milton, D.J., Owens, J.P., and Phillips, J.D. 1991. Continent-Ocean Transect E-4, Central Kentucky to Carolina Trough. Publication of Decade of North American Geology, Geological Society of America, Boulder, CO. 2 sheets.

Reed, J.K. 1980. Distribution and structure of deep-water Oculina varicosa coral reefs off central eastern Florida. Bulletin of Marine Science 30(3): 667-677. Part reprinted In W.J. Richards (ed.) Proceedings of Marine Recreational Fisheries Symposium.

Reed, J.K. 1981a. In situ growth rates of the scleractinian coral Oculina varicosa occurring with zooxanthellae on 6-m reefs and without on 80-m banks. Pp. 201-206, In Proceedings Fourth International Coral Reef Symposium, Vol. 2, May 1981, Manila, Philippines.

Reed, J.K. 1981b. Sedimentology photo and abstract. Journal of Sedimentology Petrology 51(4): 1102. Reprinted In K. Condie (In press). Origin and Evolution of Earth, Burgess Publ. Co.

Reed, J.K. 1981c. Nomination of shelf-edge Oculina coral banks as a National Marine Sanctuary. Submitted to National Oceanographic and Atmospheric Administration (NOAA), and accepted for Final Site Evaluation List, 31 pp.

Reed, J.K. 1981d. Nomination of shelf-edge Oculina coral banks as a habitat area of particular concern (HAPC) for the Coral and Coral Reef Fishery Management Plan. Submitted to and accepted by Gulf of Mexico and South Atlantic Fishery Management Councils, 24 pp.

Reed, J.K. 1981e. Research on shelf-edge Oculina coral banks off central eastern Florida. Pp. 32-33, In Summary of Results of Reefs and Hardgrounds Workshop, Duke University Marine Lab, Beaufort, N.C. Sept. 1981.

Reed, J.K. 1983. Nearshore and shelf-edge Oculina coral reefs: The effects of upwelling on coral growth and on the associated faunal communities. Pp. 119-124, In M. Reaka (ed.), The ecology of deep and shallow coral reefs, Symposia Series for Undersea Research, Vol. 1, NOAA.

Reed, J.K. 1987. The living reef. Pp. 73-77, In Ocean Realm.

Reed, J.K. 1992. Submersible studies of deep-water Oculina and Lophelia coral banks off southeastern U.S.A. Pp. 143-151, In L. Cahoon (ed.) Diving for Science 1992. Proceedings American Academy of Underwater Sciences, Wilmington, North Carolina.

Reed, J.K. 1996. Preliminary survey of mud deposits on the mid-shelf reefs off Fort Pierce, St. Lucie County, Florida. Unsolicited report submitted to the U.S. Corps of Engineers, E.P.A., Florida Department of Environmental Protection, National Marine Fisheries, and St. Lucie County Port and Airport Authority, 37 pp.

Reed, J.K. 1998a. The Gulf Stream. Florida Naturalist 71(2): 10-13.

Reed, J.K. 1998b. An assessment of Florida's deep-water Oculina coral banks. Abstract and poster. Atlantic and Gulf Reef Assessment Workshop, June 2-6, 1998, University of Miami, Florida. HBOI DBMR Miscellaneous Publications #31.

Reed, J.K. 1998c. Bioerosion and sediment production on Florida's deep-water Oculina coral Banks. Abstract. 2nd International Bioerosion Workshop, Fort Pierce, Florida. HBOI DBMR Miscellaneous Publications #35.

Reed, J.K. 2000. Oculina coral banks of Florida: conservation and management of a deep-water reserve. Pp. 2-4, In: Proceedings of the American Academy of Underwater Sciences 20th Annual Scientific Diving Symposium, Oct. 11-15, 2000, St. Petersburg, Florida.

*Reed, J.K. 2002a. Comparison of deep-water coral reefs and lithoherms off southeastern U.S.A. Hydrobiologia 471: 57-69.

Reed, J.K. 2002b. Deep-water Oculina coral reefs of Florida: biology, impacts, and management. Hydrobiologia 471: 43-55.

Reed, J.K. 2002c. Comparison of deep-water Oculina and Lophelia coral banks and lithoherms off southeastern Florida. Pp. 201, In: Proceedings of the First International Symposium on Deep-Sea Corals, July 30- August 3, 2000, Ecology Action Center, Dalhousie Univerisity, Halifax, Nova Scotia.

Reed, J.K. 2002d. Deep-water Oculina coral banks of Florida: an assessment of status, impacts, and management. Pp. 200, In: Proceedings of the First International Symposium on Deep-Sea Corals, July 30- August 3, 2000, Ecology Action Center, Dalhousie Univerisity, Halifax, Nova Scotia.

Reed, J.K. 2002e. Florida's Oculina Reefs, NOAA/ HBOI Cruise. The Slate, American Academy of Underwater Sciences.

Reed, J.K. 2003. Deep-water coral reefs off Southeastern USA. National Geographic Society, Classroom Exploration of the Oceans, 2003, Keynote presentation [http://www.coexploration.org/ceo]. HBOI DBMR Misc. Publ. Number 225.

Reed, J.K. 2004. Medicines from the deep sea: exploration of the Gulf of Mexico. The Slate, American Academy of Underwater Sciences, Vol. 1, 2004, p. 10-11, DBMR Contribution Number 230.

Reed, J.K. and R.G. Gilmore. 1981. Inshore occurrence and nuptial behavior of the roughtail stingray, Dasyatis centroura (Dasyatidae), on the continental shelf, east central Florda. Northeast Gulf Science 5(1): 59-62.

Reed, J.K. and C.M. Hoskin. 1987. Biological and geological processes at the shelf edge investigated with submersibles. Pp. 191-199, In Scientific applications of current diving technology on the U.S. Continental Shelf, NOAA Symposium Series for Undersea Research, Vol. 2.

Reed, J.K. and R.S. Jones. 1982. Deep-water coral reefs. Discovery off Florida's Coast. Oceans 15: 38-41.

Reed, J.K. and P.M. Mikkelsen. 1987. The molluscan community associated with the scleractinian coral Oculina varicosa. Bulletin of Marine Science 40(1): 99-131.

Reed, J. and S. Pomponi. 1997a. Biodiversity and distribution of deep and shallow water sponges in the Bahamas. Pp. 1387-1392, In: Proceedings of the Eighth International Coral Reef Symposium, June 24-29, 1996.

Reed, J. K. and S. Pomponi. 1997b. Final Cruise Report. Submersible and scuba collections in the coastal waters of the Bahama Islands and Florida's Oculina coral banks: Biomedical and biodiversity research of the benthic communities with emphasis on the Porifera and Gorgonacea. HBOI Miscellaneous Publication No. 327, 82 pp

Reed, J. K. and S. Pomponi. 1999c. Submersible and scuba collections in the Gulf of Mexico, Florida Keys National Marine Sanctuary, and Florida Straits: Biomedical and biodiversity research of the benthic communities with emphasis on the porifera and gorgonacea, August 5-25, 1999. HBOI DBMR Misc. Cont. Number 79.

Reed, J. K. and S. Pomponi. 2002a. Submersible and scuba collections in the Gulf of Mexico, Florida Keys National Marine Sanctuary, and Straits of Florida: biomedical and biodiversity research of the benthic communities with emphasis on Porifera and Gorgonacea. Final Cruise Report. HBOI DBMR Misc. Cont. Number 174.

Reed, J.K. and S. Pomponi. 2002b. Islands in the Stream 2002: Exploring Underwater Oases. Mission Three: Summary. Discovery of new resources with pharmaceutical potential. Final Cruise Report.

Reed, J.K. and A. Wright. 2004. Final cruise report. Submersible and scuba collections on deep-water reefs off the east coast of Florida, including the Northern and Southern Straits of Florida and Florida Keys National Marine Sanctuary for biomedical and biodiversity research of the benthic communities with emphasis on the Porifera and Gorgonacea, May 20- June 2, 2004. Conducted by the Center of Excellence, HBOI and FAU, 54 pp. HBOI DBMR Misc. Cont. Number 240.

Reed, J.K., et. al. 1986. Shelf-edge Oculina coral reefs. Pp. 466-469, In W. Seaman, Jr. (ed.), Florida aquatic habitat and fishery resources, American Fisheries Society, 560 pp.

Reed, J.K., R.H. Gore, L.E. Scotto, and K.A. Wilson. 1982. Community composition, structure, aereal and trophic relationships of decapods associated with shallow- and deep-water Oculina varicosa coral reefs. Bulletin of Marine Science 32: 761-786.

Reed, J.K., S. Pomponi, T. Frank, and E. Widder. 2002. Islands in the Stream 2002: Exploring Underwater Oases. Mission Three: Summary. Discovery of new resources with pharmaceutical potential; vision and bioluminescence in deep-sea benthos. NOAA Ocean Exploration web site: http://oceanexplorer.noaa.gov/explorations/02sab/logs/summary/summary.html, 29 pp., HBOI DBMR Misc. Cont. Number 208.

Reed, J.K., A. Wright, and S. Pomponi. 2003. Discovery of new resources with pharmaceutical potential in the Gulf of Mexico. Mission Summary Report, 2003 National Oceanic and Atmospheric Administration Office of Ocean Exploration, 31 pp. HBOI DBMR Misc. Cont. Number 224.

Reed, J.K., S. Pomponi, A. Wright, D. Weaver, and C. Paull. 2004a (submitted). Deep-water sinkholes and lithoherms of South Florida and Pourtales Terrace- Habitat and Biology.

Reed, J.K., S.A. Pomponi, A. Wright, and D. Weaver. 2004b (in prep). Habitat characterization and comparison of five deep-water coral reefs: Blake Plateau, Straits of Florida, and the Gulf of Mexico.

Reed, J.K., A. Shepard, C. Koenig, K. Scanlon, and G. Gilmore. 2004c (in press). Mapping, habitat characterization, and fish surveys of the deep-water Oculina coral reef Marine Protected Area: a review of historical and current research. Proceedings of Second International Symposium on Deep Sea Corals, Sept. 9-12, 2003, Erlanger, Germany.

Reed, J. K., A, Wright, S. Pomponi. 2004d. Medicines from the Deep Sea: Exploration of the Northeastern Gulf of Mexico. In: Proceedings of the American Academy of Underwater Sciences 23th Annual Scientific Diving Symposium, March 12-13, 2004, Long Beach, California, p. 58-70. HBOI Contribution Number 1547.

Riggs, Stanley. 1984. Paleoceanographic model of Neogene phosphoritic deposition, U.S. Continental margin. Science 223 (4632): 123- ?

Robb, J.M., Dillon, W.P., O'Leary, D.W., and Popenoe, Peter. 1996. Part II, U.S. East Coast EEZ. In Gardner, J.V., Field, M.E., and Twichell, D.C., eds., Geology of the United States' Seafloor: The View from GLORIA, Cambridge University Press, Cambridge, U.K., p.43-45.

Rowe, G.T. and R. Menzies. 1969. Zonation of large benthic invertebrates in the deep-sea off the Carolinas. Deep-sea Research 16: 531-537.

Schlee, J.S., Dillon, W.P., and Grow, J.A. 1979. Structure of the continental slope off the eastern United States. Society of Economic Paleontologists and Mineralogists, Special Publication 27, p 95-117.

Schlee, J.S., Folger, D.W., Dillon, W.P., Klitgord, K.D., and Grow, J.A. 1979. The continental margins of the western North Atlantic. Oceanus 22: 40-47.

Seaman, William (editor), 1985. Florida aquatic habitat and fishery resources. Florida Chapter of American Fisheries Society.

SEAMAP. 1987. Ross, S.W., E. Barber, R. Searles, and S. Riggs. An evaluation of methods for mapping hard bottoms in the South Atlantic Bight. SEAMAP Special Evaluation Rept. No. 8 of the Atlantic States Marine Fisheries Commission.

SEAMAP. 2001. Southeast Area Mapping and Assessment Program- South Atlantic (SEAMAP-SA). Distribution of Bottom Habitats on the Continental Shelf from North Carolina through the Florida Keys. SEAMAP-SA Bottom Mapping Workgroup, Atlantic States Marine Fisheries Commission, Washington, DC. 166 pp.

SEAMAP. 2001. Southeast Area Mapping and Assessment Program- South Atlantic (SEAMAP-SA). South Atlantic Bight Bottom Mapping CD-ROM, Version 1.2. SEAMAP-SA Bottom Mapping Workgroup, Atlantic States Marine Fisheries Commission, Washington, DC.

Sedberry, G.R. (editor). 2001. Islands in the Stream: Oceanography and Fisheries of the Charleston Bump. American Fisheries Symposium 25, American Fisheries Society, Maryland, 240 pp.

Sedberry, G., J. McGovern, and O. Pashuk. 2001. The Charleston Bump: an island of essential fish habitat in the Gulf Stream. American Fisheries Symposium 25: 3-24.

Shepard, A. and J.K. Reed. 2003. OCULINA BANKS 2003: Characterization of Benthic Habitat and Fish Populations in the Oculina Habitat Area of Particular Concern (OHAPC), Mission Summary Report. NOAA/ NURC and South Atlantic Fishery Management Council. 14 pp.

Shepard, A., P. Orlando, J. Reed, … 2001. Islands in the Stream Expedition: Oculina Habitat Area of Particular Concern, expedition summary report, 10 September 2001. NOAA Ocean Exploration Program, 7 pp.

*Sheridan, R.E., C. Drake, J. Nafe, and J. Hennion. 1966. Seismic-refraction study of continental margin east of Florida. Bull. Amer. Assoc. Petroleum Geologists 50(9): 1972-1991.

*Sheridan, R.E., J. Smith, and J. Gardner. 1969. Rock dredges from Blake Escarpment near Great Abaco Canyon. Amer. Assoc. Petroleum Geologists Bull. 53: 2551-2558.

Sheridan, R.E., Crosby, J.T., Kent, K.M., Dillon, W.P. and Paull, C.K. l981. The geology of the Blake Plateau and Bahamas region. In: The geologic atlas of the North American borderlands: Canadian Society of Petroleum Geologists, Memoir 7, p. 487-502.

*Siegler, V.B. 1959. Reconnaissance survey of the bathymetry of the Straits of Florida. Univ. Miami, Inst. Mar. Sciences, Marine Lab Rept. 59-3, 9 p.

*Smith, W.H. and D. Sandwell. 1997. Global sea floor topography from satellite altimetry and ship depth soundings. Science 277: 956-1962.

*Squires, D.F. 1959. Deep sea corals collected by the Lamont Geological Observatory. 1. Atlantic corals. American Museum Novitates. 1965: 1-42.

*Stanley, Daniel. 1969. Atlantic continental shelf and slope of the United States- color of marine sediments. Geological Survey Prof. Paper 529-D, pp. D1-15.

Stetson, T.R., D. Squires, and R. Pratt. 1962. Coral banks occurring in deep water on the Blake Plateau. Amer. Mus. Novitates, No. 2114: 1- 39.

*Stewart, H.B., Jr. 1962. Oceanographic cruise report, U.S. Coast and Geodetic Survey ship EXPLORER-1960. U.S. Dept. Commerce, Coast and Geodetic Survey, Wash., D.C., 162 p. [parts zeroxed- some stations in Florida Straits]

Sylwester, R.E., Dillon, W.P., Grow, J.A. 1979. Active growth fault on seaward of the Blake Plateau. In Gill, D. and Merriam, D.F., eds., Geomathematical and Petrophysical Studies in Sedimentology: Oxford, Pergamon Press, p. 197-209.

Taylor, M., Dillon, W. Anton, C., and Danforth, W. 1999. Seismic reflection surveys of the Blake Ridge, R/V Cape Hatteras 1992 and 1995: Data acquisition, navigation and processing. U.S. Geological Survey Open File Report 99-372 (2- CD-ROMs).

Taylor, M.H., Dillon, W.P., and Pecher, I.A. 2000. Trapping and migration of methane associated with the gas hydrate stability zone at the Blake Ridge Diapir: new insights from seismic data, Marine Geology, vol. 164, p. 79-89.

Teichert, Curt. 1958. Cold- and deep-water coral banks. Bull. Amer. Assoc. Petroleum Geologists 42: 1064-1082.

Tendal, O.S. 1992. The North Atlantic distribution of the octocoral Paragorgia arborea (L., 1758). Sarsia 77: 213-217.

Thompson, M.J. and L.E. Gulliland. 1980. Topographic mapping of shelf edge prominences off southeastern Florida, Southeastern Geology 21, 155-164.

*Top Spot, Inc. 2000? East Florida offshore fishing and diving map, Port Canaveral to Lake Worth Inlet, Map No. N220. Pasadena Hot Spot, Inc., 4016 Strawberry Rd., Pasadena, TX 77504. (bathymetry of Florida Straits)

*Top Spot, Inc. 2000? South Florida offshore fishing and diving map, Miami to Dry Tortugas, Map No. N210. Pasadena Hot Spot, Inc., 4016 Strawberry Rd., Pasadena, TX 77504. (bathymetry of Florida Straits)

Twichell, D.C., Dillon, W.P., Paull, C.K., and Kenyon, N.H. 1996. Morphology of carbonate escarpments as an indicator of erosional processes, Chapt, 6. In Gardner, J.V., Field, M.E., and Twichell, D.C., eds., Geology of the United States' Seafloor: The View from GLORIA, Cambridge University Press, Cambridge, U.K., p. 97-107.

*Uchupi, E. 1966. Shallow structure of the Straits of Florida. Science 153: 529-531.

*Uchupi, E. 1967. The continental margin south of Cape Hatteras, North Carolina: shallow structure. Southeastern Geol. 8: 155-177. (includes north Florida)

*Uchupi, E. 1968. Atlantic continental shelf and slope of the United States- physiography. U.S. Geological Survey Professional Papers 529-C: C1-C29.

*Uchupi, E. 1968. Morphology of the continental margin southeastern Florida. Southeastern Geology 11: 129-134.

*Uchupi, E. 1968. Tortugas Terrace, a slip surface? U.S. Geological Professional Papers 600-D: D231-D234.

*Uchupi, E. 1969. Morphology of the continental margin off southeastern Florida. Southeastern Geology 11: 129-134. [high definition map of Florida Straits 25 N to 29 N]

*Uchupi, E. 1969. Atlantic continental shelf and slope of the United States- shallow structure. Cont. No. 2098 WHOI, 44 pp.

*Uchupi. Elazar and K. Emery. 1967. Structure of continental margin off Atlantic coast of United States. Amer. Assoc. of Petroleum Geologists Bull. 51: 223-234.

Uchupi, E. and R. Tagg. 1966. Microrelief of the continental margin south of Cape Lookout, North Carolina. Geol. Soc. Amer. Bull. 77: 427-430.

*Univ. Miami. 1966. Dredging and trawling records of R/V John Elliott Pillsbury for 1964 and 1965. Stud. Trop. Oceanogr. Miami 4: 82-105. (some Florida records)

*Univ. Miami. 1966. Biological survey of the southwestern Caribbean, R/V JOHN ELLIOTT PILLSBURY. The Institute of Marine Science, University of Miami.

*Univ. Miami. 1966. Narrative of the cruise P-6607 to the southwestern Caribbean, R/V JOHN ELLIOTT PILLSBURY. The Institute of Marine Science, University of Miami. [Stations P317-479]

*Univ. Miami. 1968. Narrative of the cruise P-6802 to the southwestern Caribbean, R/V JOHN ELLIOTT PILLSBURY. The Institute of Marine Science, University of Miami. [Stations P587-637]

*Univ. Miami. 1968. Narrative of the cruise P-6806 to the southern Caribbean, R/V JOHN ELLIOTT PILLSBURY. The Institute of Marine Science, University of Miami. [Stations P642-803]

Ewing, Ewing and Jordan. 1966. [Blake Plateau- coral mounds]

Vaughan, D.S., C.S. Manooch, III and J.C. Potts. 2001. Assessment of the wreckfish fishery on the Blake Plateau. p. 105-119. In: Sedberry, G.R. (ed.). Island in the Stream: oceanography and fisheries of the Charleston Bump. Amer. Fish. Soc., Symp. 25. Bethesda, MD. 240 p.

Virden, W. T., T. L. Berggren, T. A. Niichel, and T. L. Holcombe. 1996. Bathymetry of the shelf-edge banks, Florida east coast, National Oceanographic and Atmospheric Administration, National Geophysical Data Center, National Marine Fisheries Service, Beaufort, North Carolina: 1.

Voss, G.L., C. Richard Robins, and J. Staiger. 1977. Study of the macro-fauna of the Tropical Western Atlantic. FAO Fisheries Rept. No. 200: 483-503. [Summary of UM vessels Pillsbury, Gerda, Gillis, Islen from 1964-1975 in tropical Atlantic from Africa, Caribbean, Panama, and Florida Straits]

Watkins, J.S., Buffler, R.T., Houston, M.H., Ladd, J.W., Shipley, T.H., Shaub, F.J., Sinton, J.B., Worzel, J.L., and Dillon, W.P. 1977. Crustal velocities from common depth point reflection data. American Geophysical Union, Geophysical Monograph 20, The Earth's Crust, p. 271-288.

Wenner, E.L. and C. Barans. 2001. Benthic habitats and associated fauna of the upper- and middle-continental slope near the Charleston Bump. American Fisheries Society Symposium 25:161-178.

*Whitmore, Jr. F. C., G. Morejohn, and H. Mullins. 1986. Fossil beaked whales- Mesoplodon longirostris dredged from the ocean bottom. National Geographic Research 2(1): 4-56.

*Zarudzki, E.F. and E. Uchupi. 1968. Organic reef alignment on the continental margin south of Cape Hatteras. Geol. Soc. America Bull. 79: 1867-1870.

Part II- Gulf of Mexico:

Ballard R. and E. Uchupi. 1970. Morphology and quaternary history of the continental shelf of the Gulf coast of the United States. Bulletin of Marine Science 20: 547-559.

Barry, J., K. Buck, and M. Tamburri. 1998. Cold seep biology and ecology. Monterey Bay Aquarium Research Institute, 1998 Annual Report.

BLM. 1977. Baseline monitoring studies, Mississippi, Alabama, Florida, outer continental shelf, 1975-1976, Vol. 3. Results. Bureau of Land Management Contract No. 08550-CT5-30.

Bright, T.J. ?. Coral reefs, nepheloid layers, gas seeps, and brine flows on hard-banks in the norhteastern Gulf of Mexico. Pp. 40-46, in ?

Bright, T. and L. Pequegnat. 1974. Biota of the West Flower Garden Bank. Gulf Publ. Co., Houston, Tx, 453 p.

Bright, T.J., G. Kraemer, G. Minnery, and S. Viada. 1984. Hermatypes of the Flower Garden Banks, northwestern Gulf of Mexico: a comparison to other western Atlantic reefs. Bull. Mar. Sci. 34: 461-476.

Bright, T., S. Gittings, and R. Zingula. 1991. Occurrence of Atlantic reef corals on the offshore platforms in the northwestern Gulf of Mexico. Northeast Gulf Science 12: 55-60.

Brooks, G. and L. Doyle, 1991. Geologic development and depositional historty of the Florida Middle Ground: a mid-shelf, temperate zone reef system in the northeastern Gulf of Mexico. Society of Sedimentary Geology Special Publication, 46: 189-203.

Brooks and Giammona. 1990. Mississippi-Alabama marine ecosystem study, year 2 annual report. OCS Study, Minerals Management Service 89-0095 to 0096, Contract No. 14-12-0001-30346, 2 vol.

Brooks, G. and C. Holmes. 1990. Modern configuration of the southwest Florida carbonate slope. Development by shelf margin progradation. Marine Geology 94: 301-315.

Brooks, J., M. Kennicutt, R. Bidigare, and R. Fay. 1985. Hydrates, oil seepage, and chemosynthetic ecosystems of the Gulf of Mexico slope. The Oceanography Report, EOS 66(10): 106.

Brooks, J., M. Kennicutt, R. Brigadare, T. Wade, E. Powell, F. Denoux, R. Fay, J. Childress, C. Fisher, I. Rossman, and G. Boland. 1987. Hydrates, oil seepage, and chemosynthetic ecosystems on the Gulf of Mexico slope: an update. The Oceanography Report EOS, May 5, 1987.

Bryant, W., A. Meyerhoff, N. Brown, Jr., M. Furrer, T. Pyle, and J. Antoine. 1969. Escarpments, reef trends, and diapatric structures, eastern Gulf of Mexico. American Association of Petroleum Geologists 53: 2506-2542.

Cairns, S.D. 1977. Stony corals. Mem. of the Hourglass Cruises, Vol. 3, Part 4, 27 pp.

Carsey, J. B. 1950. Geology of Gulf coastal area and continental shelf. Bull. Amer. Assoc. Petroleum Geologists 34: 361-386.

Continental Shelf Associates. 1985. Live bottom survey of drillsite locations in Destin Dome area block 617. Report to Chevron, 40 pp. + photos.

Continental Shelf Associates. 1985. Southwest Florida shelf regional biological communities survey, marine habitat atlas. Minerals Management Service Contract No. 14-12-0001-29036.

Continental Shelf Associates. 1987. Southwest Florida shelf regional biological communities survey, year 3, final report. OCS Study, Minerals Management Service 87-0108 to 0110, Contract No. 14-12-0001-29036, 3 vol.

Continental Shelf Associates. 1992. Mississippi- Alabama shelf pinnacle trend habitat mapping study. OCS Study, Minerals Management Service 92-0026, Contract No. 14-35-0001-30494.

Continental Shelf Associates, Texas A&M University. 1998. Northeastern Gulf of Mexico coastal and marine ecosystem program: ecosystem monitoring, Mississippi/ Alabama shelf, first annual report. OCS Study, Minerals Management Service 97-0037, BRD Contract No. 1445-CT09-96-0006.

Dames and Moore. 1979. The Mississippi, Alabama, Florida OCS baseline environmental survey. MAFLA 1977/1978. Bureau of Land Management Contract No. AA550-CT7-34.

Doyle, L. and C. Holmes. 1985. Shallow structure, stratigraphy and carbonate sedimentary processes of west Florida upper continental slope. American Association of Petroleum Geologists Bulletin 69: 1133-1144.

Environmental Science and Engineering, and LGL Ecological Research Associates. 1985. Southwest Florida shelf benthic communities study. Minerals Management Service Contract No. 14-12-0001-30071, 3 vol.

Environmental Science and Engineering, and LGL Ecological Research Associates. 1986. Southwest Florida shelf benthic communities study, year 5 annual report. OCS Study, Minerals Management Service 86-0074 to 0076, Contract No. 14-12-0001-30211, 3 vol.

Environmental Science and Engineering, LGL Ecological Research Associates, and Continental Shelf Associates. 1987. Southwest Florida shelf ecosystems study, data synthesis. Minerals Management Service Contract No. 14-12-0001-30276, 2 Vol.

Florida Institute of Oceonography. 1973. Summary of knowledge of the eastern Gulf of Mexico.

Florida Institute of Oceonography. 1977. Baseline monitoring studies. Mississippi, Alabama, Florida OCS, 1975-1976.

Gittings, S., T. Bright, and E. Powell. 1984. Hard bottom macrofauna of the East Flower Garden brine seep: impact of a long-term sulfurous brine discharge. Contributions Marine Science 27: 105-125.

Gittings, S., T. Bright, W. Schroeder, W. Sager, J. Laswell, and R. Rezak. 1992. Invertebrate assemblages and ecological controls on topographic features in the northeast Gulf of Mexico. Bulletin of Marine Science 50:435-455.

Grassle, J.F. 1985. Hydrothermal vent animals: distribution and biology. Science 229: 713-717.

Hilde, W., G. Sharman, W. Warsi, C. Lee, M. Feeley, and M. Meyer. 1981. Mapping and sub-bottom profiling. p. 6-20, in: Northern Gulf of Mexico Topographic Features Study, Texas A&M Univ.

Holmes, C. 1981. Late neocene and quaternary geology of the southwestern Florida shelf and slope. U.S. Geological Survey, 81-1029.

Hopkins, T., D. Blizzard, S. Brawley, S. Earle, D. Grimm, D. Gilbert, P. Johnson, E. Levingston, C. Lutz, J. Shaw, and B. Shaw. ? A preliminary characterization of the biotic components of composite strip transects on the Florida Middlegrounds, northeastern Gulf of Mexico. U. S. Bureau of Land Management Contract No. 0880-CT5-30, p. 32-37.

Hopkins, T., D. Blizzard, and D. Gilbert. 1977. The molluscan fauna of the Florida Middle Grounds with comments on it's zoogeographical affinities. Northeast Gulf Science 1(1): 39-47.

Hopkins, T., W. Schroeder, T. Hilde, L. Doyle, and J. Steinmetz. 1981. Northern Gulf of Mexico topographic features study. Bureau of Land Management Contract No. AA551-CT8-35, 150 pp.

Jaap, W. 2000. Observations on deep marine structures: Florida Middle Ground, Pulley Ridge, and Howell Hook from the Deepworker submersible, Sustainable Seas Expedition. Proceedings of American Academy of Underwater Sciences 20th Annual Symposium, St. Petersburg, Florida, October 2000.

Jarrett, B., A. Hine, C. Neumann, D. Naar, S. Locker, D. Mallison, and W. Jaap. 2000. Deep biostromes at Pulley Ridge, southwest Florida carbonate platform. Proceedings of American Academy of Underwater Sciences 20th Annual Symposium, St. Petersburg, Florida, October 2000.

Jordan, G. 1951. Continental slope of Apalachicola River, Florida. Bulletin American Association of Petroleum Geologists 35: 1978-1993.

Jordan, G. 1952. Reef formation in the Gulf of Mexico off Appalachicola Bay, Florida. Bulletin Geological Society of America 63: 741-744.

Kennicutt, M.C., J. Brooks, R. Bidigare, R. Fay, T. Wade, and T. MacDonald. 1985. Vent-type taxa in a hydrocarbon seep region on the Louisiana slope. Nature 317: 351-353.

Ludwick, J. 1964. Sediments in northeastern Gulf of Mexico. Pp. 208-238, in: R. Miller (ed.) Papers in Marine Geology, MacMillan Co., N.Y.

Ludwick, J. and W. Walton. 1957. Shelf edge calcareous prominences in the northeastern Gulf of Mexico. Bulletin American Association of Petroleum Petrologists 41: 2054-2101.

Moore, D. and H. Bullis Jr. 1960. A deep water coral reef in the Gulf of Mexico. Bulletin of Marine Science 10: 125-128.

Mullins, H., A. Gardulski, E. Hinchey, and A. Hine. 1988. The modern carbonate ramp-slope of central west Florida. Journal of Sedimentary Petrology 58: 273-290.

Nairn, A. and F. Stehli (eds.). 1975. The Ocean Basins and Margins, V. 3- The Gulf of Mexico and the Caribbean. Plenum Press, N.Y., 706 p.

Neurauter, Thomas. 1980. Bedforms on the west Florida shelf as detected with side scan sonor. M.S. Thesis, Univ. South Florida, 120 p.

Newton C., H. Mullins, F. Gardulski, A. Hine, and G. Dix. 1987. Coral mounds on the west Florida slope: unanswered questions regarding the development of deep-water banks. Palaios 2: 359-367.

Parker, R. and J. Curray. 1956. Fauna and bathymetry of bank on continental shelf, northwest Gulf of Mexico. Bulletin American Association of Petroleum Geologists 40: 2428-2439.

Paull, C.K., B. Hecker, R. Commeau, R. Freeman-Lynde, C. Neumann, W. Corso, S. Golubic, J. Hook, E. Sikes, and J. Curray. 1984. Biological communites at the Florida Escarpment resemble hydrothermal vent taxa. Science 226: 965-967.

Phillips, N., D. Gettleson, and K. Spring. 1990. Benthic biological studies of the southwest Florida shelf. American Zoologist 30: 65-75.

Rezak, R., T. Bright, et al. 1981. Northern Gulf of Mexico topographic features study. Bureau of Land Management, Contract No. AA551-CT8-35. [Executive Summary- copied]

Rezak, R. and T. Bright. 1983. Classification and characteristics of banks. Pp. 311-399, in: Reefs and Banks of the Northwestern Gulf of Mexico: their geological, biological, and physical dynamics. Minerals Management Service Contract No. AA851-CT1-55.

Rezak, R., T. Bright, and D. McGrail. 1985. Reefs and banks of the northern Gulf of Mexico: their geological, biological, and physical dynamics. John Wiley and Sons, N.Y., 259 pp. [parts zeroxed] [HBOI Library]

Rezak, R., W. Sager, J. Laswell, and S. Gittings. 1989. Seafloor features on Mississippi-Alabama outer continental shelf. Transactions Gulf Coast Association of Geological Societies 39:511-514.

Rezak, R., S. Gittings, and T. Bright. 1990. Biotic assemblages and ecological controls on reefs and banks of northwest Gulf of Mexico. American Zoologist 30: 23-35.

Rowe, G.T. and D. Menzel. 1971. Quantitative benthic samples from the deep Gulf of Mexico with some comments on the measurement of deep-sea benthos. Bull. Mar. Sci. 21: 556-566.

Schroeder, W., A. Shultz, and J. Dindo. 1988. Inner-shelf hardbottom areas, northeastern Gulf of Mexico. Transactions Gulf Coast Association of Geological Societies 38: 535-541.

Shipp, R. and T. Hopkins. 1978. Physical and biological observations on the northern rim of the Desoto Canyon made from a research submersible. Northeast Gulf Science 2: 113-121.

Uchupi, E. 1967. Bathymetry of the Gulf of Mexico. Gulf Coast Association Geological Society Transactions 17: 161-172.

Uchupi, E. and K. Emery. 1968. Structure of continental margin off Gulf coast of United States. American Association Petroleum Geologists Bulletin 52: 1162-1193.

United States Geological Society. 1998. Geology of shelf-edge habitats of the eastern Gulf of Mexico. USGS Information Handout, Sept. 1998.

Woodward Clyde Consultants and Continental Shelf Associates. 1983. Southwest Florida shelf ecosystems study. Minerals Management Service Contract No. 14-12-0001-29142, 4 vol.

Woodward Clyde Consultants and Continental Shelf Associates. 1985. Southwest Florida shelf ecosystems study. Minerals Management Service Contract No. 14-12-0001-29144, 7 vol.

Part III: Eastern Atlantic and General Deep Sea Reefs:

Fosså, J. H., P. B. Mortensen & D. M. Furevik, 2000a. The deep water coral *Lophelia pertusa* in Norwegian waters; distribution and fishery impacts. First Internat. Symp. Deep Sea Corals: 25.

Fosså, J. H., P. B. Mortensen & D. M. Furevik, 2000b. Lophelia-korallrev langs Nordskekysten forekomst og tilstand. Institute of Marine Research, Bergen, Fisken og Havet Nr. 2: 94 pp.

Fosså, J.H., P.B. Mortensen and D.M. Furevik. 2002. The deep-water coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts. Hydrobiologia 471: 1-12.

Freiwald, A. & J. Schönfeld, 1996. Substrate pitting and boring pattern of Hyrrokkin sarcophaga Cedhagen, 1994 (Foraminifera) in a modern deep-water coral reef mound. Mar. Micropaleon. 28: 199-207.

Freiwald, A., R. Henrich & J. Pätzold, 1997. Anatomy of a deep-water coral reef mound from Stjernsund, west Finnmark, northern Norway. Soc. sedim. Geol., SEPM spec. Pub. 56: 141-161.

Freiwald, A., J. B. Wilson & R. Henrich, 1999. Grounding Pleistocene icebergs shape recent deep-water coral reefs. Sedim. Geol. 125: 1-8.

Genin, A., P.K. Dayton, P.F. Lonsdale, and F.N. Spiess. 1986. Corals on seamount peaks provide evidence of current acceleration over deep-sea topography. Nature 322: 59-61.

Griffin, S. & E. R. Druffel, 1989. Sources of carbon to deep-sea corals. Radiocarbon 31: 533-543.

Hovland, M. and M. Risk. 2003. Do Norwegian deep-water coral reefs rely on seeping fluids? Mar. Geol. 198: 83-96.

Hovland, M., P.B. Mortensen, T. Brattegard, P. Strass and K. Rokoengen. 1998. Ahermatypic coral banks off mid-Norway: evidence for a link with seepage of light hydorcarbons. Palaios 13: 189-200.

Husebo, A., L. Nottestad, J.H. Fossa, D.M. Furevik and S.B. Jorgensen. 2002. Distribution and abundance of fish in deep-sea coral habitats. Hydrobiologia 471: 91-99.

Jensen, A. & R. Frederiksen, 1992. The fauna associated with the bank-forming deepwater coral *Lophelia pertusa* (scleractinia) on the Faroe shelf. Sarsia 77: 53-69.

Jones, J. B., 1992. Environmenal impact of trawling on the seabed: a review. New Zeal. J. Mar. Freshw. Res. 26: 59-67.

Koslow, J.A. 1997. Seamounts and the ecology of deep-sea fisheries. Amer. Sci. 85: 168-176.

Koslow J.A. and K. Gowlett-Jones. 1998. The Seamount Fauna off Southern Tasmania: Benthic Communities, Their Conservation and Impacts of Trawling. Final Report to Environment Australia and Fisheries Research Development Coorporation. Australia, 104 pp.

Koslow, J. A., G. W. Boehlert, J. D. Gordon, R. L. Haedrich, P. Lorance & N. Parin, 2000. Continetal slope and deep-sea fisheries: implications for a fragile ecosystem. ICES J. mar. Sci. 57: 548-557.

Krutschinna, J. & A. Freiwald, 1998. Microendolithic succession along live to dead Lophelia pertusa (L.) skeletons from an aphotic coral reef. Proc. 2nd Inter. Bioerosion Workshop: 43.

Le Goff-Vitry, M.C., O.G. Pybus and A.D. Rogers. 2004. Genetic structure of the deep-sea coral *Lophelia pertusa* in the northeast Atlantic revealed by microsatellites nad internal transcribed spacer sequences. Molecular Ecol. 13: 537-549.

McDonough, J.J. and K.A. Puglise. 2003. Summary: Deep-sea corals workshop. International planning and collaboration workshop for the Gulf of Mexico and the North Atlantic Ocean. Galway, Ireland, January 16-17, 2003. NOAA Tech. Memo. NMFS-SPO-60, 51 p.

Menzies, R.J., R.Y. George, and G.T. Rowe. 1973. Abyssal Environment and Ecology of the World Oceans. John Wiley and Sons, New York.

Mikkelsen, N., H. Erlenkeuser, J.S. Killingley and W.H. Berger. 1982. Norwegian corals: radiocarbon and stable isotopes in *Lophelia pertus*a. Boreas 11: 163-171.

Miller, C.A. 2001. Marine protected area framework for deep-sea coral conservation. p 145-155. In: Willison, J.H.M., J. Hall, S.E. Gass, E.L.R. Kenchington, M. Butler and P. Doherty(eds.). 2001. Proceedings of the First International symposium on Deep-Sea Corals. Ecology Action Centre. Nova Scotia Museum. Halifax, Nova Scotia. 231 p.

Mortensen, P. B. & H. T. Rapp, 1998. Oxygen and carbon isotope ratios related to growth line patterns in skeletons of *Lophelia pertusa* (L.) (Anthozoa, Scleractinia): implications for determination of linear extension rates. Sarsia 83: 433-446.

Mortensen, P. B., M. Hovland, T. Brattegard & R. Farestveit, 1995. Deep-water bioherms of the scleractinian coral *Lophelia pertusa* (L.) at 64°N on the Norwegian shelf: structure and associated megafauna. Sarsia 80: 145-158.

Richer de Forges, B., J. A. Koslow & G. C. Poore, 2000. Diversity and endemism of the benthic seamount fauna in the southwest Pacific. Nature 405: 944-947.

Roberts, C.M. 2002. Deep impact: the rising toll of fishing in the deep sea. Trends Ecol. Evol. 17: 242-245.

Roberts, S. and M. Hirshfield. 2003. Deep Sea Corals: out of sight, but no longer out of mind. Oceana. Washington, DC.

Rogers, A.D. 1994. The biology of seamounts. Advances Mar. Biol. 30: 306-350.

Rogers, A. D., 1999. The biology of *Lophelia pertusa* (Linnaeus 1758) and other deep-water reef-forming corals and impacts from human activities. Internat. Rev. Hydrobiol. 84: 315-406.

SGCOR. 2004. Report of the study group on cold-water corals (SGCOR). ICES Advisory Committee on Ecosystems, ICES CM 2004/ACE:07 ref. E.

Squires, D. F., 1964. Fossil coral thickets in Wairarapa, New Zealand. J. Paleontol. 38: 904-915.

Teichert, C., 1958. Cold- and deep-water coral banks. Bull. am. Ass. petrol. Geol. 42: 1064-1082.

Waller R.G. and P.A. Tyler. In Press. The reproductive biology of two deep-sea, reef-building scleractinians from the NE Atlantic Ocean. Coral Reefs.

Wilson, J. B., 1979a. The distribution of the coral *Lophelia pertusa* (L) [*L. prolifera* (Pallas)] in the northeast Atlantic. J. mar. biol. Ass. U.K. 59: 149-164.

Wilson, J. B., 1979b. “Patch” development of the deep-water coral *Lophelia pertusa* (L.) on Rockall Bank. J. mar. biol. Ass. U.K. 59: 165-177.

Appendix B. General Description of Distribution, Habitat and Associated Fauna of Deep Water Coral Reefs on the North Carolina Continental Slope.

Report Prepared for the South Atlantic Fishery Management Council.

GENERAL DESCRIPTION OF DISTRIBUTION, HABITAT, AND ASSOCIATED FAUNA OF DEEP WATER CORAL REEFS ON THE NORTH CAROLINA CONTINENTAL SLOPE

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GENERAL REVIEW

Most habitats of the continental slope, and even the shelf edge, are poorly studied and in many cases completely unknown. Large scale geological surveys of portions of the deeper EEZ (e.g., EEZ-SCAN 87 Scientific Staff 1991; Popenoe and Manheim 2001), have limited biological relevance and little habitat verification. These deeper areas, between 100 to 1000 m, are important frontiers, offering a transition from the continental shelf to the deep sea. Fisheries are expanding rapidly into these deep regions (Roberts 2002), and hydrocarbon exploration and development are now also exploiting these depths. Off the southeastern US (SEUS) coast (including the Gulf of Mexico) there are several unique and productive deep water habitats that can only be adequately sampled with non-conventional methods (e.g., manned submersibles) because the bottom topography is very rugged and/or the habitats are overlain by extreme currents (i.e., Gulf Stream). This report briefly summarizes data relevant to selected such unstudied and vulnerable habitats (i.e., deep coral mounds) on the North Carolina continental slope.

Deep coral reef systems are receiving increasing attention worldwide. These habitats appear to be much more extensive and important than previously known (e.g., SGCOR 2004; unpubl. data), while at the same time being severely threatened by a variety of activities (e.g., fishing, energy exploration) (Rogers 1999; Koslow et al. 2000). These high profile features may concentrate exploitable resources and enhance local productivity in ways similar to seamounts (Rogers 1994; Koslow 1997), but this has not yet been explored. *Lophelia*, the major structure building coral in the deep sea, is fragile, slow-growing (perhaps debatable), and very susceptible to physical destruction (Fossa et al. 2002). Data are lacking on how *Lophelia* coral banks form even though several hypotheses have been posed (Hovland et al. 1998; Hovland and Risk 2003). Data are also equivocal concerning individual coral and coral mound ages (M. Risk, pers. comm.) and the degree to which there is an obligate deep coral fauna. While the genetic structure (population relationships, gene flow, 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. For these reasons, locating, describing, and mapping deep corals and conducting basic biological studies in these habitats are considered global priorities (McDonough and Puglise 2003; Roberts and Hirshfield 2003).

Lophelia reefs are widespread, occurring not only on the Blake Plateau and in the Straits of Florida, but also 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 (Rogers 1999). Small colonies of these corals may be attached to various hard substrates in the appropriate depths throughout the SEUS slope. However, along the 360-500 m depth band of the Blake Plateau , starting off central North Carolina (Fig. 1), scattered (but massive) mounds or ridges (banks) rise from the plateau, and their tops and sides are covered by dense thickets of living (white) deep-sea corals, mostly *Lophelia pertusa* (but also including other genera like *Madrepora*). Along the sides and around the bases of these banks are rubble zones of dead, gray coral branches which may extend tens to hundreds of meters away from the mounds. These ahermatypic, slow-growing stony corals, lacking light-dependent symbiotic algae, are adapted to life in dark, cold waters. Radiocarbon and other dating methods indicated that such deep reefs may be hundreds to thousands of years old (Neumann et al. 1977; Wilson 1979; Mikkelsen et al. 1982; Mortensen and Rapp 1998); however, aging data are so limited (especially along the western Atlantic) that the true distribution of coral ages in the western Atlantic is unclear. The ridges and reef mounds, rising as much as 100 m from the open substrate, accelerate bottom currents which are favorable to 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).

Deep water coral habitat may be more important to western Atlantic slope species than previously known. *Lophelia*'s first discovery on the Blake Plateau was during the late 1950s (Stetson et al. 1962), and later many deep reef locations were suggested by the U.S. Geological Survey sidescan sonar mapping of the continental slope (EEZ-SCAN 87 Scientific Staff 1991). Although extensive published data are lacking, *Lophelia* reefs may populate the Blake Plateau in great abundance (Stetson et al. 1962; Paull et al. 2000; Reed 2002; Popenoe and Manheim 2001; P. Popenoe, pers. comm.). Commercially-exploited deep-water species congregate around *Lophelia* habitat, and evidence of fishing activities (trash, lost gear) was observed on some deep coral banks. Various crabs, especially galatheids, are abundant on these deep reefs, playing a role of both predator on and food for the fishes. Other invertebrates, particularly echinoderms, also populate the coral matrix in high numbers. On the relatively barren and featureless plain of the Blake Plateau, *Lophelia* reefs appear to be oases offering both shelter and food. Additionally, the coral thickets are surrounded by extensive coral rubble habitat which preliminary data indicate also support a diverse fauna.

Deep coral reefs of all types have been very poorly studied, particularly so in the western Atlantic. References on *Lophelia* banks within the US EEZ are largely geological with a few biotic observations, mostly on invertebrates (see review in Reed 2002; references in Sedberry 2001). Studies elsewhere revealed that these deep reefs harbor extensive invertebrate populations composed of hundreds of species (Jensen and Frederiksen 1992; Rogers 1999; Reed 2002). Fish studies related to the deep coral banks are almost non existent (no detailed faunal surveys are published for the western Atlantic), even in the northeastern Atlantic where these corals are better known (Husebo et al. 2002). Although our investigations so far have revealed that many species of fishes and crabs are closely associated with this unique deep-reef habitat, it is unclear whether the deep coral habitat is essential to selected fishes or invertebrates or whether they occupy it opportunistically (Rogers 1999). Assessing its significance as fish and invertebrate habitat and addressing the extent to which the deep reef fauna is unique is an important research topic that is being investigated (S.W. Ross et al., ongoing studies).

No *Lophelia* reefs lie within established or proposed Marine Protected Areas (MPAs) in the US EEZ, but if such reefs prove to be important habitat with a unique fauna (as they seem to be), they should be candidates for protection as are *Oculina* coral reefs off east-central Florida. There are a variety of potential threats to the deep coral bottoms: mining, precious coral harvest, disposal activities, petroleum exploration and development, fiber optic and other cable laying, anchoring/gear damage, and fishing activities. MPAs or Habitat Areas of Particular Concern (HAPC) may be viable options for protecting these systems, but considerable data, especially detailed maps, are critical for evaluating how and whether to protect deep coral habitat (Miller 2001).

As stated above, publications concerning deep coral banks in the SEUS are limited, and this is particularly true of the reefs off of North Carolina. The non-geological data available for

North Carolina deep corals and some areas of the SEUS are from ongoing studies of a multi-agency research team as follows: Steve W. Ross, lead Principal Investigator (Univ. North Carolina-Wilmington), K.J. Sulak (US Geological Survey), M.S. Nizinski (National Marine Fisheries Service Systematics Lab), and E.D. Baird (NC Museum of Natural Sciences). Although this research team has collected considerable data on NC deep coral mounds and has given numerous verbal presentations, publications are still forthcoming. Considering the needs of the South Atlantic Fishery Management Council to evaluate deep water habitats in a timely manner, the brief descriptions of North Carolina deep coral banks (see Fig. 1) provided below will serve as an interim tool facilitating potential management options for fragile, productive deep water habitats. This synthesis is preliminary, pending final data analyses, and should be used cautiously with prior consent of the author. Additional information should be obtained from S.W. Ross.

NORTH CAROLINA DEEP CORAL BANKS

Although coral areas were discovered on the Blake Plateau in the late 1950's, there is no indication that such corals were known off of North Carolina until the late 1960's (Squires 1959; Stetson et al. 1962). Rowe and Menzies (1968) first indicated that *Lophelia* occurred off Cape Lookout, NC, but this was only noted in a figure caption without further comment. 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 locations or other data. Likewise, Menzies et al. (1973) gave similar vague reference to a “Lophohelia” (sic) bank off of Cape Lookout, repeating one of the figures in Rowe and Menzies (1969) and presenting a bottom photograph of a reef in 458 m. Cairns (1979) indicated a locality dot off Cape Lookout in his distribution map for *Lophelia* but did not comment further. These records appear to have originated from a short training cruise of the R/V Eastward (E-25-66, I.E. Gray chief scientist) during which a coral bank was photographed by a deep sea drop camera on 30 June 1966 (station E-4937, 475 m). Whether this station was found by chance or was targeted on purpose is unclear. Yet, the photograph in Menzies et al. (1973, Fig. 4-4 B) appears to be from that cruise. Photographs from that station off of Cape Lookout (Fig. 2), are discussed in more detail below.

The USGS survey of the US EEZ mapped, using side scan sonar, a number of features termed coral mounds, including some off of NC (EEZ-SCAN 87 Scientific Staff 1991). George (2002) also discussed a coral bank southeast of Cape Fear, NC (“Agassiz Coral Hills”) in 650-750 m dominated by *Bathypsammia tintinnabulum*. Additional data to be scanned for evidence of deep corals in this area were summarized by Arendt et al. (2003). To date three major coral mounds have been located and studied off of North Carolina (Ross et al. unpubl. data), and several other possible mounds may exist. Data are still being analyzed related to these ongoing studies; however, a general description of the coral mounds and associated fauna follows. While some structural and faunal differences have been observed among these mounds, data are not yet extensive enough to determine if such differences are significant or persistent. More detailed results will be presented in several peer reviewed publications now being prepared by Ross et al.

Cape Lookout *Lophelia* Bank A

Aside from a few maps (see above) there are no published data from this coral mound. This area was apparently first occupied by the R/V Eastward (see above) which gave a location of 34° 18' N, 75° 48' W. Two trawl stations and a sonar survey of the Eastward station area in May 1983 using the R/V Delaware II (S.W. Ross, chief scientist), revealed no indication of hard bottom or coral. The Eastward navigated with LORAN A, and since their station was about 1-1.5 nmi (2-2.7 km) from the large coral bank area later sampled with Johnson-Sea-Link (JSL) submersible (Fig. 3), it is likely that the less accurate LORAN may have put the Eastward station off of the actual reef. However, the possibility that a reef does exist on or near the E-4937 station cannot be discounted without a more detailed survey of that location. The USGS side scan survey (EEZ-SCAN 87 Scientific Staff 1991) illustrated reefs in this area, and coordinates from that survey were used to guide an undersea survey using the Navy's NR-1 nuclear research submersible (Sulak and Ross, unpubl. data) during 15-18 Nov 1993. However, there also seems to be a navigation issue with this cruise in that locations plotted from the NR-1 track are offset about 0.5 nmi (1 km) from the large mounds later located by Ross et al. (Fig. 3, unpubl. data). The later ship sonar survey of the NR-1 locations did not yield any obvious reef areas. Between summer 2000 and summer 2004 Ross et al. (unpubl. data) sampled this area extensively using a variety of methods throughout the water column. Their major method for collecting bottom data on the reef proper was the JSL research submersible. Fifteen dives were made on coral mounds in this area (Fig. 3, Table 1), and observations from these totaling nearly 33 hours (bottom time) are the basis of the descriptions of habitat and fauna below.

Preliminary observations suggest that this area contains the most extensive coral mounds off North Carolina; however, it must be emphasized that data are lacking to adequately judge overall sizes and areal coverage. Ross et al. JSL dives in this area ranged from 370-447 m (Table 1). Mean bottom temperatures ranged from 6.3 to 10.9° C, while mean bottom salinities were always around 35 ‰ (Table 2). There appear to be several prominences capping a ridge system, thus, presenting a very rugged and diverse bathymetry (Fig. 4), but there are also other mounds away from the main ridge sampled (Fig. 3). The main mound system rises vertically nearly 80 m over a distance of about 1 km, and in places exhibits slopes in excess of 50-60 degrees. Sides and tops of these mounds are covered with extensive colonies of living *Lophelia pertusa* (Fig. 4), with few other corals being observed. Dead colonies and coral rubble interspersed with sandy channels are also abundant (Fig. 4). Extensive coral rubble zones surround the mounds for a large, but unknown, distance (exact area not yet surveyed), especially at the bases of the mounds/ridges, and in places seem to be quite thick. These mounds appear to be formed by successive coral growth, collapse, and sediment entrapment (Wilson 1979; Popenoe and Manheim 2001). These topographic highs accelerate bottom currents which favor attached filter-feeders.

Because fishes are somewhat disturbed by submersibles, data on the fish community has accumulated slowly; however, this group is quite diverse on the coral habitat. Although Ross et al. have so far identified over 43 benthic or benthopelagic fish species on and around these coral banks, only data from the primary coral areas are presented here. Of the twenty five total fish species occurring on prime coral habitat of Bank A, nine dominate the data (Table 3, Fig. 5).

Beryx decadactylus (Fig. 5) usually occurs in large aggregations moving over the reef, while most other major species occur as single individuals. Many of these species are cryptic, being well hidden deep in the corals (e.g., *Hoplostethus occidentalis*, *Netenchelys exoria*, *Conger oceanicus*). The morid, *Laemonema melanurum*, is one of the larger fishes abundant at every site with corals. This fish seems to rarely leave the prime reef area. Trash and entangled fishing gear were observed on this reef, suggesting some level of commercial fishing pressure.

Initially the most impressive biological aspect of these coral mounds (aside from the corals themselves) was the well developed and abundant invertebrate fauna (Table 4). We have not yet detected major differences in the invertebrate fauna among the three North Carolina banks; therefore, this paragraph is relevant to all three areas. Galatheid crabs (especially *Eumunida picta*) and the brisingid basket star (*Novodinia antillensis*) were particularly obvious, perching high in coral bushes to catch passing animals or filter in the currents (Fig. 5). One very different aspect of the North Carolina deep coral habitat compared to the rest of the South Atlantic Bight is the massive numbers of a brittle star (*Ophiacantha bidentata*) covering both dead and living coral colonies (somewhat apparent on the coral behind *B. decadactylus*, Fig. 5 and Fig. 8). These are perhaps the most abundant macroinvertebrate on these banks. In places the bottom is covered with huge numbers of several species of anemones (Figs. 5, 8, 10). The abundance of filter feeders suggest a food rich habitat.

Cape Lookout *Lophelia* Bank B

Except for a few maps (see above) there are no published data from this coral mound. The USGS side scan survey (EEZ-SCAN 87 Scientific Staff 1991) illustrated reefs in this area, and, as above, coordinates from that survey guided the cruise using the NR-1 nuclear research submersible (Sulak and Ross, unpubl. data) during 15-18 Nov 1993. The same navigation issue with this cruise described above was also apparent in this area, NR-1 stations being about 1-1.4 nmi (2-2.6 km) from major mounds located later by Ross et al. Between summer 2001 and summer 2004 Ross et al. (unpubl. data) sampled this area using a variety of methods throughout the water column. The JSL submersible was the major method for collecting bottom data on the reef proper. Five dives were made on coral mounds in this area (Fig. 6, Table 1), and observations from these totaling 10.4 hours form the basis of the descriptions of habitat and fauna below.

The least amount of data are available for this area. Mounds appear to cover a smaller area than those described above, but here again better mapping data are needed. Ross et al. JSL dives in this area ranged from 396-449 m (Table 1). Mean bottom temperatures ranged from 5.8 to 10.4° C, and as above mean bottom salinities were always around 35 ‰ (Table 2). These mounds rise at least 53 m over a distance of about 0.4 km. There is a small mound away from the main system (Fig. 6), and in general these mounds (Fig. 7) were less dramatic than those described above. They appeared to be of the same general construction as Bank A, appearing to be built of coral rubble matrix that had trapped sediments. Extensive fields of coral rubble surrounded the area. Both living and dead corals were common on this bank, with some living bushes being quite large (Fig. 7).

Preliminary analyses (Ross et al. unpubl.) have identified 11 fish species from this bank, but it is clear that the species list would be much higher in this well developed habitat if there were more samples. The dominant fish species appears to be *Helicolenus dactylopterus*, followed by *L. melanurum, H. occidentalis, L. barbatulum*, and *N. exoria* (Table 3, Fig. 8). Although *H. dactylopterus* (Fig. 5) can be common on all habitats, it clearly occurs most often around structures. It is intimately associated with the coral substrate, and it is very abundant around this reef habitat.

The invertebrate fauna on this reef system does not appear substantially different from Bank A (see above, Table 4, Fig. 8).

Cape Fear *Lophelia* Bank

Aside from the map in EEZ-SCAN 87 Scientific Staff (1991**)** there are no published data from this coral mound and no indication that it was sampled before the studies initiated by Ross et al. (unpubl. data) between summer 2002 and summer 2004. Ross et al. located this bank based on estimated coordinates from the USGS survey (EEZ-SCAN 87 Scientific Staff 1991**)**. As above, the JSL submersible was the major method for collecting bottom data on the reef proper. Seven dives were made on coral mounds in this area (Fig. 9, Table 1), and observations from these totaling 15.4 hours were used to describe the habitat and fauna.

Sampling in this area was focused on a relatively small area (Fig. 9), but data are lacking to accurately estimate the size and area covered by coral mounds or rubble zones. Ross et al. JSL dives in this area ranged from 371-449 m (Table 1). Mean bottom temperatures ranged from 8.7 to 11.7° C, and as above mean bottom salinities were always near 35 ‰ (Table 2). These mounds rise nearly 80 m over a distance of about 0.4 km, and exhibit some of the most rugged habitat and vertical excursion of any area sampled (Fig. 10). This mound system also appears to be of the same general construction as Banks A and B, being built of coral rubble matrix with trapped sediments. Fields of coral rubble are common around the area. Both living and dead corals were common on this bank (Fig. 10).

The greatest numbers of large fishes were observed on this bank. Twelve total fish species were observed here, but as above, this list should increase with increasing sampling effort. As on Bank A, *B. decadactylus* was the most common fish, followed closely by *Polyprion americanus* (wreckfish) (Table 3). So far, of the three North Carolina banks, this is the only area where wreckfish have been observed (Fig. 11), and on some dives 8-10 large individuals were seen swimming slowly along the sides of the ridges. However, it is very likely that wreckfish occur on the other banks. As on the other two banks, *L. melanurum* was common here, always on prime reef habitat. *Conger oceanicus* (always large adults) and *Myxine glutinosa* (Fig. 11) were both frequently observed on this bank.

The invertebrate fauna on this reef system does not appear substantially different from Banks A and B (see above, Table 4, Fig. 11).

Potential NC Coral Mounds

Several potential deep coral banks (Fig. 1) were identified in the USGS survey of the EEZ off of North Carolina (EEZ-SCAN 87 Scientific Staff 1991). During the above referenced NR-1 survey (Sulak and Ross unpubl. data, 1993) and again during a cruise of the R/V Cape Hatteras (S.W. Ross, Chief Scientist, 2001), attempts were made to locate the bank between Cape Lookout Bank A and Bank B (Fig. 1). However, no coral mounds were observed in this area. It is possible that there are coral mounds in this area but the small search pattern and potential navigation issues prevented finding them.

Other banks may exist on the slope south of 33° N (Fig. 1). As far as known these have not been accurately located or confirmed as coral banks, although the location referenced by George (2002) is near one of these areas. These banks would be important to confirm as they would occur in what may be a transition area between a region of coral/sediment built mounds composed almost entirely of *Lophelia pertusa* and the area to the south where coral development is generally quite different.

SUMMARY AND RECOMMENDATIONS

The three North Carolina *Lophelia* mounds (as far as known to date) represent the northernmost coral banks in the SAB, and significant deep coral habitats are not apparent on the US 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. These three NC banks are generally similar in physical attributes and faunal composition. Some observed differences, however, are being investigated. These systems support a well developed community that appears to be different from the surrounding non-reef habitats. In fact, preliminary analyses suggest that the fish community on these deep reefs is composed of many species that do not (or at least rarely) occur off of the reefs. 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 et al. unpubl. data). Most likely these species only appeared to be rare because they occurred in a difficult to sample environment. 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. However, invertebrate associations with the reef habitat seem to be more opportunistic than is the case for certain fish species. Additional data are required from diverse habitats to confirm this.

Some commercially-exploited deep-water fishes, like wreckfish (*Polyprion americanus*) (Vaughan et al. 2001) and blackbelly rosefish (*Helicolenus dactylopterus*), utilize *Lophelia* habitat extensively. Other potentially exploitable species are also associated with deep corals (royal red shrimps, rock crabs, bericiform fish species, eels). Signs of past fishing effort were observed on some North Carolina banks, but the extent to which fishermen sample these areas is unknown. The potential for new deep water fisheries on and around these banks is unknown.

The banks so far examined off of North Carolina are different than much of the coral habitat to the south on the Blake Plateau. Although requiring confirmation, these mounds along the 360-450 m depth zone appear to be formed by successive coral growth, collapse, and sediment entrapment (Wilson 1979; Popenoe and Manheim 2001). Their tops and sides are mostly covered by dense thickets of living (white) *Lophelia pertusa*, and they are surrounded by coral rubble zones. These features are almost exclusively dominated by *L. pertusa*, the diversity of other corals being low. Bottom currents that are too strong may prevent mound formation (Popenoe and Manheim 2001) because sediments can not be trapped. 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 facilitating coral mound formation (Rogers 1999). See Reed (unpubl. rept. to SAFMC 2004) for a review of Blake Plateau and Florida deep coral habitat.

Recommendations

Detailed mapping of the 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 350-500 m. While this recommendation relates to the whole slope of the SEUS, priority should be given to known coral sites and areas of suspected coral mounds.

If HAPCs or MPAs were to be proposed for the deep coral banks off of North Carolina, Cape Lookout Banks A and B should be contained in one unit (i.e., box) and the Cape Fear Bank in a separate box.

If protected areas are established for SEUS deep coral banks, long term monitoring and research plans should accompany this strategy.

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.

Of the vast number of important ecological/biological studies that could be proposed, a broad trophodynamics study of the coral banks and surrounding area (whole water column) would probably provide the most impact for funds expended. Knowing the flow of energy in a system facilitates evaluation of anthropogenic impacts and the allows predictions about the consequences of natural change.

A regional working group composed of scientists and relevant agency personnel should be formed to begin evaluating data, deep reef status, and to take the lead on formulation of plans to study and manage these habitats.

LITERATURE CITED

Arendt, M.D., C.A. Barans, G.R. Sedberry, R.F. Van Dolah, J.K. Reed, S.W. Ross. 2003. Summary of seafloor mapping and benthic sampling in 200-2000m from North Carolina through Florida. Final rept. Deep Water Mapping Project Phase II. SAFMC. Charleston, SC.

Cairns, S.D. 1979. The deep-water scleractinia of the Caribbean Sea and adjacent waters. In: Hummelinck, P.W. and L.J. Van Der Steen (Eds.). Studies on the fauna of Curacao and other Caribbean Islands. Foundation for Scientific research in Surinam and the Netherlands Antilles. Utrecht.

EEZ-SCAN 87 Scientific Staff. 1991. Atlas of the U.S. exclusive economic zone, Atlantic continental margin. USGS Misc. Invest. Ser. I-2054.

Fossa, J.H., P.B. Mortensen and D.M. Furevik. 2002. The deep-water coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts. Hydrobiologia 471: 1-12.

Genin, A., P.K. Dayton, P.F. Lonsdale, and F.N. Spiess. 1986. Corals on seamount peaks provide evidence of current acceleration over deep-sea topography. Nature 322: 59-61.

George, R.Y. 2002. Ben Franklin temperate reef and deep sea “Agassiz Coral Hills” in the Blake Plateau off North Carolina. Hydrobiologia 471: 71-81.

Hovland, M., P.B. Mortensen, T. Brattegard, P. Strass and K. Rokoengen. 1998. Ahermatypic coral banks off mid-Norway: evidence for a link with seepage of light hydorcarbons. Palaios 13: 189-200.

Hovland, M. and M. Risk. 2003. Do Norwegian deep-water coral reefs rely on seeping fluids? Mar. Geol. 198: 83-96.

Husebo, A., L. Nottestad, J.H. Fossa, D.M. Furevik and S.B. Jorgensen. 2002. Distribution and abundance of fish in deep-sea coral habitats. Hydrobiologia 471: 91-99.

Jensen, A. and R. Frederiksen. 1992. The fauna associated with the bank-forming deepwater coral *Lophelia pertusa* (Scleractinaria) on the Faroe Shelf. Sarsia 77: 53-69.

Koslow, J.A. 1997. Seamounts and the ecology of deep-sea fisheries. Amer. Sci. 85: 168-176.

Koslow, J.A., G.W. Boehlert, J.D.M. Gordon, R.L. Haedrich, P. Lorance, and N. Parin. 2000. Continental slope and deep-sea fisheries: implications for a fragile ecosystem. ICES J. Mar. Sci. 57: 548-557.

Le Goff-Vitry, M.C., O.G. Pybus and A.D. Rogers. 2004. Genetic structure of the deep-sea coral *Lophelia pertusa* in the northeast Atlantic revealed by microsatellites nad internal transcribed spacer sequences. Molecular Ecol. 13: 537-549.

McDonough, J.J. and K.A. Puglise. 2003. Summary: Deep-sea corals workshop. International planning and collaboration workshop for the Gulf of Mexico and the North Atlantic Ocean. Galway, Ireland, January 16-17, 2003. NOAA Tech. Memo. NMFS-SPO-60, 51 p.

Menzies, R.J., R.Y. George, and G.T. Rowe. 1973. Abyssal Environment and Ecology of the World Oceans. John Wiley and Sons, New York.

Mikkelsen, N., H. Erlenkeuser, J.S. Killingley and W.H. Berger. 1982. Norwegian corals: radiocarbon and stable isotopes in *Lophelia pertusa*. Boreas 11: 163-171.

Miller, C.A. 2001. Marine protected area framework for deep-sea coral conservation. p 145-155. In: Willison, J.H.M., J. Hall, S.E. Gass, E.L.R. Kenchington, M. Butler and P. Doherty (eds.). 2001. Proceedings of the First International symposium on Deep-Sea Corals. Ecology Action Centre. Nova Scotia Museum. Halifax, Nova Scotia. 231 p.

Mortensen, P.B. and H.T. Rapp. 1998. Oxygen and carbon isotope ratios related to growth line patterns in skeletons of *Lophelia pertusa* (L) (Anthozoa, Scleractinia): implications for determination of linear extension rates. Sarsia 83: 433-446.

Neumann, A.C., J.W. Kofoed and G. Keller. 1977. Lithoherms in the Straits of Florida. Geology 5: 4–10.

Paull, C.K., A.C. Neumann, B.A. am Ende, W. Ussler III and N.M. Rodriguez. 2000. Lithoherms on the Florida-Hatteras slope. Mar. Geol. 166: 83-101.

Reed, J.K. 2002. Comparison of deep-water coral reefs and lithoherms off southeastern U.S.A. Hydrobiologia 471: 57-69.

Roberts, S. and M. Hirshfield. 2003. Deep Sea Corals: out of sight, but no longer out of mind. Oceana. Washington, DC.

Rogers, A.D. 1994. The biology of seamounts. Advances Mar. Biol. 30: 306-350.

Rogers, A.D. 1999. The biology of *Lophelia pertusa* (Linnaeus 1758) and other deep-water reef-forming corals and impacts from human activities. Internat. Rev. Hydrobiol. 84: 315-406.

Rowe, G.T. and R.J. Menzies. 1968. Deep bottom currents off the coast of North Carolina. Deep-Sea Res. 15: 711-719.

Rowe, G.T. and R.J. Menzies. 1969. Zonation of large benthic invertebrates in the deep-sea off the Carolinas. Deep-Sea Res. 16: 531-537.

Popenoe, P. and F.T. Manheim. 2001. Origin and history of the Charleston Bump-geological formations, currents, bottom conditions, and their relationship to wreckfish habitats on the Blake Plateau. P. 43-93. In: G.R. Sedberry (ed.). Island in the Stream: oceanography and fisheries of the Charleston Bump. Amer. Fish. Soc., Symp. 25. Bethesda, MD.

Roberts, C.M. 2002. Deep impact: the rising toll of fishing in the deep sea. Trends Ecol. Evol. 17: 242-245.

Sedberry, G.R. (ed.). 2001. Island in the Stream: oceanography and fisheries of the Charleston Bump. Amer. Fish. Soc., Symp. 25. Bethesda, MD. 240 p.

SGCOR. 2004. Report of the study group on cold-water corals (SGCOR). ICES Advisory Committee on Ecosystems, ICES CM 2004/ACE:07 ref. E.

Squires, D.F. 1959. Deep sea corals collected by the Lamont Geological Observatory. I. Atlantic corals. Amer. Mus. Novitates No. 1965: 1-42.

Stetson, T.R., D.F. Squires and R.M. Pratt. 1962. Coral banks occurring in deep water on the Blake Plateau. Amer. Mus. Novitates 2114: 1-39.

Vaughan, D.S., C.S. Manooch, III and J.C. Potts. 2001. Assessment of the wreckfish fishery on the Blake Plateau. p. 105-119. In: Sedberry, G.R. (ed.). Island in the Stream: oceanography and fisheries of the Charleston Bump. Amer. Fish. Soc., Symp. 25. Bethesda, MD. 240 p.

Wilson, J.B. 1979. "Patch" development of the deep-water coral *Lophelia pertusa* (L.) on Rockall Bank. J. Mar. Biol. Assoc. U.K. 59: 165-177.

Table 1. Johnson-Sea-Link research dives conducted on deep coral (*Lophelia*) banks off of North Carolina by S.W. Ross et al. from summer 2000 through summer 2004. Start, end and total times represent bottom times in minutes. CL=Cape Lookout, CF=Cape Fear.

			Time			Start		End		S	E
Station	Date	Location	Start	End	Total	Latitude	Longitude	Latitude	Longitude	Depth (m)	
JSL 4206	28 Jul 00	CL Lophelia A	0842	1036	114	34° 19.633	75° 46.330	34° 19.447	75° 47.249	430	389
JSL 4207	28 Jul 00	CL Lophelia A	1556	1745	109	34° 19.569	75° 47.134	34° 19.417	75° 47.295	418	405
JSL 4361	22 Sep 01	CL Lophelia A	0844	1123	159	34° 19.685	75° 47.372	34° 19.689	75° 47.528	427	384
JSL 4362	22 Sep 01	CL Lophelia A	1621	1836	135	34° 19.425	75° 47.488	34° 19.418	75° 47.507	399	370
JSL 4363	23 Sep 01	CL Lophelia A	0902	1115	129	34° 19.423	75° 47.453	34° 19.412	75° 47.497	417	371
JSL 4364	23 Sep 01	CL Lophelia A	1602	1853	171	34° 18.840	75° 47.013	34° 18.765	75° 47.130	441	398
JSL 3304	11 Aug 02	CL Lophelia A	0833	1100	147	34° 19.720	75° 47.043	34° 19.510	75° 47.207	447	386
JSL 3305	11 Aug 02	CL Lophelia A	1630	1859	149	34° 19.460	75° 47.198	34° 19.477	75° 47.200	416	385
JSL 3306	12 Aug 02	CL Lophelia A	0832	1059	147	34° 19.477	75° 47.200	34° 19.452	75° 47.251	418	384
JSL 3307	12 Aug 02	CL Lophelia A	1624	1711	47	34° 19.485	75° 47.452	34° 19.499	75° 47.545	416	383
JSL 3430	23 Aug 03	CL Lophelia A	1624	1859	155	34° 19.366	75° 47.334	34° 19.404	75° 47.249	415	394
JSL 3431	24 Aug 03	CL Lophelia A	0836	1052	136	34° 19.517	75° 47.044	34° 19.421	75° 47.237	432	388
JSL 3432	24 Aug 03	CL Lophelia A	1647	1857	130	34° 19.427	75° 47.158	34° 19.482	75° 47.213	424	385
JSL 4692	15 Jun 04	CL Lophelia A	0829	1033	124	34° 19.428	75° 47.172	34° 19.444	75° 47.218	426	383
JSL 4693	15 Jun 04	CL Lophelia A	1620	1827	127	34° 19.436	75° 47.140	34° 19.512	75° 47.148	431	392
JSL 4365	24 Sep 01	CL Lophelia B	0842	1115	153	34° 11.344	75° 53.795	34° 11.406	75° 53.743	431	414
JSL 4366	24 Sep 01	CL Lophelia B	1618	1732	74	34° 10.754	75° 53.507	34° 10.765	75° 53.370	449	437
JSL 3429	23 Aug 03	CL Lophelia B	0854	1110	136	34° 11.151	75° 54.028	34° 11.421	75° 53.753	435	415
JSL 4694	16 Jun 04	CL Lophelia B	0829	1041	132	34° 11.277	75° 53.618	34° 11.284	75° 53.788	440	396
JSL 4695	16 Jun 04	CL Lophelia B	1649	1859	130	34° 11.406	75° 53.647	34° 11.411	75° 53.739	442	414
JSL 3308	13 Aug 02	CF Lophelia	0829	1058	149	33° 34.330	76° 28.054	33° 34.434	76° 27.905	449	373
JSL 3425	21 Aug 03	CF Lophelia	0821	1047	146	33° 34.380	76° 27.930	33° 34.465	76° 27.866	386	374
JSL 3426	21 Aug 03	CF Lophelia	1636	1903	147	33° 34.381	76° 27.906	33° 34.326	76° 27.911	371	377
JSL 3427	22 Aug 03	CF Lophelia	0833	1051	138	33° 34.278	76° 27.750	33° 34.477	76° 27.697	381	418
JSL 3428	22 Aug 03	CF Lophelia	1611	1817	126	33° 34.384	76° 27.949	33° 34.441	76° 27.886	377	371
JSL 4696	17 Jun 04	CF Lophelia	0831	1025	114	33° 34.367	76° 27.708	33° 34.360	76° 27.670	390	402
JSL 4697	17 Jun 04	CF Lophelia	1642	1824	102	33° 34.570	76° 27.835	33° 34.587	76° 27.773	405	411

Table 2. Bottom temperature and salinity data from Johnson-Sea-Link (JSL) dives on three *Lophelia* coral bank areas off of North Carolina (S.W. Ross et al. unpubl. data).

Station	Date	Site	Mean Temp (°C) ± SE	Temp Range (°C)	Mean Salinity (ppt) ± SE	Salinity Range
JSL 4206	28 Jul 00	CL Lophelia A	8.49 ± 0.021	5.64-10.64	35.20 ± 0.002	34.04-36.20
JSL 4207	28 Jul 00	CL Lophelia A	8.63 ± 0.006	6.23-9.44	35.20 ± 0.001	34.06-35.81
JSL 4361	22 Sep 01	CL Lophelia A	9.49 ± 0.002	9.09-9.92	35.22 ± 0.000	35.02-35.60
JSL 4362	22 Sep 01	CL Lophelia A	10.13 ± 0.003	9.22-10.57	35.31 ± 0.001	34.99-35.70
JSL 4363	23 Sep 01	CL Lophelia A	10.44 ± 0.002	9.90-10.80	35.35 ± 0.000	35.11-35.52
JSL 4364	23 Sep 01	CL Lophelia A	10.06 ± 0.005	9.00-10.86	35.30 ± 0.001	35.03-35.53
JSL 3304	11 Aug 02	CL Lophelia A	9.61 ± 0.009	6.30-10.88	35.26 ± 0.001	33.91-36.03
JSL 3305	11 Aug 02	CL Lophelia A	9.24 ± 0.003	8.97-10.12	35.21 ± 0.001	34.70-35.69
JSL 3306	12 Aug 02	CL Lophelia A	10.90 ± 0.008	8.87-14.85	35.39 ± 0.002	34.02-36.09
JSL 3307	12 Aug 02	CL Lophelia A	10.15 ± 0.002	9.83-10.54	35.30 ± 0.001	34.99-35.49
JSL 3430	23 Aug 03	CL Lophelia A	6.33 ± 0.003	5.90-6.88	35.06 ± 0.000	34.90-35.56
JSL 3431	24 Aug 03	CL Lophelia A	7.08 ± 0.007	6.20-8.29	35.08 ± 0.000	34.92-35.28
JSL 3432	24 Aug 03	CL Lophelia A	8.27 ± 0.003	7.45-9.04	35.11 ± 0.200*	34.91-35.31*
JSL 4692	15 Jun 04	CL Lophelia A	9.81 ± 0.001	9.55-9.99	35.28 ± 0.000	35.19-35.36
JSL 4693	15 Jun 04	CL Lophelia A	9.11 ± 0.003	8.04-9.57	35.20 ± 0.000	35.02-35.34
JSL 4365	24 Sep 01	CL Lophelia B	10.01 ± 0.002	9.58-10.30	35.27 ± 0.000	35.13-35.41
JSL 4366	24 Sep 01	CL Lophelia B	9.81 ± 0.002	9.61-10.14	35.25 ± 0.000	35.11-35.43
JSL 3429	23 Aug 03	CL Lophelia B	5.82 ± 0.001	5.42-5.97	35.04 ± 0.000	34.99-35.12
JSL 4694	16 Jun 04	CL Lophelia B	10.43 ± 0.005	9.39-11.19	35.36 ± 0.001	35.20-35.53
JSL 4695	16 Jun 04	CL Lophelia B	9.95 ± 0.002	9.70-11.34	35.32 ± 0.000	35.02-35.83
JSL 3308	13 Aug 02	CF Lophelia	9.13 ± 0.002	8.42-9.53	35.18 ± 0.001	34.80-35.45
JSL 3425	21 Aug 03	CF Lophelia	9.54 ± 0.001	9.54-9.72	35.20 ± 0.000	35.10-35.34
JSL 3426	21 Aug 03	CF Lophelia	10.18 ± 0.005	9.25-11.22	35.29 ± 0.001	35.00-35.60
JSL 3427	22 Aug 03	CF Lophelia	8.69 ± 0.004	7.93-9.83	35.15 ± 0.001	34.75-35.61
JSL 3428	22 Aug 03	CF Lophelia	9.13 ± 0.002	8.68-9.70	35.19 ± 0.000	35.14-35.26
JSL 4696	17 Jun 04	CF Lophelia	9.10 ± 0.001	9.00-9.54	35.14 ± 0.000	35.05-35.30
JSL 4697	17 Jun 04	CF Lophelia	11.70 ± 0.002	11.01-12.09	35.48 ± 0.000	35.33-35.67

*JSL 3432 salinity data taken from video records

Table 3. Dominant benthic fish species (in order of decreasing abundance) observed during submersible dives on three North Carolina deep coral reef areas based on unpublished data of S.W. Ross et al. (2000-2003). Species that are currently or potentially of commercial importance are noted with an *. Common names are given where known.

Cape Lookout *Lophelia* Bank A

*Beryx decadactylus** (red bream)
*Helicolenus dactylopterus** (blackbelly rosefish)
Hoplostethus occidentalis
Laemonema melanurum
*Conger oceanicus** (conger eel)
Netenchelys exoria
Laemonema barbatulum (shortbeard codling)
Idiastion kyphos
Scyliorhinus retifer (chain dogfish)
TOTAL NO. SPP. 25

Cape Lookout *Lophelia* Bank B

*Helicolenus dactylopterus**
Laemonema melanurum
Hoplostethus occidentalis
Laemonema barbatulum
Netenchelys exoria
TOTAL NO. SPP. 11

Cape Fear *Lophelia* Bank

*Beryx decadactylus**
*Polyprion americanus** (wreckfish)
Laemonema melanurum
*Conger oceanicus**
Myxine glutinosa (Atlantic hagfish)
TOTAL NO. SPP. 12

Table 4. Dominant benthic macroinvertebrates occupying deep coral (*Lophelia*) banks off of North Carolina. This list is preliminary (from S.W. Ross et al. unpubl.) and is not separated by area as invertebrate data have not been fully analyzed. Some taxa can only be given general common names at this time.

Lophelia pertusa (coral)
Madrepora oculata (coral)
Eumunida picta (squat lobster)
Ophiacantha bidentata (brittle star)
Echinus gracilis (urchin)
E. tylodes (urchin)
Novodinia antillensis (brisingid starfish)
Bathynectes sp. (portunid crab)
Rochina crassa (spider crab)
Cidaris rugosa (pencil urchin)
Peltaster placenta (starfish)
Poraniella pulvillus (starfish)
Ilex spp. (Squids)
Actinaugi rugosa (Venus flytrap anemone)
anemones
glass sponges
hermit crabs
shrimps
Octopi

Appendix C. Habitat and Fauna of Deep-Water Coral Reefs off the Southeastern USA - A Report to the South Atlantic Fishery Management Council. Addendum to 2004 Report. 2005-2006 Update- East Florida Reefs.

Report Prepared for the South Atlantic Fishery Management Council.

HABITAT AND FAUNA OF DEEP-WATER CORAL REEFS OFF THE SOUTHEASTERN USA

A Report to the South Atlantic Fishery Management Council
Addendum to 2004 Report
2005-2006 Update- East Florida Reefs

by
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ABSTRACT

In 2004 a Summary Report (Reed 2004) was compiled by the PI at the request of the South Atlantic Fishery Management Council (SAFMC) to provide a preliminary, general summary on the status of current knowledge concerning deep-water (> 200 m) reefs off the southeastern U.S. from Florida to North Carolina. The purpose was to prioritize areas of deep-water, live-bottom habitats for: 1) potential designation as Habitat Areas of Particular Concern (HAPC) or Marine Protected Areas (MPA) by the SAFMC, and 2) high-resolution habitat maps and habitat characterization studies.

The following report is an update to the 2004 Report that provides new data collected from eight expeditions using submersible or ROV off eastern Florida during 2005 and 2006. Based on the 2004 Report and the data from this report that was presented by the PI to the Coral and Habitat Advisory Panels (SAFMC meeting, June 2006), the SAFMC has proposed six new deep-water reef HAPCs off southeastern US. The resource potential of the deep-water habitats in this region is unknown in terms of fisheries and novel compounds yet to be discovered from associated fauna that may be developed as pharmaceutical drugs. Activities involving bottom trawling, pipelines, or oil/gas production could negatively impact these reefs.

JUSTIFICATION

The South Atlantic Fishery Management Council (R. Pugliese) requested that this update to the 2004 Report on the state of knowledge of deep sea coral ecosystems (DSCE) off Florida be available in time for the Coral and Habitat Advisory Panels meeting of the SAFMC, June 9, 2006. The Council needs immediate scientific data and maps as it considers designation of new Habitat Areas of Particular Concern (HAPC) to protect DSCE areas. Such protection may be needed to prevent long-term (perhaps permanent) damage, such as has occurred on shallower *Oculina* reefs off Florida and *Lophelia* banks in the northeastern Atlantic, both destroyed in part by trawling. After trawlers were banned from the *Oculina* HAPC, there is justified concern that trawlers may move to deeper habitats in search of valuable commercial fisheries, such as royal red shrimp or benthic finfish. The resource potential of the deep-water habitats in this region is unknown in terms of fisheries and novel compounds yet to be discovered from associated fauna that may be developed as pharmaceutical drugs. Although these habitats are not currently designated as MPAs or HAPCs, they are incredibly diverse and irreplaceable resources. Activities involving bottom trawling, pipelines, or oil/gas production could negatively impact these reefs.

OBJECTIVES

Objectives of this report and accompanying DVD are the following:

1) Compile a list of research cruises that explored the deep-water reefs off eastern Florida from 2005 to 2006.
2) Compile list of submersible dives, including dive number, date, location, GPS coordinates, depth, and habitat type for each dive (DVD- Excel file).

3) Provide Powerpoint presentation of this report, including insitu digital still images and video of newly discovered bottom habitat, that was presented to the Coral and Habitat Advisory Panels meeting of the SAFMC, June 9, 2006 (DVD- ppt file).
4) Provide Cruise Report from the following expedition: Florida's Deep-Water Oases: Exploration of Deep Reef Ecosystems, May 31- June 9, 2006 (DVD- ppt file). This expedition provided for the first time an assessment of the biodiversity and relative abundance of the benthic, fish and zooplankton communities; geological features; physical processes; and biochemical compounds of interest for drug discovery within a deep-water reef ecosystem.

INTRODUCTION

Deep-Sea Coral Reefs (from Reed, 2004)

Deep-water reefs are sometimes defined as bioherms, coral banks, or lithoherms (Teichert, 1958; Stetson et al., 1962; Neumann et al., 1977; Wilson, 1979; Reed, 1980; Freiwald et al. 1997; Fosså et al. 2000; Paull et al., 2000). Some deep-water reefs consist of caps of living coral on mounds of unconsolidated mud and coral debris, such as some *Oculina* and *Lophelia* coral reefs (Reed 2002a,b; Reed et al. 2005, 2006), whereas deep-water lithoherms are defined as high-relief, lithified carbonate limestone mounds rather than unconsolidated mud mounds (Neumann et al., 1977). Rogers (1999) has suggested that deep-water coral bioherms fall within the definition of a coral reef based on their physical and biological characteristics. Various types of deep-water, high-relief bioherms are common off the southeastern United States, along the base of the Florida-Hatteras Slope, on the Blake Plateau, in the Straits of Florida, and eastern Gulf of Mexico (Reed et al., 2005, 2006). Only a small percentage of deep-water reefs have had their benthic and fish resources characterized.

Florida DSCE

Deep sea coral ecosystems (DSCE) in U.S. EEZ waters exist along the eastern and southwest Florida shelf slope (in addition to the *Oculina* Marine Protected Area and deep shelf-edge reefs with hermatypic coral). These include a variety of high-relief, hard-bottom, live-bottom habitats at numerous sites along the base of the Florida-Hatteras Slope off northeastern and central eastern Florida, the Straits of Florida, the Miami Terrace and Pourtales Terrace off southeastern Florida, and the southwestern Florida shelf slope. The predominate coral on these reefs are the azooxanthellate, colonial scleractinian corals, *Lophelia pertusa*, *Madrepora oculata*, and *Enallopsammia profunda*; various species of hydrocorals of the family Stylasteridae, and species of the bamboo octocoral of the family Isididae. Various types of high-relief, live-bottom habitat have been discovered in the area: *Lophelia* mud mounds, lithoherms, sinkholes, ancient Miocene escarpments and karst topographic features (Reed 2002b; Reed et al., 2004a,b, 2005, 2006). These all provide hard-bottom substrate and habitat for sessile macrofauna including deep-water corals, octocorals (gorgonians), black coral, and sponges, which in turn provide habitat and living space for a relatively unknown but biologically rich and diverse community of associated fish, crustaceans, mollusks, echinoderms, polychaete and sipunculan worms, and other macrofauna, many of which are undoubtedly undescribed species.

Recent research expeditions by Principal Investigator (PI), J. Reed, Harbor Branch Oceanographic Institution (HBOI), using HOVs (human occupied vehicle) and ROVs (remotely operated vehicle) along with previous research by the PI in the 1990s and 1980s, have compiled new information on the status, distribution, habitat, and biodiversity of some of these relatively unknown and newly discovered deep reef ecosystems. In 2004, during a State of Florida funded mission with the *Johnson-Sea-Link* (*JSL*) Submersible, the PI discovered nearly 300 potential targets during echosounder transects that may be newly discovered deep-water reefs off the east coast of Florida, some of which are up to 168 m (550 feet) in height at depths of 732 m (2400 feet) (Reed and Wright, 2004; Reed et al., 2004b, 2005, 2006). Expeditions in 2002 and 2003 for biomedical research by the PI and funded by the National Oceanic and Atmospheric Administration's Office of Ocean Exploration (NOAA OE) enabled preliminary exploration of additional deep-water reef sites in the western Atlantic (Blake Plateau) and eastern Gulf of Mexico on southwest Florida shelf slope (Reed, 2003, 2004; Reed and Pomponi, 2002b; Reed et al., 2002, 2003, 2004d, 2006). These were the first HOV and ROV dives ever to document the habitat and benthic biodiversity of some of these relatively unknown deep-water reefs.

This report provides new information based on eight expeditions on deep-water reefs off eastern Florida and Straits of Florida using submersible or ROV during 2005 and 2006.

RESULTS

Cruise Summaries

The following summarizes all expeditions that explored deep-water reefs off eastern Florida during 2005 and 2006.

1) Title: Florida's Deep-Water Oases: Exploration of Deep Reef Ecosystems
   Institution: Harbor Branch Oceanographic Institution (HBOI), Division of Biomedical Marine Research (DBMR)
   Principal Investigators: John Reed, Amy Wright (HBOI)
   Ship/Submersible: R/V *Seward Johnson*, *Johnson-Sea-Link* I submersible
   Dates: April 4-15, 2005
   Location: Bahamas- Bimini, Cay Sal; Florida- Miami Terrace
   Number of submersible dives: 18
   New reef sites discovered: 2 new reef sites ground truthed w/ sub

2) Title: Center of Excellence for Biotechnology and Marine Biomedical Research-Exploration of Deep Reef Ecosystems
   Institutions: Harbor Branch Oceanographic Institution (HBOI), Division of Biomedical Marine Research (DBMR); Florida Atlantic University, Center of Excellence for Biotechnology and Marine Biomedical Research
   Principal Investigators: John Reed, Amy Wright, Shirley Pomponi (HBOI); Russ Kerr, Frank Mari (FAU)
   Ship/Submersible: R/V *Seward Johnson*, *Johnson-Sea-Link* I submersible
   Dates: August 2-16, 2005
   Location: Miami Terrace, Straits of Florida
   Number of submersible dives: 27
   New reef sites discovered: 9 new reef sites ground truthed w/ sub

3) Title: Florida's Deep-Water Oases: Exploration of Deep Reef Ecosystems
Institutions: Harbor Branch Oceanographic Institution (HBOI), Division of Biomedical Marine Research (DBMR); Oregon Institute of Marine Biology, NOVA Southeastern University, Smithsonian Institution, NOAA Office of Ocean Exploration (funding agency)
Principal Investigators: Sandra Brooke (OIMB), John Reed (HBOI), Charles Messing (NOVA)
Ship/Submersible: R/V *Seward Johnson, Johnson-Sea-Link* I submersible
Dates: Nov. 7-20, 2005
Location: Florida *Lophelia* Reefs, Miami and Pourtales Terrace
Number of submersible dives: 14
New reef sites discovered: 8 new reef sites ground truthed w/ sub; 31 new potential targets from echosounder

4) Title: Seafarer Proposed Natural Gas Pipeline Route Deep-Water Survey
Institutions: Harbor Branch Oceanographic Institution (HBOI), ENSR Corp.
Principal Investigator: John Reed (HBOI)
Ship/Submersible: R/V *Seward Johnson*, *Johnson-Sea-Link* I submersible
Dates: February 28- March 7, 2006
Location: Florida *Lophelia* Reefs, Straits of Florida
Number of submersible dives: 9
New reef sites discovered: 1 new reef site ground truthed w/ sub; 18 nm ground truthed w/ sub

5) Title: Calypso Proposed Natural Gas Deep-Water Port Site Survey
Institutions: NOVA Southeastern University, Harbor Branch Oceanographic Institution (HBOI), Florida Fish and Wildlife Research Institute, Naval Surface Warfare Center, Suez Inc.
Principal Investigator: Charles Messing (NOVA), John Reed (HBOI), Sandra Brooke (FWRI)
Ship/Submersible: R/V *Walton Smith*, TONGS ROV
Dates: April 15-18, 2006
Location: Miami Terrace, Straits of Florida
Number of ROV dives: 15 transect legs
New reef sites discovered: 24^2 nm ground truthed w/ ROV; 36 reef/hard bottom sites recorded

6) Title: Calypso Proposed Natural Gas Pipeline Route Deep-Water Survey
Institutions: NOVA Southeastern University, Harbor Branch Oceanographic Institution (HBOI), Naval Surface Warfare Center, Suez Inc.
Principal Investigator: Charles Messing (NOVA), John Reed (HBOI)
Ship/Submersible: R/V *Walton Smith*, *TONGS* ROV
Dates: May 11-15, 2006
Location: Miami Terrace, Straits of Florida

Number of ROV dives: 15 transect legs
New reef sites discovered: 50 nm ground truthed w/ ROV; 51 reef/hard bottom sites recorded

7) Title: Florida's Deep-Water Oases: Exploration of Deep Reef Ecosystems
Institution: Harbor Branch Oceanographic Institution (HBOI), Division of Biomedical Marine Research (DBMR); University of Miami, RSMAS
Principal Investigators: John Reed, Shirley Pomponi, Amy Wright (HBOI); Mark Grasmueck, Gregor Eberli (UM)
Ship/Submersible: R/V *Seward Johnson*, *Johnson-Sea-Link* II submersible
Dates: May 22-30, 2006
Location: Bahamas- Bimini, Lucaya; Florida- Miami Terrace
Number of submersible dives: 12
New reef sites discovered: 9 new reef sites ground truthed w/ sub; four 2x2 nm high def multibeam maps groundtruthed

8) Title: Florida's Deep-Water Oases: Exploration of Deep Reef Ecosystems
Institution: Harbor Branch Oceanographic Institution (HBOI), Division of Biomedical Marine Research (DBMR); University of Miami, RSMAS; Florida Fish and Wildlife Research Institute; NOVA Southeastern University; University of Florida
Principal Investigators: John Reed, Tracey Sutton, Tammy Frank, Marsh Youngbluth (HBOI); Charles Messing (NOVA); Chuck Jacoby (UF); Robert Ginsburg, Chris Langdon (UM); Tina Udouj (FWRI)
Ship/Submersible: R/V *Seward Johnson*, *Johnson-Sea-Link* II submersible
Dates: May 31- June 9, 2006
Location: Miami Terrace, Straits of Florida
Number of submersible dives: 16
New reef sites discovered: 2 reef sites ground truthed w/ sub. Detailed ecological assessment of the biodiversity and relative abundance of the benthic, fish and zooplankton communities; geological features; physical processes within this ecosystem; and biochemical compounds of interest for drug discovery.

REFERENCES

Reed, J.K. 2002a. Comparison of deep-water coral reefs and lithoherms off southeastern U.S.A. Hydrobiologia 471: 57-69.

Reed, J.K. 2002b. Deep-water Oculina coral reefs of Florida: biology, impacts, and management. Hydrobiologia 471: 43-55.

Reed, J.K. 2003. Deep-water coral reefs off Southeastern USA. National Geographic Society, Classroom Exploration of the Oceans, 2003, Keynote presentation [http://www.coexploration.org/ceo].

Reed, J.K. 2004a. General description of deep-water coral reefs of Florida, Georgia and South Carolina: A summary of current knowledge of the distribution, habitat, and associated fauna. A Report to the South Atlantic Fishery Management Council, NOAA, NMFS, 71 pp.

Reed, J.K. 2004b. Medicines from the deep sea: exploration of the Gulf of Mexico. The Slate, American Academy of Underwater Sciences, Vol. 1, 2004, p. 10-11.

Reed, J. K. and S. Pomponi. 1999. Submersible and scuba collections in the Gulf of Mexico, Florida Keys National Marine Sanctuary, and Florida Straits: Biomedical and biodiversity research of the benthic communities with emphasis on the porifera and gorgonacea, August 5-25, 1999.

Reed, J. K. and S. Pomponi. 2002a. Submersible and scuba collections in the Gulf of Mexico, Florida Keys National Marine Sanctuary, and Straits of Florida: biomedical and biodiversity research of the benthic communities with emphasis on Porifera and Gorgonacea. Final Cruise Report.

Reed, J.K. and S. Pomponi. 2002b. Islands in the Stream 2002: Exploring Underwater Oases. Mission Three: Summary. Discovery of new resources with pharmaceutical potential. Final Cruise Report.

Reed, J.K. and A. Wright. 2004. Final cruise report. Submersible and scuba collections on deep-water reefs off the east coast of Florida, including the Northern and Southern Straits of Florida and Florida Keys National Marine Sanctuary for biomedical and biodiversity research of the benthic communities with emphasis on the Porifera and Gorgonacea, May 20- June 2, 2004. Conducted by the Center of Excellence, HBOI and FAU, 54 pp.

Reed, J.K., R.H. Gore, L.E. Scotto, and K.A. Wilson. 1982. Community composition, structure, aereal and trophic relationships of decapods associated with shallow- and deep-water Oculina varicosa coral reefs. Bulletin of Marine Science 32: 761-786.

Reed, J.K., S. Pomponi, T. Frank, and E. Widder. 2002. Islands in the Stream 2002: Exploring Underwater Oases. Mission Three: Summary. Discovery of new resources with pharmaceutical potential; vision and bioluminescence in deep-sea benthos. NOAA Ocean Exploration web site: http://oceanexplorer.noaa.gov/explorations/02sab/logs/summary/summary.html, 29 pp.

Reed, J.K., A. Wright, and S. Pomponi. 2003. Discovery of new resources with pharmaceutical potential in the Gulf of Mexico. Mission Summary Report, 2003 National Oceanic and Atmospheric Administration Office of Ocean Exploration, 31 pp.

Reed, J. K., A, Wright, S. Pomponi. 2004. Medicines from the Deep Sea: Exploration of the Northeastern Gulf of Mexico. In: Proceedings of the American Academy of Underwater Sciences 23rd Annual Scientific Diving Symposium, March 12-13, 2004, Long Beach, California, p. 58-70.

Reed, J.K., S. Pomponi, A. Wright, D. Weaver, and C. Paull. 2005. Deep-water sinkholes and bioherms of South Florida and Pourtales Terrace- Habitat and Fauna. Bulletin of Marine Science 77:267-296

Reed, J.K., A. Shepard, C. Koenig, K. Scanlon, and G. Gilmore. 2005. Mapping, habitat characterization, and fish surveys of the deep-water *Oculina* coral reef Marine Protected Area: a review of historical and current research. Pp. 443-465, *In* (A. Freiwald, J. Roberts, *Ed*.), Cold-water Corals and Ecosystems, Proceedings of Second International Symposium on Deep Sea Corals, Sept. 9-12, 2003, Erlanger, Germany, Springer-Verlag, Berlin Heidelberg.

Reed, J.K., D. Weaver, S.A. Pomponi. 2006. Habitat and fauna of deep-water *Lophelia pertusa* coral reefs off the Southeastern USA: Blake Plateau, Straits of Florida, and Gulf of Mexico. Bulletin of Marine Science 78(2): 343-375.

Reed, J.K., C. Koenig, A. Shepard. 2006 (in review). Effects of bottom trawling on a deep-water *Oculina* coral ecosystem. Proceeding of 3rd International Deep Sea Coral Symposium, Bulletin of Marine Science.

Appendix D. Review of Distribution, Habitats, and Associated Fauna of Deep Water Coral Reefs on the Southeastern United States Continental Slope (North Carolina to Cape Canaveral, FL).

Report Prepared for the South Atlantic Fishery Management Council.

REVIEW OF DISTRIBUTION, HABITATS, AND ASSOCIATED FAUNA OF DEEP WATER CORAL REEFS ON THE SOUTHEASTERN UNITED STATES CONTINENTAL SLOPE (NORTH CAROLINA TO CAPE CANAVERAL, FL)

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INTRODUCTION

Most habitats of the continental slope, and even the shelf edge, are poorly studied and in many cases completely unknown. These deeper areas, between 100 to 1000 m, are important frontiers, offering a transition from the continental shelf to the deep sea. Fisheries are expanding rapidly into these deep regions (Roberts 2002), and hydrocarbon exploration and development are now also exploiting these depths. Off the southeastern US (SEUS) coast (including the Gulf of Mexico) there are several unique and productive deep water habitats that have been difficult to study with conventional methods because the bottom topography is very rugged and the habitats are overlain by extreme currents (i.e., Gulf Stream). This report briefly summarizes data relevant to selected such poorly studied and vulnerable habitats (i.e., deep coral mounds) on the SEUS continental slope from Cape Lookout, NC to just south of Cape Canaveral, FL deeper than 200 m.

Deep (or cold water) coral reef systems are receiving more attention worldwide. There is increasing evidence that deep water (aphotic) corals are important fish habitat (Costello et al. 2005), a repository of data on ocean climate and productivity (Adkins et al. 1998; Williams et al. in press), and are hotspots of increased biodiversity, including undescribed species. This is underscored by the growing literature and management concern directed toward these ecosystems (e.g., Morgan and Pizer 2005; Deep Sea Coral Habitat Act introduced in 2005). These habitats appear to be more extensive and important than previously known (e.g., SGCOR 2004; S.W. Ross, unpubl. data), while at the same time being severely threatened by a variety of activities (e.g., fishing, energy exploration) (Rogers 1999; Koslow et al. 2000). Although more extensive surveys are needed, *Lophelia* reefs (plus many other coral species) appear to populate the SEUS continental slope in great abundance (Stetson et al. 1962; Paull et al. 2000; Reed 2002a; Popenoe and Manheim 2001; P. Popenoe, pers. comm.). By one estimate the SEUS and Gulf of Mexico have the most extensive deep coral areas in the US (Hain and Corcoran 2004); however, these large regions are poorly explored (even considering recent expeditions). These high profile features concentrate exploitable resources and enhance local productivity in ways similar to seamounts (Rogers 1994; Koslow 1997), but this has not been adequately examined. For these reasons, locating, describing, and mapping deep corals and conducting basic biological studies in these habitats are considered global priorities (McDonough and Puglise 2003; Roberts and Hirshfield 2003; Puglise et al. 2005).

Deep water coral habitat may be more important to western Atlantic slope species than previously known. Commercially-exploited deep-water species congregate around deep coral habitat, and evidence of fishing activities (trash, lost gear) was observed on some deep coral banks. Various invertebrates, particularly galatheid squat lobsters and echinoderms, are abundant on these deep reefs, playing roles of both predator on and food for the fishes. The deep reefs are oases offering both shelter and food. Additionally, the coral thickets are surrounded by extensive coral rubble habitat which preliminary data indicate also support a diverse fauna.

Deep coral reefs of all types have been poorly studied, particularly so in the western Atlantic. References on deep coral banks within the SEUS EEZ are largely geological with a few biotic observations, mostly on invertebrates (see review in Reed 2002; references in Sedberry 2001; Reed et al. 2006). Studies elsewhere revealed that these deep reefs harbor extensive invertebrate populations composed of hundreds of species (Jensen and Frederiksen 1992; Rogers 1999; Reed 2002). Fish studies related to the deep coral banks are almost non existent (no detailed faunal surveys are published for the western Atlantic), even in the northeastern Atlantic where these corals are better known (Husebo et al. 2002). Although our investigations so far have revealed that many species of fishes and crabs are closely associated with this unique deep-reef habitat, 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 and Costello et al. 2005). Assessing its significance as fish and invertebrate habitat and addressing the extent to which the deep reef fauna is unique is an important research topic being investigated (S.W. Ross et al., ongoing studies).

No deep coral reefs are yet designated as Marine Protected Areas (MPAs) in the US EEZ deeper than 200 m, but if such reefs prove to be important habitat with unique fauna (as they seem to be), they should be candidates for protection as are *Oculina* coral reefs off east-central Florida. There are a variety of potential threats to the deep coral bottoms: mining, precious coral harvest, disposal activities, petroleum exploration and development, fiber optic and other cable laying, anchoring/gear damage, and fishing activities. MPAs or Habitat Areas of Particular Concern (HAPC) may be viable options for protecting these systems, but considerable data, especially detailed maps, are critical for evaluating how and whether to protect deep coral habitat (Miller 2001).

As stated above, publications concerning deep coral banks in the SEUS are limited, particularly for reefs off North Carolina. Much of the data in this review of SEUS deep corals are from ongoing studies of a multi-agency research team (Steve W. Ross, lead Principal Investigator, Univ. North Carolina-Wilmington). Although this research team has collected considerable data on deep coral mounds and has given numerous verbal presentations, publications are still forthcoming. Considering the needs of the South Atlantic Fishery Management Council (SAFMC) to evaluate deep water habitats in a timely manner, the brief descriptions of SEUS deep coral banks (Fig. 1) provided below will serve as an interim tool facilitating potential management options for fragile, productive deep water habitats. This synthesis is preliminary, pending final data analyses and scientific publications, and should be used cautiously with prior consent of the author. Additional information should be obtained from S.W. Ross.

HISTORY OF DEEP CORAL RESEARCH IN THE SEUS

The history of deep coral research in the SEUS is temporally and spatially sporadic. Until recently deep coral research was often a by-product of non coral projects. The major studies that document deep water corals in the area are briefly reviewed. The review below is roughly chronological and not intended to be inclusive.

Deep water corals were first reported on the Blake Plateau from 1880 collections of the steamer <u>Blake</u> (Agassiz 1888). These collections were poorly documented, and Agassiz summarized the Blake Plateau bottom as being hard and barren. The research vessel <u>Albatross</u> collected corals on the Blake Plateau in 1886 using beam trawls and tangles. Some of the *Lophelia* specimens in those collections were deposited in the US National Museum, but were otherwise poorly documented. Much later, Squires (1959) noted several scleractinian species dredged in 1954 off Palm Beach, FL in 686 m. Cairns (1979) corrected coral identifications from Squires (1959) which resulted in the above collection containing *Lophelia pertusa*, *Crispatotrochus* (=*Caryophyllia*) *squiresi*, *Enallopsammia profunda*, and *Tethocyathus variabilis*.

An area of very rough topography containing deep corals was described on the Blake Plateau off South Carolina. Many mounds and ridges were surveyed by depth sounder in 1956, 1957, 1959, and 1960 (Stetson et al. 1962). However, thheese features were not confirmed to support extensive

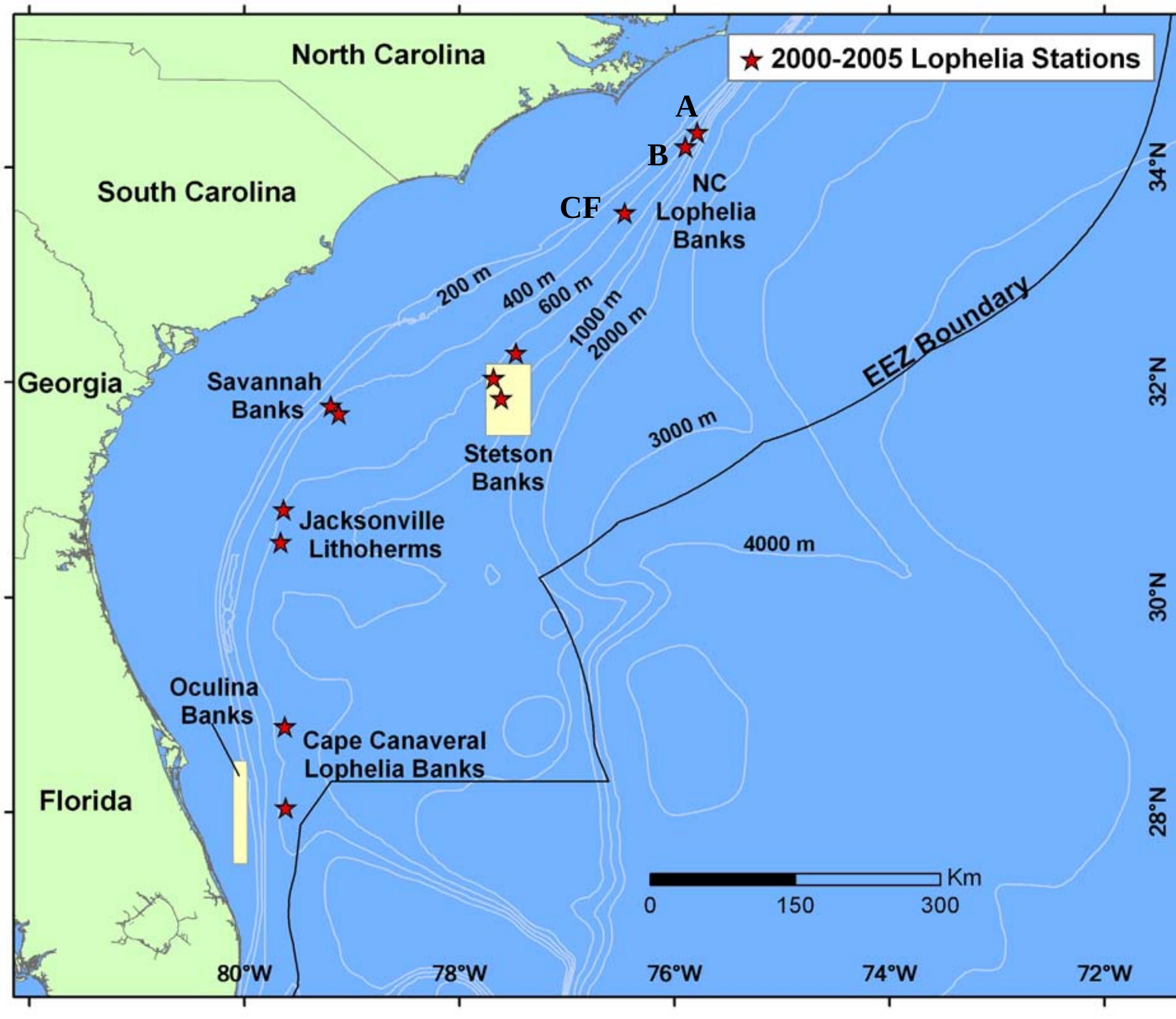

Figure 1. Ross et al. deep coral study sites (red stars), 2000-2005. CF=Cape Fear.

coral habitat until they were dredged and photographed in 1961 (Stetson 1961). Stetson et al. (1962) gave the first detailed accounting of SEUS coral banks in an area now called the "Stetson Banks" (Fig. 1), confirming that the major hard corals were *L. 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", and two dives confirmed that *Enallopsammia* (=*Dendrophyllia*) and *Lophelia* occurred in certain areas (Milliman et al. 1967). Also from 1967 sampling, Neumann and Ball (1970) described coral topped mounds (to 15 m high) along the slope off Biscayne Bay, FL (around 700-825 m).

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), it seems that such corals were not known 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 further 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. Likewise, Menzies et al. (1973) vaguely referenced a "Lophohelia" bank off Cape Lookout, repeating a figure in Rowe and Menzies (1969) and presenting a bottom photograph of a reef in 458 m. Cairns (1979) plotted a locality off Cape Lookout in his distribution map for *Lophelia* without comment. Aside from Uchupi (1967), the above North Carolina records seem to have 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, Fig. 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 R/V Eastward's depth sounder (L. McCloskey and G. Rowe, pers. comm.). There were a few other short Eastward cruises to this area off Cape Lookout under direction of 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, unpubl. data). To date three major coral mounds have been located and studied off North Carolina (Reed and Ross 2005; S.W. Ross et al., unpubl. data), and several other mounds may exist. The slope off Cape Lookout appears to be the northern extent of deep sea, cold water corals in the SEUS region.

References for the SEUS deep coral areas continued to result from studies that were generally not directed toward corals or that were geological in nature. Exceptions include Cairns (1979, 1981, 2000, 2001a), who listed ranges for a number of deep sea Scleractinia and azooxanthellate corals in this area, relying mostly on museum records. From five Alvin dives in 1971 in the eastern Florida Straits off Little Bahama Bank, Neumann et al. (1977) described hard carbonate mounds that were covered in various corals (*Lophelia* and *Enallopsammia*) and other invertebrates, and coined the term "lithoherms" for these structures. In this same area in 1982 and also using Alvin, several coral species were collected and aged, indicating that these animals lived from several hundred up to 1800 years (Griffin and Druffel 1989; Druffel et al. 1990, 1995). Since 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 sea corals. During a study of surficial and deeper sediments of the Florida-Hatteras slope and inner Blake Plateau, Ayers and Pilkey (1981) documented a number of coral banks, collected corals, and dated several coral samples. 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 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 some soft and hard coral occurrences on the Blake Plateau. Many deep reef locations were suggested by the U.S. Geological Survey sidescan sonar mapping (cruises in 1987) of the continental slope (EEZ-SCAN 87 Scientific Staff 1991); however, this large scale geological survey had little habitat verification. Perhaps the first study to document the invertebrate community associated with deep coral habitat in this area 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 1980 Alvin dives. 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 a portion of the Blake Plateau around 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) also discussed a coral habitat southeast of Cape Fear, NC ("Agassiz Coral Hills") in 650-750 m dominated by *Bathypsammia tintinnabulum*. Apparently the *B. tintinnabulum* used by Emilini et al. (1978) came from the area and collections described by George (2002). Reed (2002a, b, 2006) described several large areas of deep corals on the Blake Plateau. As part of a SEAMAP bottom mapping project, data to be scanned for evidence of deep corals in this area were summarized by Arendt et al. (2003).

Beginning in 2000 and continuing through the present, deep coral (or related habitat) research in the SEUS was stimulated by funding of several studies through the NOAA Office of Ocean Exploration (supplemented by other sources). Teams lead by Principal Investigators S. Brooke, S. Pomponi, S.W. Ross, and G.R. Sedberry explored deep coral banks throughout the SEUS, mapping habitats, cataloging fauna, and conducting basic biological studies. A multi-investigator effort to create detailed habitat classifications (Southeastern US Deep-Sea Corals initiative, SEADESC) from past submersible dives in the area is underway. A related effort to generally locate hard bottom or coral habitat between 200 and 2000 m (SEAMAP) is also underway. Future publications should be forthcoming from the considerable data collected by these efforts.

DEEP SEA CORALS OF THE SEUS

The SEUS slope area, including the slope off the Florida Keys, appears to have a unique assemblage of deep water Scleractinia (Cairns and Chapman 2001). The warm temperate assemblage identified by Cairns and Chapman (2001) contained about 62 species, four endemic to the region. This group was characterized by many free living species, few species living deeper than 1000 m, and many species with amphi-Atlantic distributions. Based on literature the SEUS region contains at least 109 species of deep corals (classes Hydrozoa and Anthozoa, Ross and Nizinski in press). This number is conservative, since collection of corals has rarely been a research priority.

Lophelia pertusa, the major structure building coral in the deep sea, is fragile and susceptible to physical destruction (Fossa et al. 2002). *Lophelia* reefs are widespread, occurring not only on the SEUS slope, but also 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). Coral habitats dominated by *Lophelia pertusa* are common throughout the SEUS in depths of about 370 to at least 800 m. Reed and Ross (2005) summarized area deep coral research. While their study areas do not cover all known deep coral habitat in the region, they have conducted work over most of the well known coral sites (Fig. 1). Although *Lophelia* may occur in small scattered colonies attached to various hard substrates, it also forms complex, high profile features (bioherms). The ridges and reef mounds, some rising more than 100 m from the open substrate, accelerate bottom currents which are favorable to attached filter-feeders. Thus, the growing reef alters local currents, enhancing the environment for continued coral growth and faunal recruitment (Genin et al. 1986). Along the sides and around the bases of these banks are rubble zones of dead coral pieces which may extend large distances away from the mounds.

Data are lacking on how *Lophelia* coral banks form despite several hypotheses (Hovland et al. 1998; Hovland and Risk 2003; Masson et al. 2003). The mounds off North Carolina and those in some other SEUS locations (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 deep coral habitats in the area (especially on the Blake Plateau) seem to be formed by coral colonization of appropriate hard substrates, without mound formation by the corals. Bottom currents that are too strong may prevent mound formation (Popenoe and Manheim 2001) because sediments cannot be trapped. 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 formed, elevated topography appears to be an important attribute for well developed coral communities (Masson et al. 2003). Although exactly how these corals feed and grow are poorly known, data indicate that food sources are not chemosynthetic and are probably surface derived (Duineveld et al. 2004).

These deep reefs may be hundreds to tens of 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 the distribution of coral mound ages in the western Atlantic is unclear. Regardless, it seems likely that most of these structures are at least thousands of years old. While the genetic structure (gene flow, population relationships, taxonomic relationships) of *Lophelia* in the northeastern Atlantic has been described (Le Goff-Vitry et al. 2004), such studies are just beginning in the western Atlantic ©. Morrison et al., unpubl. data).

Bamboo (Family Isididae, four species) and black corals (Families Leiopathidae and Schizopathidae, ca. four species) are also important structure forming corals in the SEUS (Fig. 2). 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. Bamboo and black coral colonies, occurring either singly or in small aggregations, may be observed either in association with hard coral colonies or as separate entities. Furthermore, some of these living components of the deep reefs (e.g., black corals, zoanthids) are hundreds to thousands of years old (Griffin and Druffel 1989; Druffel et al. 1995; Williams et al. in press; C. Holmes and S.W. Ross, unpubl. data), the oldest animals on Earth. They 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. A major effort to investigate these geochemical data is being started by USGS ©. Holmes and S.W. Ross)

NORTH CAROLINA DEEP CORAL BANKS

Off North Carolina, *Lophelia* forms what may be considered classic mounds (three areas surveyed so far) that appear to be a sediment/coral rubble matrix topped with almost monotypic stands of *L. pertusa* (Figs. 3-4). Although *Lophelia* is the dominant hard coral off North Carolina, other scleractinians contribute to the overall complexity of the habitat. These include the colonial

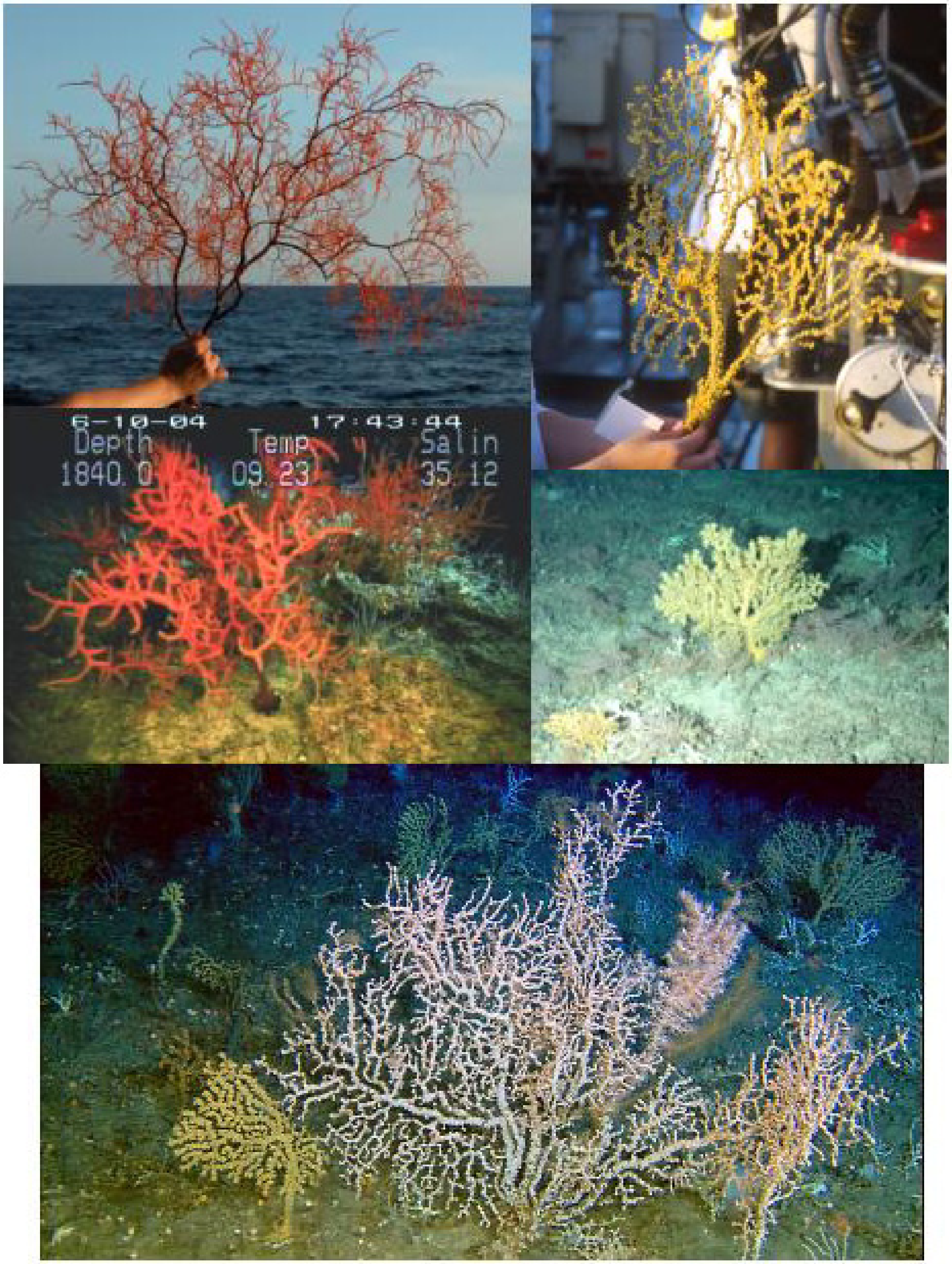

Figure 2. Selected views of Black corals and Bamboo corals on the Blake Plateau (Ross et al., unpubl. data).

corals *Madrepora oculata* and *Enallopsammia* spp. as well as a variety of solitary corals. These hard corals tend to live on or within the *Lophelia* matrix. The three North Carolina *Lophelia* mounds are the northernmost coral banks in the SEUS. 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 three NC banks are generally similar in physical attributes and faunal composition. Some observed differences, however, are being investigated, and more detailed results will be presented in several peer reviewed publications in preparation (Ross et al.). For convenience these three areas have been designated as Cape Lookout *Lophelia* Bank A, Cape Lookout *Lophelia* Bank B, and Cape Fear *Lophelia* Bank. These names are to facilitate research and may eventually be changed. General descriptions of the NC coral mounds and associated fauna follows. Since there is almost no data published for the NC deep coral banks and because they are different than those to the south, they are discussed in more detail below.

Several potential deep coral banks were identified in the USGS survey of the EEZ off of North Carolina (EEZ-SCAN 87 Scientific Staff 1991). Attempts were made (Ross et al. cruises) to locate a few of these banks to no avail. These coral mounds, especially off southern North Carolina, would be important to document as they would occur in what may be a transition area between a region of coral/sediment built mounds composed almost entirely of *L. pertusa* and the area to the south where coral development is generally quite different.

Biological Communities of the North Carolina Coral Banks

Fish communities are extensive but difficult to document on and around these coral banks. Some level of commercial fishing activity seems to occur on the NC Banks, as we have observed trash and entangled fishing gear on the reefs. Because the fish data have been extensively analyzed and are nearly ready for submission for publication, a more detailed treatment of the region’s fish data is presented below.

An impressive biological aspect of these coral mounds (aside from the corals themselves) is the well developed and abundant invertebrate fauna. We have not yet detected major differences in the invertebrate fauna among the three North Carolina banks. Galatheid crabs (especially *Eumunida picta*) and the brisingid basket star (*Novodinia antillensis*) were particularly obvious, perching high in coral bushes to catch passing animals or filter in the currents (Fig. 5). One very different aspect of the North Carolina deep coral habitat compared to the rest of the South Atlantic Bight is the massive numbers of a brittle star (*Ophiacantha bidentata*) covering both dead and living coral colonies. They are perhaps the most abundant macroinvertebrate on these banks and may constitute a major food source (Brooks et al. in review). In places the bottom is covered with huge numbers of several species of anemones (Fig. 5). The abundance of filter feeders suggest a food rich habitat.

Cape Lookout *Lophelia* Bank A

Aside from a few maps (see above) there are no published data from this coral mound. This area was apparently first occupied by the R/V Eastward (see above) which gave a location of 34 18' N, 75 48' W. Two trawl stations and a sonar survey of the Eastward station area in May 1983 using the R/V Delaware II (S.W. Ross, chief scientist), revealed no indication of hard bottom or coral. The Eastward navigated with LORAN A, and since their station was about 1-1.5 nmi (2-2.7

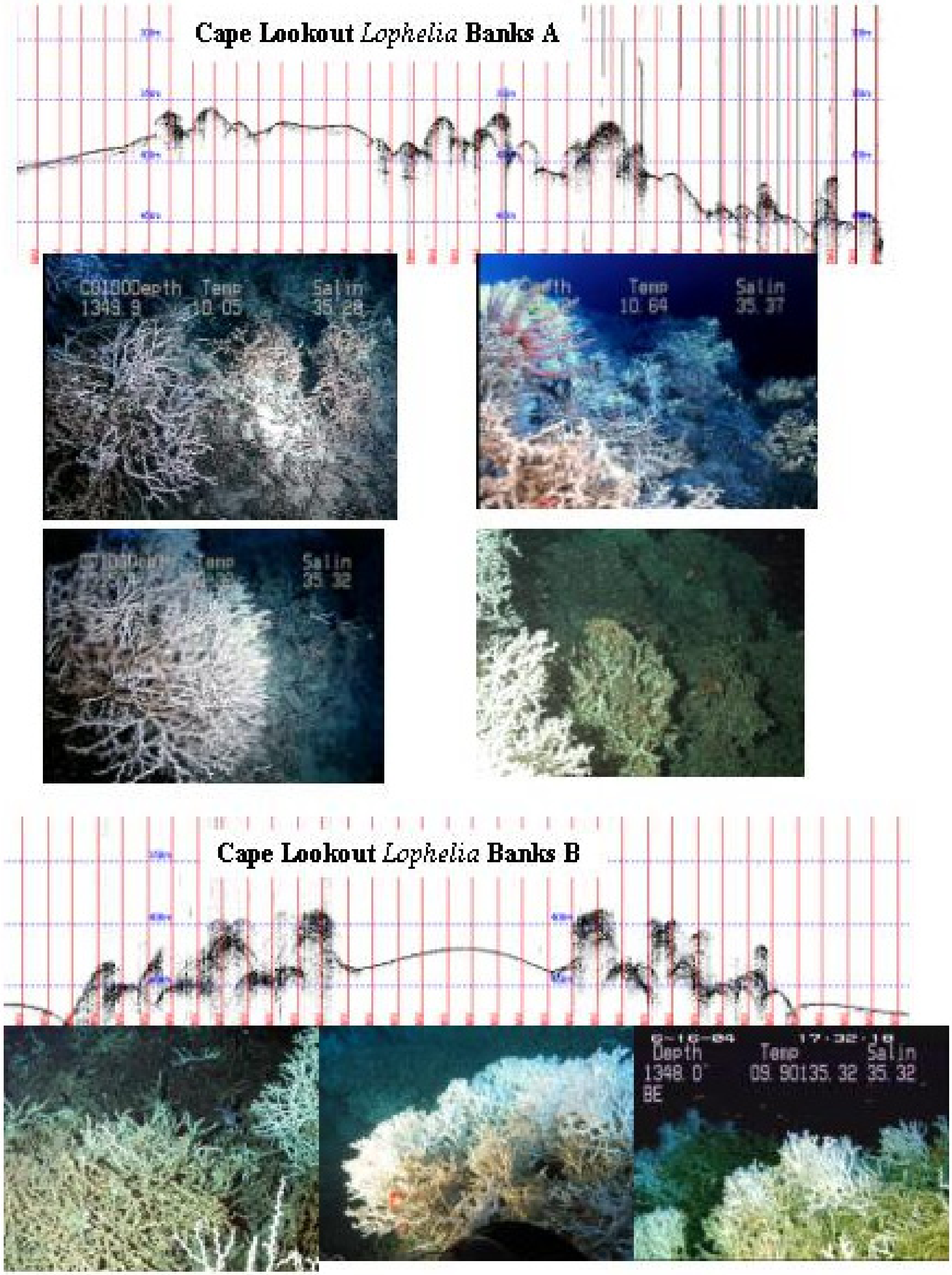

Figure 3. Selected views of *Lophelia pertusa* habitat and depth sounder recordings for the two deep coral mounds off Cape Lookout, NC (Ross et al., unpubl. data).

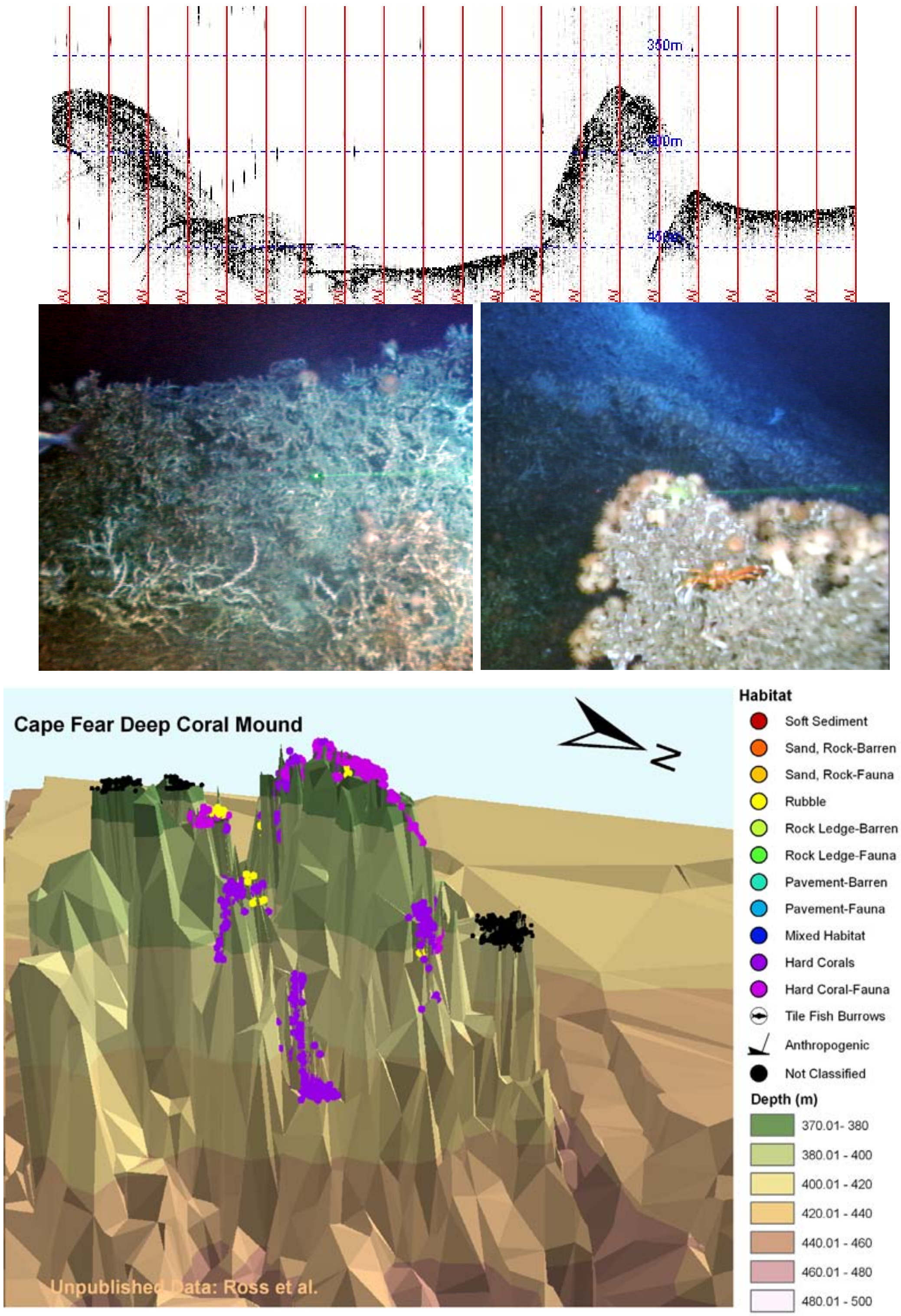

Figure 4. Selected views of the deep coral mound off Cape Fear, NC. Bottom panel is a 3-D reconstruction of this feature with general habitat classifications (SEADESC) from JSL dives (S.W. Ross, unpubl. data).

Figure 5. Various invertebrates common on SEUS deep coral banks. From left to right and top to bottom: *Eumunida picta* perched on *Lophelia pertusa*, *Rochina crassa* sitting on dead *Lophelia*, close up of *Echinus* urchin with brittle stars (*Ophiacantha bidentata*) among coral branches, anemone *Actinauge*, basket star *Novodinia antillensis*, two anemonies and brittle stars among coral branches. These photographs were from North Carolina coral banks (S.W. Ross et al. unpubl. data).

km) from the large coral bank area sampled later (Fig. 3), it is likely that the less accurate LORAN may have put the Eastward station off of the actual reef. However, the possibility that a reef does exist on or near the E-4937 station cannot be discounted without a more detailed survey of that location. The USGS side scan survey (EEZ-SCAN 87 Scientific Staff 1991) illustrated reefs in this area, and coordinates from that survey guided a cruise using the Navy's NR-1 nuclear research submersible (Sulak and Ross, unpubl. data) during 15-18 Nov 1993. However, there also seemed to be a navigation issue with this cruise in that locations plotted from the NR-1 track are offset about 0.5 nmi (1 km) from the large mounds later located by Ross et al. (unpubl. data). A later ship sonar survey of the NR-1 locations did not yield obvious reef areas. Between summer 2000 and fall 2005 Ross et al. (unpubl. data) sampled this area extensively using a variety of methods throughout the water column. Their major method for collecting bottom data on the reef proper was the JSL research submersible. Seventeen dives were made on coral mounds in this area (Fig. 6, Table 1), and observations from these totaled nearly 37 hours (bottom time).

Preliminary observations suggest that this area contains the most extensive coral mounds off North Carolina; however, data are lacking to adequately judge overall sizes and areal coverage. Ross et al. JSL dives in this area ranged from 370-447 m (Table 1). Mean bottom temperatures ranged from 6.3 to 10.9 C, while mean bottom salinities were always around 35 (Table 2). There appear to be several prominences capping a ridge system, thus, presenting a very rugged and diverse bathymetry (Fig. 6), but there are also other mounds away from the main ridge sampled (Fig. 6). The main mound system rises vertically nearly 80 m over a distance of about 1 km, and in places exhibits slopes in excess of 50-60 degrees. Sides and tops of these mounds are covered with extensive colonies of living *Lophelia pertusa* (Fig. 3), with few other corals being observed. Dead colonies and coral rubble interspersed with sandy channels are also abundant. Extensive coral rubble zones surround the mounds for a large, but unknown, distance (exact area not yet surveyed), especially at the bases of the mounds/ridges, and in places seem to be quite thick. These mounds appear to be formed by successive coral growth, collapse, and sediment entrapment (Wilson 1979; Popenoe and Manheim 2001). These topographic highs accelerate bottom currents which favor attached filter-feeders, and very strong bottom currents have been observed.

Cape Lookout *Lophelia* Bank B

Except for a few maps (see above) there are no published data from this coral mound. The USGS side scan survey (EEZ-SCAN 87 Scientific Staff 1991) illustrated reefs in this area, and, as above, coordinates from that survey guided the cruise using the NR-1 nuclear research submersible (Sulak and Ross, unpubl. data) during 15-18 Nov 1993. The same navigation issue with this cruise described above was also apparent in this area, NR-1 stations being about 1-1.4 nmi (2-2.6 km) from major mounds located later by Ross et al. Between summer 2001and fall 2005 Ross et al. (unpubl. data) sampled this area using a variety of methods throughout the water column. The JSL submersible was the major method for collecting bottom data on the reef proper. Nine dives were made on coral mounds in this area (Fig. 7, Table 1), and observations from these totaled about 20 hours.

The least amount of data are available for this area. Mounds appear to cover a smaller area than those described above, but here again better mapping data are needed. Ross et al. JSL dives in this area ranged from 375-450 m (Table 1). Mean bottom temperatures ranged from 5.8 to 10.4 C, and as above mean bottom salinities were always around 35 (Table 2). These mounds rise at least

Table 1. Johnson-Sea-Link (JSL) research dives conducted on deep coral habitat on the slope of the southeastern US by S.W. Ross et al., summer 2000-fall 2005. Start, end and total times represent bottom times in minutes.

Station	**Date**	**Location**	Start Time	End Time	Total Time (min)	Start Lat	Start Long	End Lat	End Long	Start-End Depth (m)
JSLI-2000-4206	28-Jul-00	Cape Lookout A	08:42	10:36	114	34° 19.52	75° 47.05	34° 19.45	75° 47.25	430-389
JSLI-2000-4207	28-Jul-00	Cape Lookout A	15:56	17:45	109	34° 19.57	75° 47.13	34° 19.42	75° 47.29	418-405
JSLI-2001-4361	22-Sep-01	Cape Lookout A	08:44	11:23	159	34° 19.68	75° 47.37	34° 19.69	75° 47.53	427-384
JSLI-2001-4362	22-Sep-01	Cape Lookout A	16:21	18:36	135	34° 19.43	75° 47.49	34° 19.42	75° 47.51	399-370
JSLI-2001-4363	23-Sep-01	Cape Lookout A	09:02	11:15	133	34° 19.42	75° 47.45	34° 19.41	75° 47.50	417-371
JSLI-2001-4364	23-Sep-01	Cape Lookout A	16:02	18:53	171	34° 18.84	75° 47.01	34° 18.77	75° 47.13	442-398
JSLI-2001-4365	24-Sep-01	Cape Lookout B	08:42	11:15	153	34° 11.34	75° 53.80	34° 11.41	75° 53.74	431-414
JSLI-2001-4366	24-Sep-01	Cape Lookout B	16:18	17:32	74	34° 10.75	75° 53.51	34° 10.77	75° 53.37	449-437
JSLII-2002-3304	11-Aug-02	Cape Lookout A	08:33	11:01	148	34° 19.71	75° 47.04	34° 19.51	75° 46.21	447-386
JSLII-2002-3305	11-Aug-02	Cape Lookout A	16:30	18:59	149	34° 19.46	75° 47.20	34° 19.48	75° 47.20	416-385
JSLII-2002-3306	12-Aug-02	Cape Lookout A	08:32	10:59	147	34° 19.4	75° 47.2	34° 19.45	75° 47.25	418-384
JSLII-2002-3307	12-Aug-02	Cape Lookout A	16:24	17:11	47	34° 19.48	75° 47.45	34° 19.50	75° 47.55	416-383
JSLII-2002-3308	13-Aug-02	Cape Fear	08:29	10:58	149	33° 34.33	76° 29.05	33° 34.43	76° 27.90	449-373
JSLII-2003-3419	17-Aug-03	Stetson	08:40	10:51	131	32° 01.75	77° 40.44	32° 02.01	77° 40.49	622-597
JSLII-2003-3420	17-Aug-03	Stetson	16:18	18:24	126	32° 02.01	77° 40.71	32° 02.04	77° 40.93	626-629
JSLII-2003-3425	21-Aug-03	Cape Fear	08:21	10:47	146	33° 34.38	76° 27.93	33° 34.46	76° 27.87	386-379
JSLII-2003-3426	21-Aug-03	Cape Fear	16:36	19:03	147	33° 34.38	76° 27.91	33° 34.33	76° 27.91	371-377
JSLII-2003-3427	22-Aug-03	Cape Fear	08:33	10:51	138	33° 34.28	76° 27.75	33° 34.48	76° 27.70	381-418
JSLII-2003-3428	22-Aug-03	Cape Fear	16:11	18:17	126	33° 34.38	76° 27.95	33° 34.44	76° 27.89	377-371
JSLII-2003-3429	23-Aug-03	Cape Lookout B	08:54	11:10	136	34° 11.15	75° 54.03	34° 11.42	75° 53.75	435-415
JSLII-2003-3430	23-Aug-03	Cape Lookout A	16:24	18:59	155	34° 19.37	75° 47.33	34° 19.40	75° 47.25	415-394
JSLII-2003-3431	24-Aug-03	Cape Lookout A	08:36	10:52	136	34° 19.52	75° 47.04	34° 19.42	75° 47.24	432-389
JSLII-2003-3432	24-Aug-03	Cape Lookout A	16:47	18:57	130	34° 19.43	75° 47.16	34° 19.48	75° 47.21	424-385
JSLI-2004-4681	09-Jun-04	North Cape Canaveral	09:10	11:12	122	28º 47.55	79º 37.19	28º 47.60	79º 37.31	783-709
JSLI-2004-4682	09-Jun-04	North Cape Canaveral	17:06	19:08	122	28º 47.76	79º 37.30	28º 47.75	79º 37.24	770-760
JSLI-2004-4683	10-Jun-04	Jacksonville Lithoherms	08:32	10:55	143	30º 31.05	79º 39.62	30º 30.97	79º 39.72	568-544
JSLI-2004-4684	10-Jun-04	Jacksonville Lithoherms	16:37	18:43	126	30º 30.94	79º 39.62	30º 30.84	79º 39.62	569-554
JSLI-2004-4685	11-Jun-04	Jacksonville Lithoherms	08:45	11:00	135	30º 48.81	79º 37.81	30º 48.70	79º 37.93	652-636
JSLI-2004-4686	11-Jun-04	Jacksonville Lithoherms	17:02	18:55	113	30º 30.13	79º 39.09	30º 30.10	79º 39.18	638-593
JSLI-2004-4687	12-Jun-04	Savannah Banks	08:32	10:13	101	31º 44.36	79º 06.09	31º 44.52	79º 05.66	540-497
JSLI-2004-4688	12-Jun-04	Savannah Banks	16:27	18:00	93	31º 46.45	79º 11.70	31º 46.56	79º 11.59	532-516
JSLI-2004-4689	13-Jun-04	Stetson	08:37	10:37	120	31º 49.15	77º 36.77	31º 49.15	77º 36.20	672-668
JSLI-2004-4692	15-Jun-04	Cape Lookout A	08:29	10:33	124	34º 19.43	75º 47.17	34º 19.44	75º 47.22	425-384
JSLI-2004-4693	15-Jun-04	Cape Lookout A	16:20	18:27	127	34º 19.44	75º 47.14	34º 19.51	75º 47.15	431-392
JSLI-2004-4694	16-Jun-04	Cape Lookout B	08:29	10:41	132	34º 11.28	75º 53.62	34º 11.28	75º 53.79	440-396
JSLI-2004-4695	16-Jun-04	Cape Lookout B	16:49	18:59	130	34º 11.41	75º 53.65	34º 11.41	75º 53.74	442-414

JSLI-2004-4696	17-Jun-04	Cape Fear	08:31	10:25	114	33º 34.37	76º 27.71	33º 34.36	76º 27.67	390-402
JSLI-2004-4697	17-Jun-04	Cape Fear	16:42	18:24	102	33º 34.57	76º 27.83	33º 34.59	76º 27.77	405-411
JSLI-2004-4698	18-Jun-04	Stetson	09:42	11:31	109	31º 49.45	77º 36.69	31º 49.56	77º 36.79	703-664
JSLI-2004-4699	18-Jun-04	Stetson	16:59	19:09	130	31º 50.89	77º 36.72	31º 50.75	77º 36.77	696-660
JSLI-2004-4700	19-Jun-04	Jacksonville Lithoherms	09:37	11:07	90	30º 30.76	79º 39.68	30º 30.85	79º 39.60	564-558
JSLI-2004-4701	19-Jun-04	Jacksonville Lithoherms	17:04	18:43	99	30º 28.94	79º 38.50	30º 28.93	79º 38.38	647-674
JSLI-2004-4702	20-Jun-04	North Cape Canaveral	08:38	10:42	124	28º 47.70	79º 37.40	28º 47.61	79º 37.38	738-713
JSLI-2004-4703	20-Jun-04	North Cape Canaveral	17:08	18:52	104	28º 46.62	79º 36.96	28º 46.62	79º 36.96	756-742
JSLI-2004-4704	21-Jun-04	South Cape Canaveral	08:37	10:41	124	28º 02.64	79º 36.82	28º 02.53	79º 36.75	739-738
JSLI-2004-4705	21-Jun-04	South Cape Canaveral	17:18	19:08	110	28º 02.16	79º 36.84	28º 02.38	79º 36.78	725-689
JSLI-2005-4890	17-Oct-05	Cape Lookout A	08:36	10:43	127	34º 19.59	75º 47.09	34º 19.47	75º 47.22	420-389
JSLI-2005-4891	17-Oct-05	Cape Lookout A	16:32	18:27	115	34º 19.49	75º 47.44	34º 19.37	75º 47.56	433-380
JSLI-2005-4892	18-Oct-05	Cape Lookout B	08:22	10:42	140	34º 13.90	75º 52.44	34º 14.08	75º 52.33	411-375
JSLI-2005-4893	18-Oct-05	Cape Lookout B	16:30	18:31	121	34º 14.00	75º 52.30	34º 14.19	75º 52.28	418-371
JSLI-2005-4894	19-Oct-05	Cape Lookout B	08:22	10:59	157	34º 10.66	75º 53.59	34º 11.00	75º 53.36	450-409
JSLI-2005-4895	19-Oct-05	Cape Lookout B	16:22	18:51	149	34º 12.96	75º 53.09	34º 12.96	75º 53.02	413-395
JSLI-2005-4896	20-Oct-05	Cape Fear	08:24	10:50	146	33º 34.18	76º 27.89	33º 34.17	76º 27.77	397-375
JSLI-2005-4897	20-Oct-05	Cape Fear	16:21	18:26	125	33º 34.64	76º 27.98	33º 34.65	76º 27.95	443-408
JSLI-2005-4898	21-Oct-05	Stetson North	08:37	10:35	118	32º 15.94	77º 28.42	32º 16.17	77º 28.47	642-550
JSLI-2005-4899	21-Oct-05	Stetson North	16:22	18:25	123	32º 15.84	77º 28.82	32º 15.83	77º 29.02	603-587
JSLI-2005-4900	22-Oct-05	Savannah Banks	17:03	19:17	134	31º 44.36	79º 06.16	31º 44.57	79º 05.53	543-519
JSLI-2005-4901	23-Oct-05	Savannah Banks	08:28	08:35	7	31º 42.36	79º 07.42	31º 42.30	79º 07.39	508-507
JSLI-2005-4902	26-Oct-05	Savannah Banks	16:39	18:58	139	31º 42.26	79º 07.88	31º 42.32	79º 07.31	516-514
JSLI-2005-4903	27-Oct-05	Stetson	08:30	10:21	111	32º 01.12	77º 40.00	32º 00.95	77º 40.16	633-633
JSLI-2005-4904	27-Oct-05	Stetson	16:29	18:52	143	31º 50.81	77º 36.83	31º 50.79	77º 36.74	652-657
JSLI-2005-4905	30-Oct-05	Savannah Banks	16:12	18:35	143	31º 46.91	79º 12.26	31º 46.43	79º 12.10	541-515
JSLI-2005-4906	30-Oct-05	Savannah Banks	17:26	18:52	86	31º 46.49	79º 11.64	31º 46.62	79º 11.56	525-515
JSLI-2005-4907	01-Nov-05	Jacksonville Lithoherms	08:28	10:47	139	30º 48.15	79º 38.39	30º 48.03	79º 38.50	534-530
JSLI-2005-4908	01-Nov-05	Jacksonville Lithoherms	16:38	18:55	137	30º 31.12	79º 39.63	30º 31.26	79º 39.41	585-625

Table 2. Bottom temperature and salinity data from Johnson-Sea-Link (JSL) dives on deep coral habitat on the slope of the southeastern US (S.W. Ross et al. unpubl. data).

Station	**Date**	Location	Mean Temp (C°) **± SE**	Temp Range (C°)	Mean Salinity **± SE**	Salinity Range
JSLI-2000-4206	28-Jul-00	Cape Lookout A	8.49 ± 0.02	5.64-10.64	35.20 ± 0.00	34.04-36.20
JSLI-2000-4207	28-Jul-00	Cape Lookout A	8.63 ± 0.01	6.23-9.44	35.20 ± 0.00	34.06-35.81
JSLI-2001-4361	22-Sep-01	Cape Lookout A	9.49 ± 0.00	9.09-9.92	35.22 ± 0.00	35.02-35.60
JSLI-2001-4362	22-Sep-01	Cape Lookout A	10.13 ± 0.00	9.22-10.57	35.31 ± 0.00	34.99-35.70
JSLI-2001-4363	23-Sep-01	Cape Lookout A	10.44 ± 0.00	9.90-10.80	35.35 ± 0.00	35.11-35.52
JSLI-2001-4364	23-Sep-01	Cape Lookout A	10.06 ± 0.01	9.00-10.86	35.30 ± 0.00	35.03-35.53
JSLII-2002-3304	11-Aug-02	Cape Lookout A	9.61 ± 0.01	6.30-10.88	35.26 ± 0.00	33.91-36.03
JSLII-2002-3305	11-Aug-02	Cape Lookout A	9.24 ± 0.00	8.97-10.12	35.21 ± 0.00	34.70-35.69
JSLII-2002-3306	12-Aug-02	Cape Lookout A	10.90 ± 0.01	8.87-14.85	35.39 ± 0.00	34.02-36.09
JSLII-2002-3307	12-Aug-02	Cape Lookout A	10.15 ± 0.00	9.83-10.54	35.30 ± 0.00	34.99-35.49
JSLII-2003-3430	23-Aug-03	Cape Lookout A	6.33 ± 0.00	5.90-6.88	35.06 ± 0.00	34.90-35.56
JSLII-2003-3431	24-Aug-03	Cape Lookout A	7.08 ± 0.01	6.20-8.29	35.08 ± 0.00	34.92-35.28
JSLII-2003-3432	24-Aug-03	Cape Lookout A	8.27 ± 0.00	7.45-9.04	35.13 ± 0.00	34.81-35.31
JSLI-2004-4692	15-Jun-04	Cape Lookout A	9.81 ± 0.00	9.55-9.99	35.28 ± 0.00	35.19-35.36
JSLI-2004-4693	15-Jun-04	Cape Lookout A	9.11 ± 0.00	8.04-9.57	35.20 ± 0.00	35.02-35.34
JSLI-2005-4890	17-Oct-05	Cape Lookout A	8.14 ± 0.01	5.51-8.98	35.13 ±0.00	34.89-35.32
JSLI-2005-4891	17-Oct-05	Cape Lookout A	9.03 ± 0.00	8.36-9.6	35.19 ± 0.00	35.06-35.36
JSLI-2001-4365	24-Sep-01	Cape Lookout B	10.01 ± 0.00	9.58-10.30	35.27 ± 0.00	35.13-35.41
JSLI-2001-4366	24-Sep-01	Cape Lookout B	9.81 ± 0.00	9.61-10.14	35.25 ± 0.00	35.11-35.43
JSLII-2003-3429	23-Aug-03	Cape Lookout B	5.82 ± 0.00	5.42-5.97	35.04 ± 0.00	34.99-35.12
JSLI-2004-4694	16-Jun-04	Cape Lookout B	10.43 ± 0.01	9.39-11.19	35.36 ± 0.00	35.20-35.53
JSLI-2004-4695	16-Jun-04	Cape Lookout B	9.95 ± 0.00	9.70-11.34	35.32 ± 0.00	35.02-35.83
JSLI-2005-4892	18-Oct-05	Cape Lookout B	8.77 ± 0.00	8.64-9.73	35.13 ± 0.00	35.01-35.32
JSLI-2005-4893	18-Oct-05	Cape Lookout B	9.12 ± 0.00	8.42-9.60	35.16 ± 0.00	35.04-35.30
JSLI-2005-4894	19-Oct-05	Cape Lookout B	7.55 ± 0.00	6.30-8.24	35.07 ± 0.00	34.96-35.22
JSLI-2005-4895	19-Oct-05	Cape Lookout B	7.77 ± 0.00	7.63-7.93	35.04 ± 0.00	34.98-35.04
JSLII-2002-3308	13-Aug-02	Cape Fear	9.13 ± 0.00	8.42-9.53	35.18 ± 0.00	34.80-35.45
JSLII-2003-3425	21-Aug-03	Cape Fear	9.54 ± 0.00	9.54-9.72	35.20 ± 0.00	35.10-35.34
JSLII-2003-3426	21-Aug-03	Cape Fear	10.18 ± 0.01	9.25-11.22	35.29 ± 0.00	35.00-35.60
JSLII-2003-3427	22-Aug-03	Cape Fear	8.69 ± 0.00	7.93-9.83	35.15 ± 0.00	34.75-35.61
JSLII-2003-3428	22-Aug-03	Cape Fear	9.13 ± 0.00	8.68-9.70	35.19 ± 0.00	35.14-35.26
JSLI-2004-4696	17-Jun-04	Cape Fear	9.10 ± 0.00	9.00-9.54	35.14 ± 0.00	35.05-35.30
JSLI-2004-4697	17-Jun-04	Cape Fear	11.70 ± 0.00	11.01-12.09	35.48 ± 0.00	35.33-35.67
JSLI-2005-4896	20-Oct-05	Cape Fear	8.06 ± 0.00	7.91-8.26	35.06 ± 0.00	35.01-35.10
JSLI-2005-4897	20-Oct-05	Cape Fear	8.00 ± 0.00	7.78-8.23	35.06 ± 0.00	34.98-35.12
JSLI-2005-4898	21-Oct-05	Stetson North	7.97 ± 0.00	7.22-8.10	35.09 ± 0.00	35.03-35.17
JSLI-2005-4899	21-Oct-05	Stetson North	8.64 ± 0.00	8.13-9.91	35.14 ± 0.00	35.01-35.32
JSLII-2003-3419	17-Aug-03	Stetson	10.89 ± 0.00	10.78-11.03	35.39 ± 0.00	35.37-35.41
JSLII-2003-3420	17-Aug-03	Stetson	9.91 ± 0.00	9.83-10.06	35.25 ± 0.00	35.23-35.27
JSLI-2004-4689	13-Jun-04	Stetson	12.20 ± 0.00	12.12-12.30	35.55 ± 0.00	35.51-35.60
JSLI-2004-4698	18-Jun-04	Stetson	11.00 ± 0.00	10.94-11.82	35.36 ± 0.00	35.31-35.54
JSLI-2004-4699	18-Jun-04	Stetson	10.97 ± 0.00	10.93-11.13	35.36 ± 0.00	35.27-35.47
JSLI-2005-4903	27-Oct-05	Stetson	7.57 ± 0.00	7.34-8.05	35.18 ± 0.00	35.14-35.22
JSLI-2005-4904	27-Oct-05	Stetson	9.71 ± 0.00	8.19-11.76	35.30 ± 0.00	34.92-35.79

JSLI-2004-4687	12-Jun-04	Savannah Banks	9.07 ± 0.00	8.97-9.13	35.12 ± 0.00	35.09-35.14
JSLI-2004-4688	12-Jun-04	Savannah Banks	8.20 ± 0.00	8.18-8.26	35.02 ± 0.00	35.00-35.04
JSLI-2005-4900	22-Oct-05	Savannah Banks	9.18 ± 0.00	9.06-9.26	35.16 ± 0.00	35.02-35.18
JSLI-2005-4901	23-Oct-05	Savannah Banks	…	…	…	…
JSLI-2005-4902	26-Oct-05	Savannah Banks	8.11 ± 0.00	8.08-8.21	35.02 ± 0.00	35.00-35.05
JSLI-2005-4905	30-Oct-05	Savannah Banks	7.69 ± 0.00	7.53-7.84	35.01 ± 0.00	34.97-35.04
JSLI-2005-4906	30-Oct-05	Savannah Banks	7.37 ± 0.00	7.36-7.56	34.96-35.04	35.00 ± 0.00
JSLI-2004-4683	10-Jun-04	Jacksonville Lithoherms	10.53 ± 0.00	10.34-10.90	35.28 ± 0.00	35.13-35.48
JSLI-2004-4684	10-Jun-04	Jacksonville Lithoherms	9.63 ± 0.01	9.04-10.50	35.18 ± 0.00	34.85-35.50
JSLI-2004-4685	11-Jun-04	Jacksonville Lithoherms	7.84 ± 0.00	7.80-7.98	34.99 ± 0.00	34.93-35.03
JSLI-2004-4686	11-Jun-04	Jacksonville Lithoherms	9.91 ± 0.00	9.80-10.02	35.21 ± 0.00	35.17-35.26
JSLI-2004-4700	19-Jun-04	Jacksonville Lithoherms	7.64 ± 0.00	7.52-8.34	34.97 ± 0.00	34.88-35.08
JSLI-2004-4701	19-Jun-04	Jacksonville Lithoherms	7.37 ± 0.00	7.31-7.50	34.95 ± 0.00	34.92-34.99
JSLI-2005-4907	01-Nov-05	Jacksonville Lithoherms	7.91 ± 0.00	7.46-8.29	35.02 ± 0.00	34.94-35.09
JSLI-2005-4908	01-Nov-05	Jacksonville Lithoherms	7.33 ± 0.00	7.22-7.61	34.98 ± 0.00	34.94-35.00
JSLI-2004-4681	09-Jun-04	North Cape Canaveral	6.75 ± 0.00	6.73-6.89	34.90 ± 0.00	34.86-34.94
JSLI-2004-4682	09-Jun-04	North Cape Canaveral	6.80 ± 0.00	6.78-6.96	34.90± 0.00	34.84-34.99
JSLI-2004-4702	20-Jun-04	North Cape Canaveral	6.55 ± 0.00	6.54-6.65	34.91 ± 0.00	34.87-34.95
JSLI-2004-4703	20-Jun-04	North Cape Canaveral	6.75 ± 0.00	6.73-6.80	34.91 ± 0.00	34.87-34.94
JSLI-2004-4704	21-Jun-04	South Cape Canaveral	6.30 ± 0.00	6.28-6.36	34.90 ± 0.00	34.88-34.92
JSLI-2004-4705	21-Jun-04	South Cape Canaveral	6.29 ± 0.00	6.28-6.34	34.90 ± 0.00	34.89-34.92

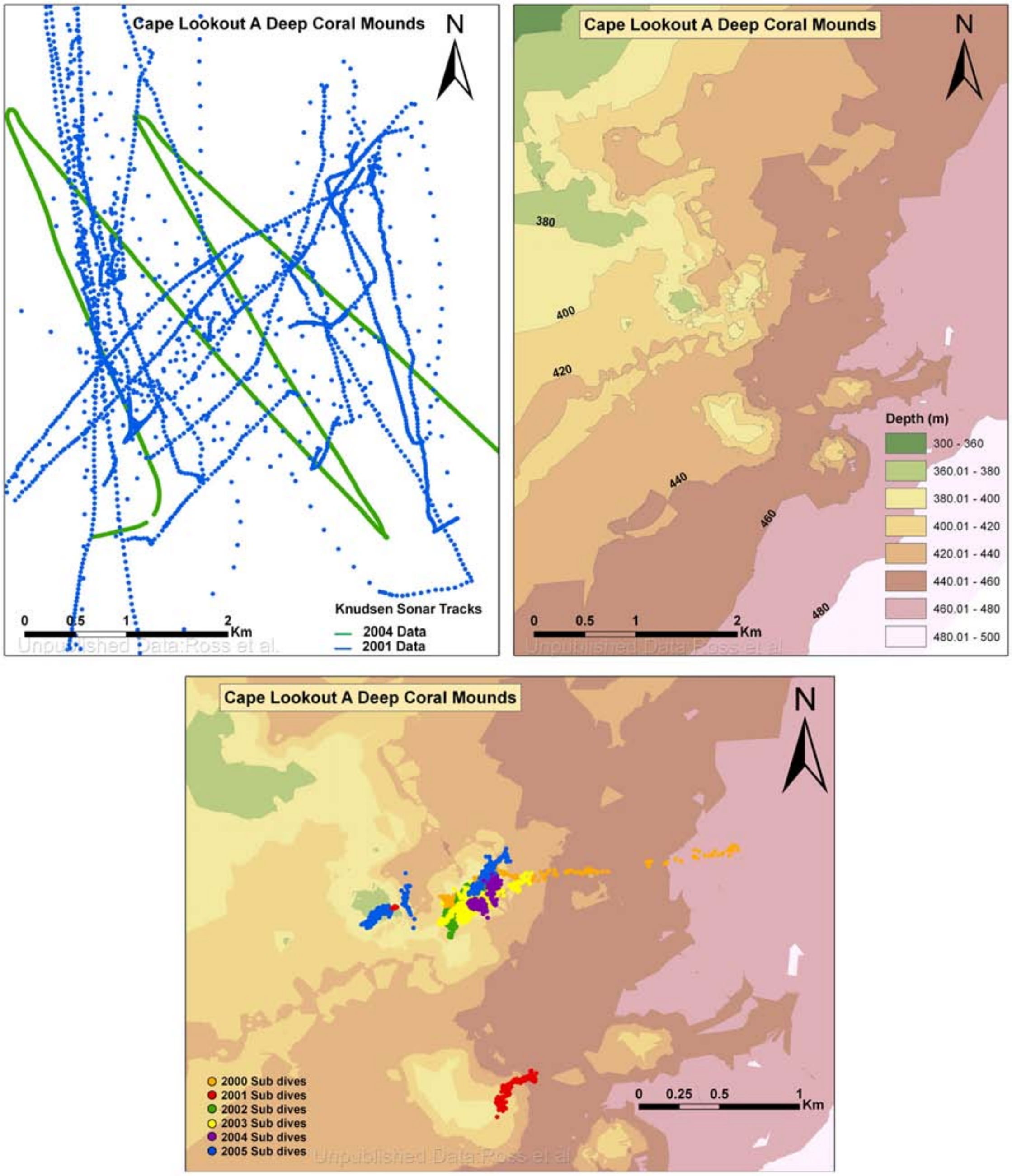

Figure 6. Ship collected sonar tracks (top left) and resulting bathymetry maps (top right) from the deep coral area off Cape Lookout, NC (A). In this area additional data from our files were added for the bathymetry map. Bottom panel shows JSL submersible dive tracks in this area from 2000-2005. All data are from Ross et al. (unpublished). See Fig. 1 to locate this area.

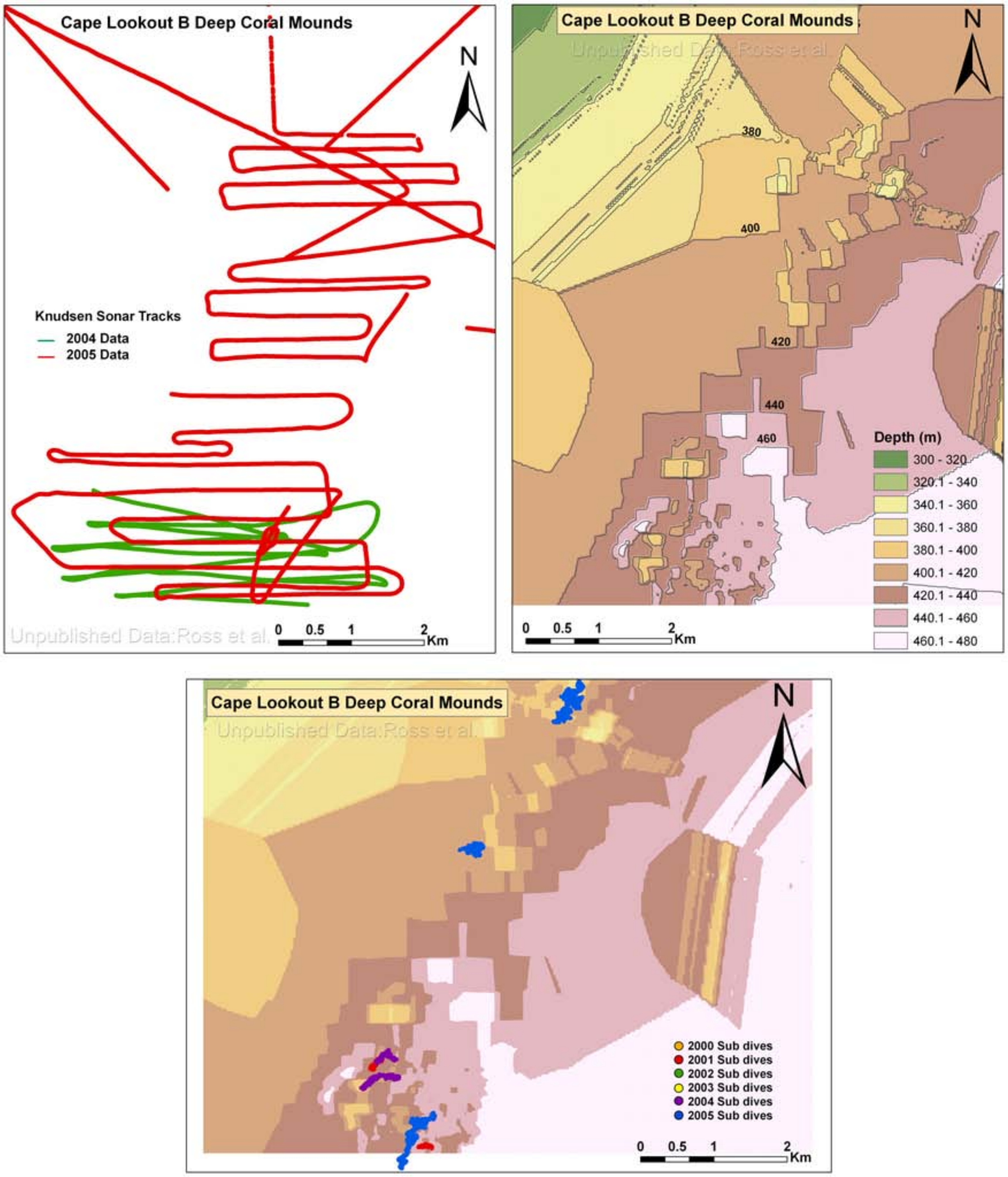

Figure 7. Ship collected sonar tracks (top left) and resulting bathymetry maps (top right) from the deep coral area off Cape Lookout, NC (B). Bottom panel shows JSL submersible dive tracks in this area from 2000-2005. All data are from Ross et al. (unpublished). See Fig. 1 to locate this area.

53 m over a distance of about 0.4 km. There is a small mound away from the main system (Fig. 7), and in general these mounds were less dramatic than those described above. They appeared to be of the same general construction as Bank A, built of coral rubble matrix that had trapped sediments. Extensive fields of coral rubble surrounded the area. Both living and dead corals were common on this bank, with some living bushes being quite large (Fig. 3).

Cape Fear *Lophelia* Bank

Aside from the map in EEZ-SCAN 87 Scientific Staff (1991**)** there are no published data from this coral mound and no indication that it was sampled before the studies initiated by Ross et al. (unpubl. data) between summer 2002 and fall 2005. Ross et al. located this bank based on estimated coordinates from the USGS survey (EEZ-SCAN 87 Scientific Staff 1991**)**. As above, the JSL submersible was the major method for collecting bottom data on the reef proper. Nine dives were made on coral mounds in this area (Fig. 8, Table 1), and observations from these totaled about 20 hours.

Sampling in this area was focused on a relatively small area (Fig. 8), but data are lacking to accurately estimate the size and area covered by coral mounds or rubble zones. Ross et al. JSL dives in this area ranged from 371-449 m (Table 1). Mean bottom temperatures ranged from 8.0 to 11.7 C, and as above mean bottom salinities were always near 35 (Table 2). These mounds rise nearly 80 m over a distance of about 0.4 km, and exhibit some of the most rugged habitat and vertical excursion of any area sampled (Fig. 4). This mound system also appears to be of the same general construction as Banks A and B, being built of coral rubble matrix with trapped sediments. Fields of coral rubble are common around the area. Both living and dead corals were common on this bank (Fig. 4).

CORAL BANKS OF THE BLAKE PLATEAU (South Carolina to Florida)

South of Cape Fear sediment/coral mounds are smaller and scattered; however, *L. pertusa* and other hard and soft corals populate the abundant hard substrates of the Blake Plateau in great numbers. Overall, species diversity of anthozoans and other associated sessile invertebrates (e.g., sponges, hydrozoans) increases south of Cape Fear, NC. For convenience, some deep coral study areas in this region have been named, giving the impression of isolated areas of coral habitat. It appears, however, that Blake Plateau coral habitats are larger and more continuous than these names imply. Future detailed mapping of the area (some planned for fall 2006) combined with ground truthing will clarify coral habitat distributions and the extent to which areas may require discrete names.

There is existing research data for this area, but historically most of it was geological (see history above). Most deep coral expeditions south of North Carolina concentrated around the area described by Stetson et al. (1962), referred to as “Stetson Banks” (Fig. 9), an area off GA (“Savannah Banks”, Fig. 10), the Charleston Bump (Sedberry 2001), a large area straddling the GA-FL border (“Jacksonville Lithoherms”, Fig. 11) and numerous coral sites along the FL East coast (Figs. 12 and 13). General properties of these study areas were described in several papers by Reed and colleagues (Reed 2002, Reed unpubl. rept. to SAFMC 2004, Reed and Ross 2005, Reed et al. 2005, 2006). See the history section above for other references to this area.

Because it is unclear that these coral study areas are physically separate, I do not discuss them

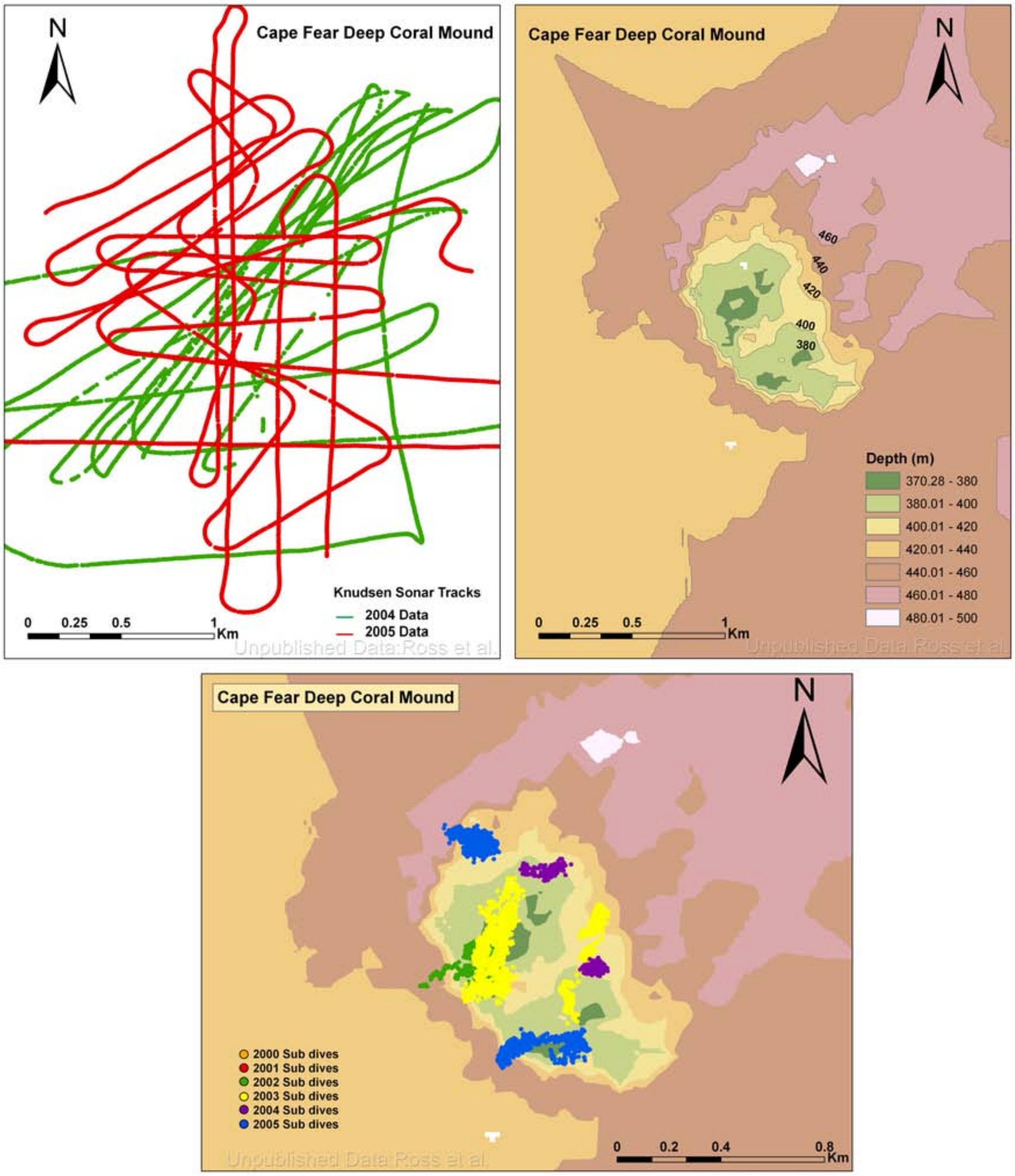

Figure 8. Ship collected sonar tracks (top left) and resulting bathymetry maps (top right) from the deep coral area off Cape Fear, NC. Bottom panel shows JSL submersible dive tracks in this area from 2000-2005. All data are from Ross et al. (unpublished). See Fig. 1 to locate this area and Fig. 4 for a 3-D view.

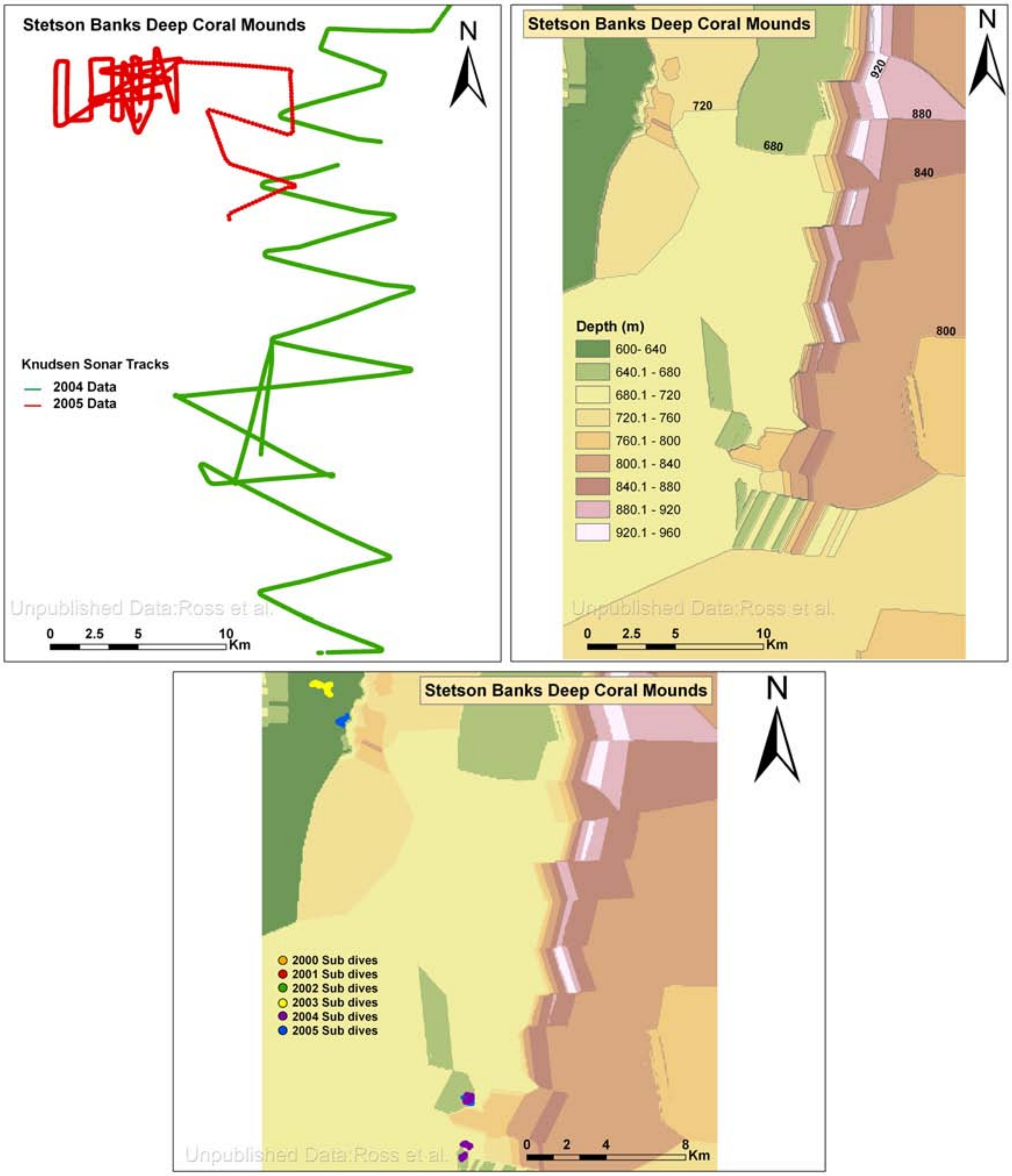

Figure 9. Ship collected sonar tracks (top left) and resulting bathymetry maps (top right) from the Stetson deep coral area off of SC. Bottom panel shows JSL submersible dive tracks in this area from 2000-2005. All data are from Ross et al. (unpublished). See Fig. 1 to locate this area.

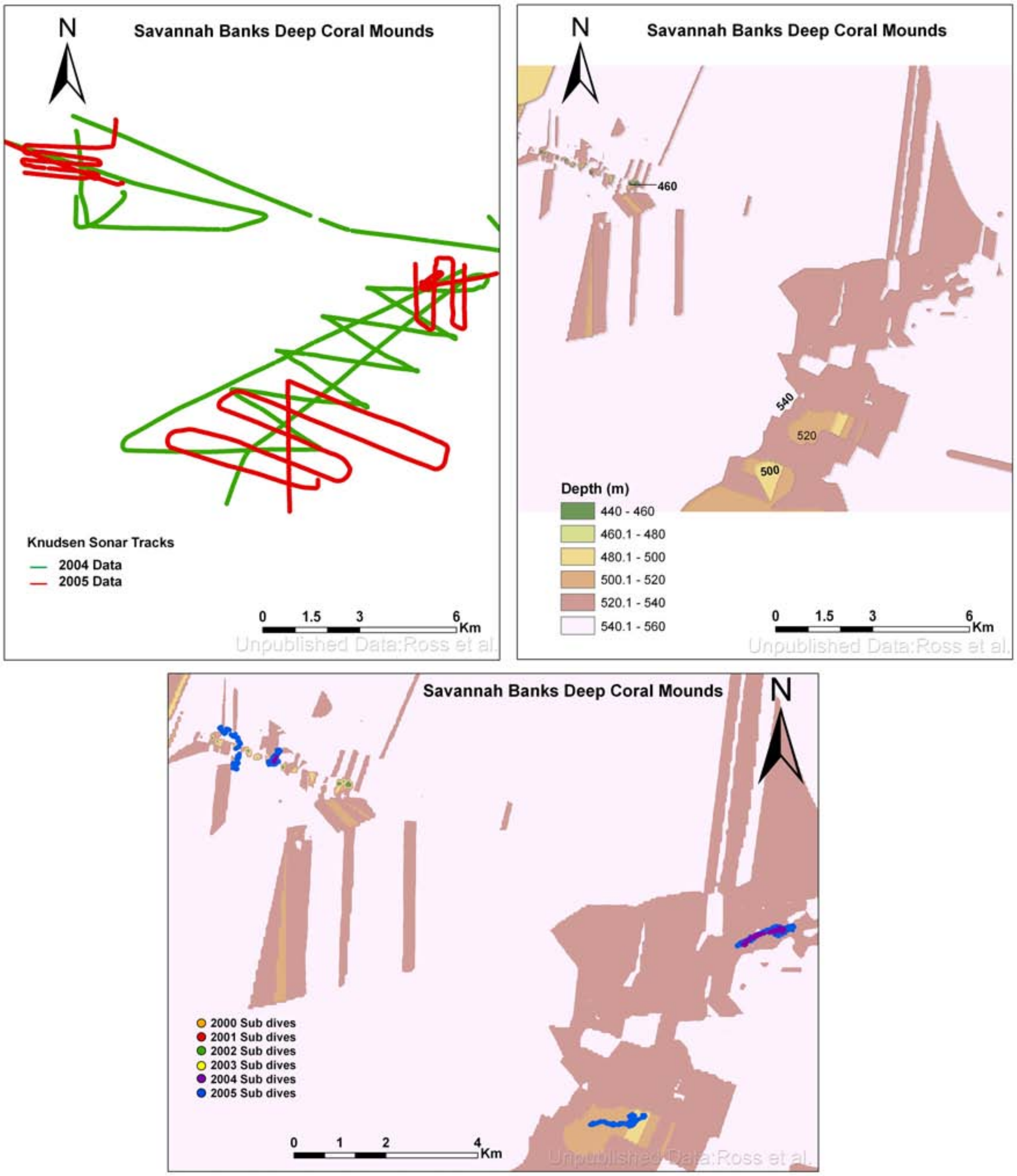

Figure 10. Ship collected sonar tracks (top left) and resulting bathymetry maps (top right) from the Savannah Banks deep coral area off of SC-GA. Bottom panel shows JSL submersible dive tracks in this area from 2000-2005. All data are from Ross et al. (unpublished). See Fig. 1 to locate this area.

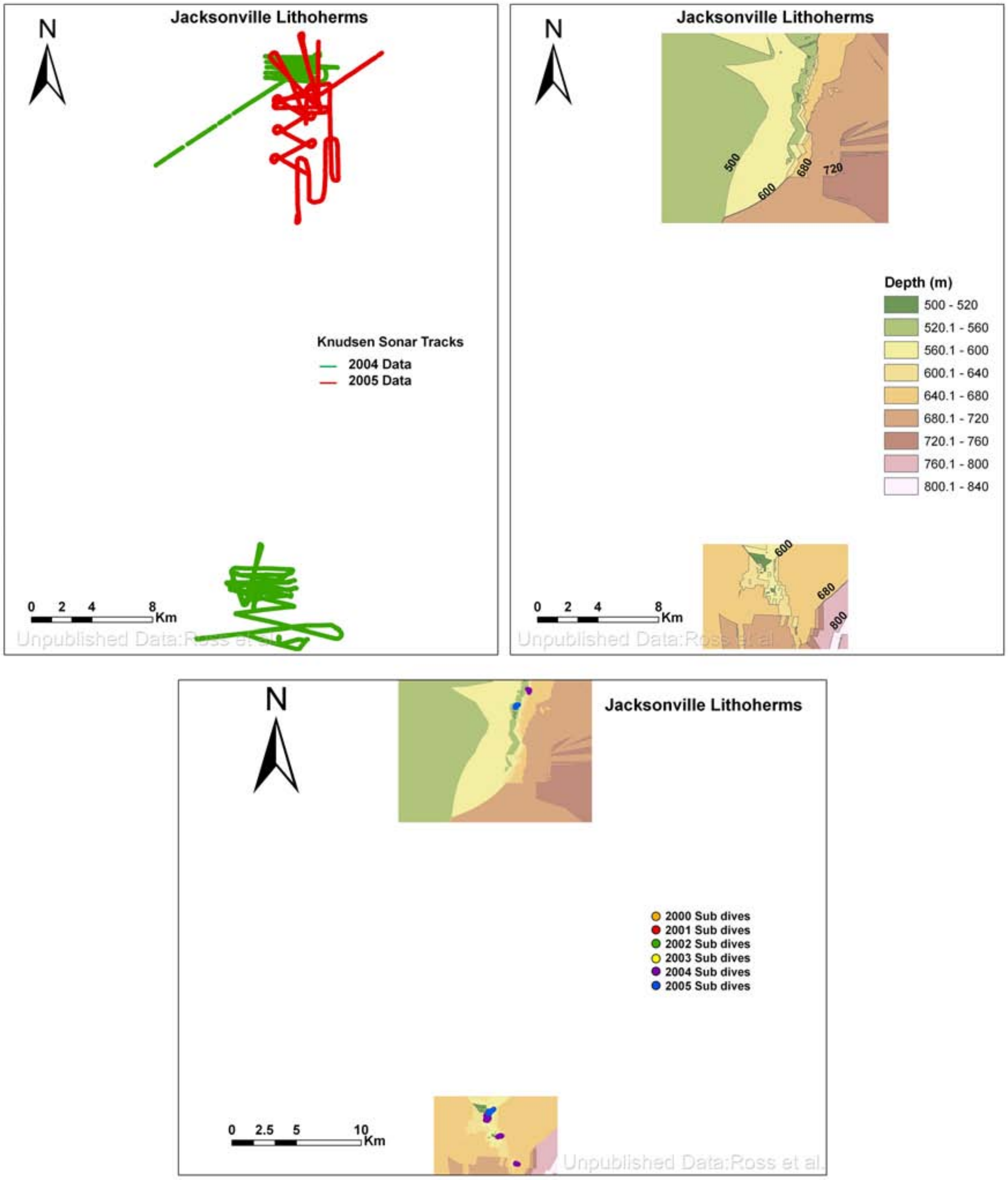

Figure 11. Ship collected sonar tracks (top left) and resulting bathymetry maps (top right) from the Jacksonville Banks deep coral area off of GA-FL. Bottom panel shows JSL submersible dive tracks in this area from 2000-2005. All data are from Ross et al. (unpublished). See Fig. 1 to locate this area.

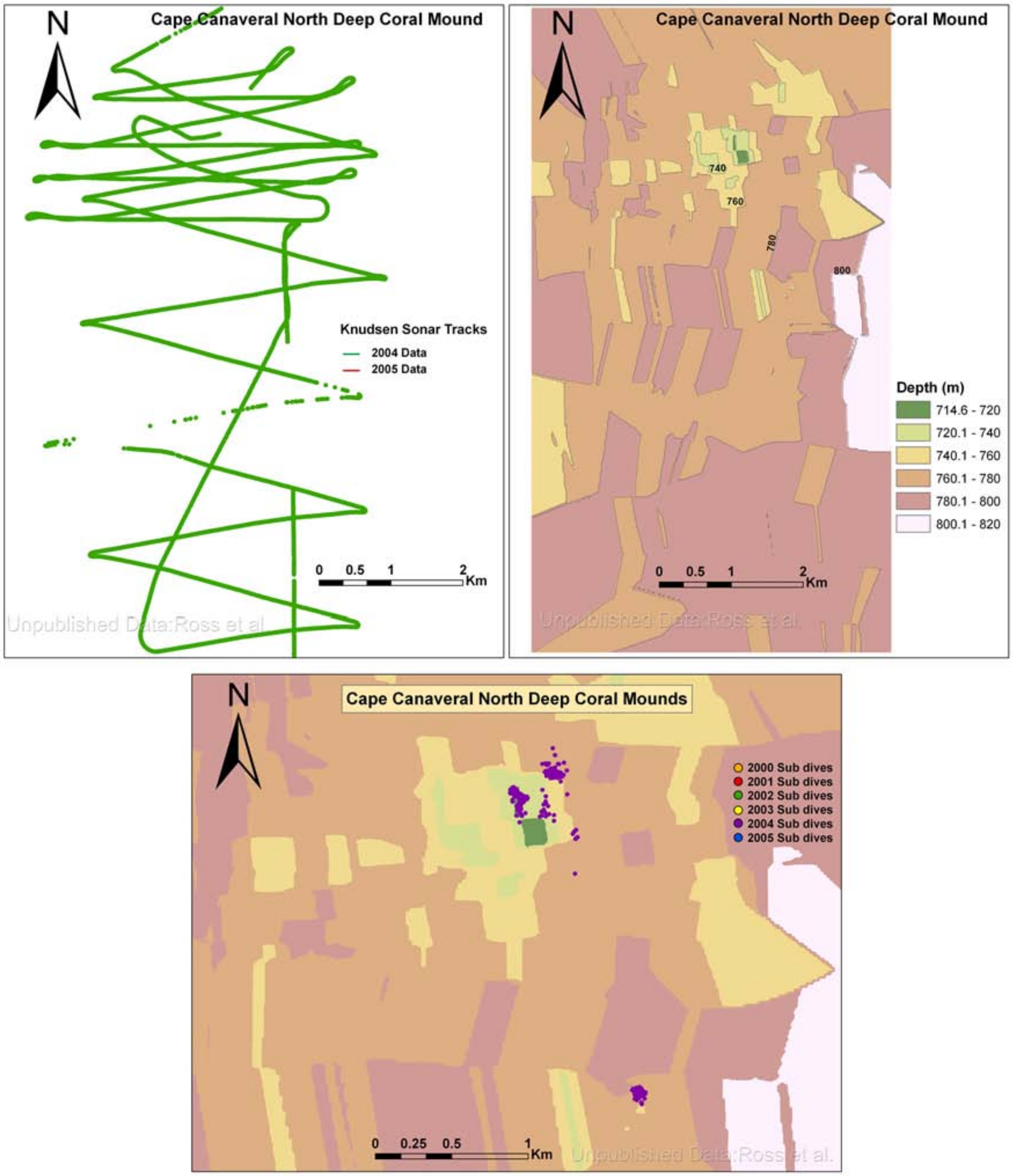

Figure 12. Ship collected sonar tracks (top left) and resulting bathymetry maps (top right) from the deep coral area just north of Cape Canaveral, FL. Bottom panel shows JSL submersible dive tracks in this area from 2000-2005. All data are from Ross et al. (unpublished). See Fig. 1 to locate this area.

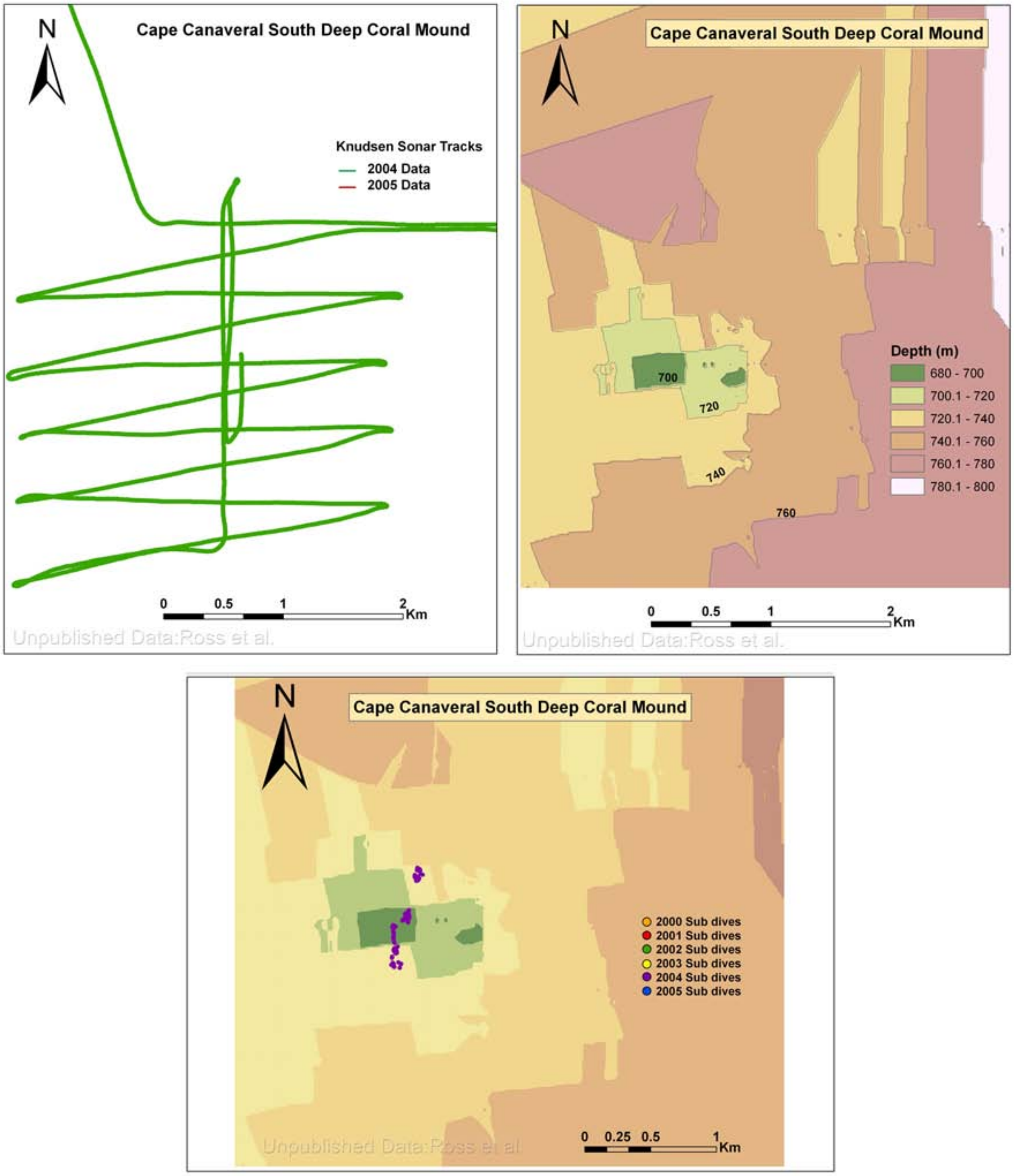

Figure 13. Ship collected sonar tracks (top left) and resulting bathymetry maps (top right) from the deep coral area just south of Cape Canaveral, FL. Bottom panel shows JSL submersible dive tracks in this area from 2000-2005. All data are from Ross et al. (unpublished). See Fig. 1 to locate this area.

individually. Note some differences between sites in the mapping and fish sections below. A few general observations are relevant. The Stetson Bank is a very large region of extremely diverse, rugged topography and bottom types. There is a deep canyon on the eastern side of this system with abundant corals on its western rim. While the surface waters of Stetson Bank are often outside the main Gulf Stream path, bottom currents can be quite strong. This is one of the deeper and more interesting of the Blake Plateau coral areas and warrants further exploration. The Savannah Bank system appears to have a heavier sediment load, perhaps because it is closest to the continental shelf. Deep corals occur there in scattered patches and are often less well developed than at other sites. Many sites in the "Jacksonville area" were composed of rocky ledges to which corals were attached, especially on the northern end. Bottom types in this area are diverse as is the fauna. Topographic highs, most having corals, are very abundant from the "Jacksonville area" to just south of Cape Canaveral (see also Reed et al. 2005, 2006). Faunal diversity is quite high in this region.

MAPPING DEEP CORAL BANKS

Basic SEUS study area maps were created by displaying varying combinations of data collected by the surface ships and submersible (S.W. Ross et al. Unpubl. data). The sonar track maps were simply the 2-D files of individual surveys color-coded by year with the addition of a scale, legend and north arrow (top left panel, Figs. 6-13). The 2-D raster files of the sonar data were combined with contours, labels, a scale, legend and north arrow to create the bathymetric maps (top right panels Figs. 6-13). The dive site maps were the various dive tracks, color-coded by year, laid over the 2-D raster files without the contours or the contour labels with addition of a scale bar, legend and north arrow (bottom panels Figs. 6-13). These base maps will be improved as additional data are analyzed, eventually leading to color-coded habitat maps with bathymetry. Three dimensional views will also be generated. An example of a three dimensional habitat map for one of the North Carolina sites is presented (Fig. 4, bottom).

Mapping Data Quality Issues

Data available for this mapping effort varied greatly by year of the project. For instance, Knudsen sonar data were only available for two years (2004, 2005), and many sites have dive data from only one or two years. Data problems ranged from uncertain position information to missing dive track data. The maps generated with these data have some limitations. Site maps resulting from fewer sonar surveys or fewer dives display less details and may be less accurate. Data confirmation was difficult, but when dive or sonar data were available from multiple years at the same locations, the datasets did corroborate one another. These maps have been and will be used for planning research missions and displaying general habitat characteristics. They are good interim tools until more detailed mapping using multibeam sonar is undertaken. Such a survey of the area's deep coral banks is sorely needed. Despite the above issues, it is important to note that these geospatial depth and habitat data represent the first such data for these areas of the SEUS slope. Most available maps are on large scales and/or present data at low resolution.

DEEP CORAL BANK FISH COMMUNITY DATA

Despite increasing research attention toward deep coral systems, knowledge of fish communities is still relatively lacking. In the cool temperate to boreal northeastern Atlantic Mortensen et al. (1995), Husebo et al. (2002), and Costello et al. (2005) noted that *Lophelia* habitat seemed to be important to fishes. However, in the northwestern Atlantic Auster (2005) suggested that deep corals were no more important to fishes than other reef type habitats. Deep coral ecosystem fish data from the SEUS and Gulf of Mexico are more limited, with studies reporting only a few taxa, many not identified to species, from only a few areas (Messing et al. 1990; Wenner and Barans 2001; Reed et al. 2005, 2006). The summary below represents the first extensive treatment of fish communities on deep coral slope habitats of this region (Ross and Quattrini, ms in prep. a, b).

We identified at least 57 unique taxa from our video analyses over all locations (2003-2004 data). A number of these species have never been reported from this region and some of those were thought to be rare (e.g., Caruso et al. in press). While most of the species richness was within prime reef or transition habitats (36 and 35 species, respectively) (Table 3, Fig. 14), the soft substrate off reef habitats supported a different but well developed fauna. The ichthyofauna of all three general habitat types was dominated by relatively few species, with little overlap in species between prime reef and off reef habitats. In particular, prime reef was characterized by *Laemonema melanurum, Hoplostethus occidentalis*, *Beryx decadactylus*, and *Conger oceanicus.* These species were never or only rarely observed on off reef, soft substrates and only rarely in the transition habitats. The off reef areas were characterized by *L. barbatulum, Fenestraja plutonia, Myxine glutinosa*, and *Merluccius albidus*, with *F. plutonia* and *M. albidus* never occurring on prime reef. When *Helicolenus dactylopterus* was observed away from reef habitat, it was usually near whatever structure was available (anemones, depressions). Transition habitat exhibited a mixture of species that could be found on either prime reef or off reef. The large, commercially important wreckfish (*Polyprion americanus*) seemed to move over several habitats from the base of mounds on rubble areas with little profile to the tops of ledges. Our preliminary conclusion from these data is that there is an obligate deep reef fish community that is tied to structured habitat (whether coral or rock). Ecologically, this parallels community structure found in shallow tropical reef systems.

Species richness was higher at northern deep coral banks (off North Carolina) than those sampled from South Carolina to Florida. Results from multidimensional scaling analysis confirmed that regional differences existed in the ichthyofauna of the SEUS. The three North Carolina sites clustered together, the sites in the middle of the region (Stetson, Savannah, Jacksonville) grouped together, and the two Cape Canaveral areas grouped together. Similarity analysis further supported that these groups were significantly different from one another. The drivers of these assemblages (SIMPER analysis) were: NC Group - *B. decadactylus, H. occidentalis, C. oceanicus, L. barbatulum, H. dactylopterus*; Middle Group - *L. melanurum, Nezumia sclerorhynchus, Trachyscorpia cristulata*; Canaveral Group - *N. sclerorhynchus, F. plutonia, Synaphobranchus kaupii*. Additional analyses are in progress and will include additional years of data, especially from the Ross et al. 2005 cruise (Ross and Quattrini ms in prep. b). Hypotheses to be considered to explain these differences include: zoogeography effects (latitude/temperature), depth effects, habitat structure or quality influences, other (physical oceanography, food resources, recruitment).

Table 3. Benthic fish species identified from analysis of Johnson-Sea-Link video data (2000-2004) at deep coral sampling locations along the southeastern United States slope from Cape Lookout, NC to just south of Cape Canaveral, FL. These are unpublished data of Ross et al. and are being analyzed for geographic and habitat patterns.

Taxa
Myxinidae
Myxine glutinosa
Chimaeridae
Chimaera sp.
Squalidae
Cirrhigaleus asper
Squalus cubensis
Odontaspididae
Odontaspis ferox
Scyliorhinidae
Scyliorhinus spp.
Scyliorhinus meadi
Scyliorhinus retifer
Carcharhinidae
Carcharhinus spp.
Rajidae
Dactylobatus armatus
Fenestraja plutonia
Mobulidae
Manta birostris
Synaphobranchidae
Dysommina rugosa
Synaphobranchus spp.
Synaphobranchus kaupii
Congridae
Conger oceanicus
Nettastomatidae
Nettenchelys exoria
Sternoptychidae
Maurolicus weitzmani
Polyipnus clarus
Sternoptyx sp.
Stomiidae
Chauliodus sloani
Chlorophthalmidae
Chlorophthalmus agassizi
Paralepididae
Undetermined
Myctophidae
Undetermined
Diaphus dumerilii

Bythitidae
Bellottia apoda
Bythites gerdae
Diplacanthopoma brachysoma
Macrouridae
Undetermined
Nezumia spp.
Nezumia aequalis
Nezumia sclerorhynchus
Moridae
Laemonema spp.
Laemonema barbatulum
Laemonema melanurum
Physiculus spp.
Physiculus karrerae
Merlucciidae
Merluccius spp.
Merluccius albidus
Lophiidae
Lophiodes beroe
Lophiodes monodi
Lophius cf. *americanus*
Chaunacidae
Chaunax stigmaeus
Ogcocephalidae
Dibranchus atlanticus
Trachichthyidae
Hoplostethus occidentalis
Berycidae
Beryx decadactylus
Zeidae
Zenopsis conchifera
Scorpaenidae
Helicolenus dactylopterus
Idiastion kyphos
Neomerinthe hemingwayi
Pontinus rathbuni
Trachyscorpia cristulata
Acropomatidae
Synagrops spp.
Polyprionidae
Polyprion americanus
Serranidae
Anthiinae
Anthias woodsi
Hemanthias aureorubens

Trichiuridae
Undetermined

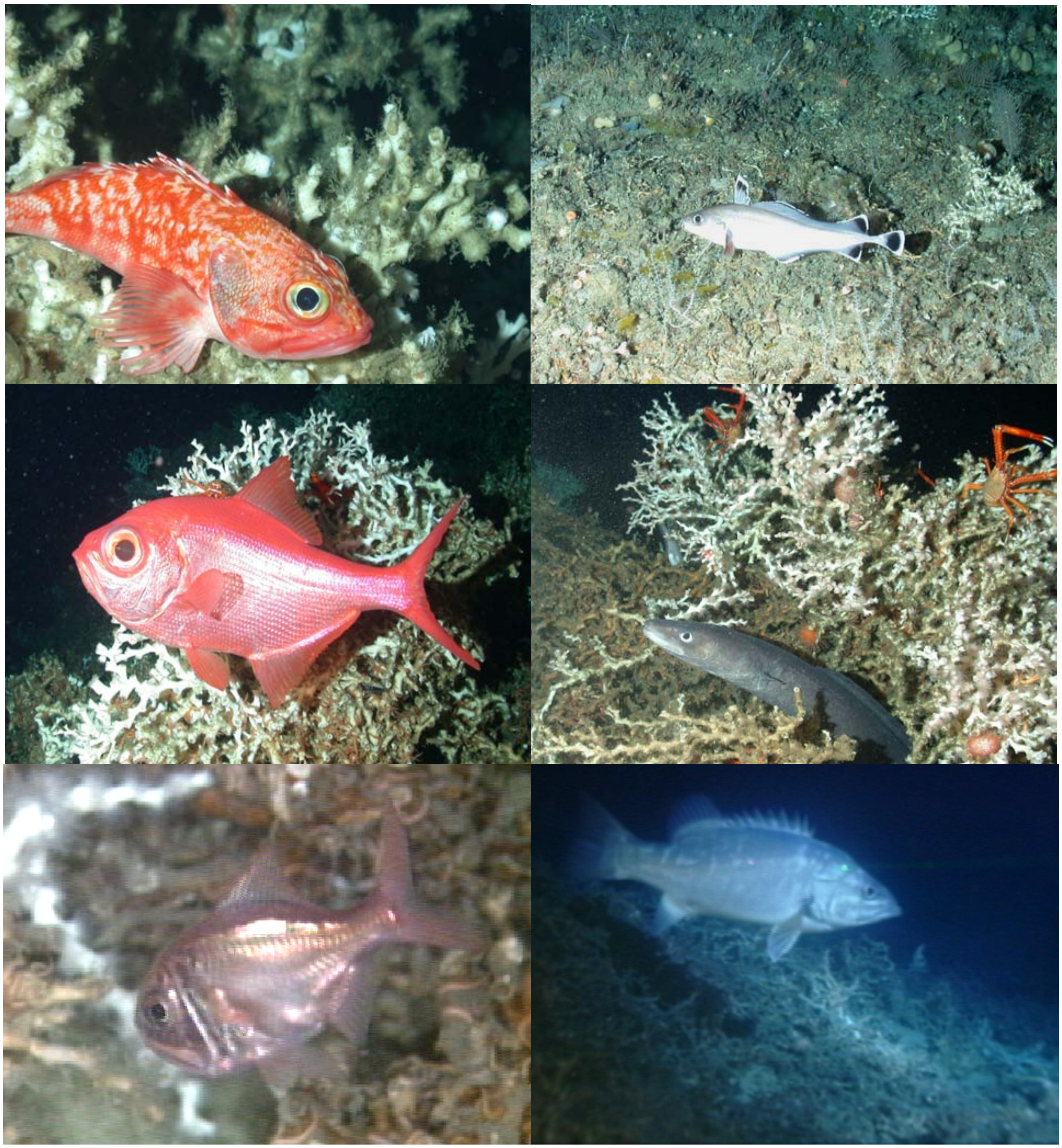

Figure 14. Selected deep reef fishes from coral banks off the southeastern United States. From left to right and top to bottom: *Helicolenus dactylopterus, Laemonema melanurum, Beryx decadactylus, Conger oceanicus, Hoplostethus occidentalis, Polyprion americanus.* All photos from Ross et al. (unpubl. data).

SUMMARY AND RECOMMENDATIONS

These systems support a well developed community that appears to be different from the surrounding non-reef habitats. In fact, preliminary analyses suggest that the fish community on these deep reefs is composed of many species that do not (or at least rarely) occur off of the reefs. 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 et al. unpubl. data). Most likely these species only appeared to be rare because they occurred in a difficult to sample environment. 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. However, invertebrate associations with the reef habitat seem to be more opportunistic than is the case for certain fish species. Additional data are required from diverse habitats to confirm this.

Some commercially-exploited deep-water fishes, like wreckfish (*Polyprion americanus*) (Vaughan et al. 2001) and blackbelly rosefish (*Helicolenus dactylopterus*), utilize *Lophelia* habitat extensively. Other potentially exploitable species are also associated with deep corals (royal red shrimps, rock crabs, bericiform fish species, eels). Signs of past fishing effort were observed on some coral banks, but the extent to which fishermen sample these areas is unknown. The potential for new deep water fisheries on and around these banks is unknown.

The banks examined off of North Carolina are different than much of the coral habitat to the south on the Blake Plateau. The NC features are almost exclusively dominated by *L. pertusa*, the diversity of other corals being low. The fish and invertebrate faunas also differ between North Carolina and Blake Plateau deep coral areas.

Recommendations

Detailed mapping of the 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 350-500 m. While this recommendation relates to the whole slope of the SEUS, priority should be given to known coral sites and areas of suspected coral mounds.

Deeper areas of the Blake Plateau are virtually unexplored. The hard substrate region of the Blake Spur and Blake Escarpment and the 800-1000 m depth just to the West should be explored for deep coral habitat.

The HAPCs proposed by the SAFMC need some minor boundary adjustments based on additional recent data.

If protected areas are established for SEUS deep coral banks, long term monitoring and research plans should accompany this strategy.

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.

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

Life history data for most deep water species are lacking, and this data need should be addressed.

Biodiversity of deep coral habitats requires additional study as these habitats appear to host huge numbers of species.

A regional working group composed of scientists and relevant agency personnel should be formed to begin evaluating data, deep reef status, and to take the lead on formulation of plans to study and manage these habitats.

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LITERATURE CITED

Adkins, J.F., H. Cheng, E.A. Boyle, E.R.M. Druffel and R.L. Edwards. 1998. Deep-sea coral evidence for rapid change in ventilation of the deep North Atlantic 15,400 year ago. Science 280: 725-728.

Agassiz, A. 1888. Three cruises of the United States Coast and Geodetic Survey steamer “Blake” in the Gulf of Mexico, in the Caribbean Sea, and along the Atlantic coast of the United States, from 1877 to 1880. Vol. 1. Bull. Museum of Comparative Zoology, Harvard 14: 1-314.

Arendt, M.D., C.A. Barans, G.R. Sedberry, R.F. Van Dolah, J.K. Reed, S.W. Ross. 2003. Summary of seafloor mapping and benthic sampling in 200-2000m from North Carolina through Florida. Final rept. Deep Water Mapping Project Phase II. SAFMC. Charleston, SC.

Auster, P.J. 2005. Are deep-water corals important habitats for fishes? p. 747-760. In: Freiwald, A. and J.M. Roberts (eds.). Cold-Water Corals and Ecosystems. Springer-Verlag. Berlin Heidelberg.

Ayers, M.W. and O.H. Pilkey. 1981. Piston cores and surficial sediment investigations of the Florida-Hatteras slope and inner Blake Plateau. p. 5-1-5-89. In: Popenoe, P. (ed.). Environmental geologic studies on the southeastern Atlantic outer continental shelf. USGS Open File Rept. 81-582-A.

Blake, J.A., B. Hecker, J.F. Grassle, B. Brown, M. Wade, P.D. Boehm, E. Baptiste, B. Hilbig, N.

Maciolek, R. Petrecca, R.E. Ruff, V. Starczak, and L. Watling. 1987. Study of Biological Processes on the U.S. South Atlantic Slope and Rise: Phase 2. U.S. Department of the Interior, Minerals Management Service, Atlantic OCS Region, Environmental Assessment Section. Herndon, VA.

Brooks, R.A., M.S. Nizinski, S.W. Ross and K.J. Sulak. In review. Sublethal Injury Rate in a Deepwater Ophiuroid, *Ophiacantha bidentata*, an Important Component of Western Atlantic *Lophelia* Reef Communities. Mar. Biol.

Cairns, S.D. 1979. The deep-water scleractinia of the Caribbean Sea and adjacent waters. In: Hummelinck, P.W. and L.J. Van Der Steen (Eds.). Studies on the fauna of Curacao and other Caribbean Islands. Foundation for Scientific research in Surinam and the Netherlands Antilles. Utrecht.

Cairns, S.D. 1981. Marine flora and fauna of the Northeastern United States, Scleractinia. NOAA Tech. Rept. NMFS Circular 438. 14 p.

Cairns, S.D. 2000. A revision of the shallow-water azooxanthellate Scleractinia of the western Atlantic. Studies on the Natural History of the Caribbean Region 75. 240 p.

Cairns, S.D. 2001a. A generic revision and phylogenetic analysis of the Dendrophylliidae (Cnidaria: Scleractinia). Smithsonian Cont. Zool. 615: 75 p.

Cairns, S.D. and R.E. Chapman. 2001. Biogeographic affinities of the North Atlantic deep-water Scleractinia. Pp 30-57. In: J.H.M. Willison, J. Hall, S.E. Gass, E.L.R. Kenchington, M. Butler and P. Doherty (eds.). Proceedings of the First International Symposium on Deep-sea Corals. Ecology Action Centre, Halifax, Nova Scotia.

Caruso, J.H., S.W. Ross, K.J. Sulak and G.R. Sedberry. in press. Deep-water chaunacid and lophiid anglerfishes (Pisces: Lophiiformes) off the Southeastern United States. J. Fish Biol.

Costello, M.J., M. McCrea, A. Freiwald, T. Lundalv, L. Jonsson, B.J. Brett, T.C.E. van Weering, H. de Haas, J.M. Roberts and D. Allen. 2005. Role of cold-water *Lophelia pertusa* coral reefs as fish habitat in the NE Atlantic. p. 771-805. In: Freiwald, A. and J.M. Roberts (eds.). Cold-Water Corals and Ecosystems. Springer-Verlag. Berlin Heidelberg.

Druffel, R.M., L.L. King, R.A. Belastock and K.O. Buesseler. 1990. Growth rate of a deep-sea coral using ^{210}Pb and other isotopes. Geochim. Acta 54: 1493-1500.

Druffel, R.M., S. Griffin, A. Witter, E. Nelson, J. Southon, M. Kashgarian and J. Vogel. 1995. *Gerardia*: bristlecone pine of the deep-sea? Geochim. Cosmochim Acta 59: 5031-5036.

Duineveld, G.C.A., M.S.S. Lavaleye and E.M. Berghuis. 2004. Particle flux and food supply to a seamount cold-water community (Galicia Bank, NW Spain). Mar. Ecol. Prog. Ser. 277: 13-23.

EEZ-SCAN 87 Scientific Staff. 1991. Atlas of the U.S. exclusive economic zone, Atlantic continental margin. USGS Misc. Invest. Ser. I-2054.

Emiliani, C., J.H. Hudson and R.Y. George. 1978. Oxygen and carbon isotope growth record in a reef coral from the Florida Keys and a deep-sea coral from Blake Plateau. Science 202: 627-629.

Fossa, J.H., P.B. Mortensen and D.M. Furevik. 2002. The deep-water coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts. Hydrobiologia 471: 1-12.

Genin, A., P.K. Dayton, P.F. Lonsdale, and F.N. Spiess. 1986. Corals on seamount peaks provide evidence of current acceleration over deep-sea topography. Nature 322: 59-61.

Genin, A., C.K. Paull and W.P. Dillon. 1992. Anomalous abundances of deep-sea fauna on a rocky bottom exposed to strong currents. Deep-Sea Res. 39: 293-302.

George, R.Y. 2002. Ben Franklin temperate reef and deep sea “Agassiz Coral Hills” in the Blake

Plateau off North Carolina. Hydrobiologia 471: 71-81.
Griffin S. and E.R.M. Druffel. 1989. Sources of carbon to deep-sea corals. Radiocarbon 31: 533-543.
Hain, S. and E. Corcoran (eds.). 2004. 3. The status of the cold-water coral reefs of the world. p. 115-135. In: Wilkinson, C. (ed.). Status of coral reefs of the world: 2004. Vol. 1. Australian Inst. of Mar. Sci. Perth, Western Australia.
Hovland, M., P.B. Mortensen, T. Brattegard, P. Strass and K. Rokoengen. 1998. Ahermatypic coral banks off mid-Norway: evidence for a link with seepage of light hydorcarbons. Palaios 13: 189-200.
Hovland, M. and M. Risk. 2003. Do Norwegian deep-water coral reefs rely on seeping fluids? Mar. Geol. 198: 83-96.
Husebo, A., L. Nottestad, J.H. Fossa, D.M. Furevik and S.B. Jorgensen. 2002. Distribution and abundance of fish in deep-sea coral habitats. Hydrobiologia 471: 91-99.
Jensen, A. and R. Frederiksen. 1992. The fauna associated with the bank-forming deepwater coral *Lophelia pertusa* (Scleractinaria) on the Faroe Shelf. Sarsia 77: 53-69.
Koslow, J.A. 1997. Seamounts and the ecology of deep-sea fisheries. Amer. Sci. 85: 168-176.
Koslow, J.A., G.W. Boehlert, J.D.M. Gordon, R.L. Haedrich, P. Lorance, and N. Parin. 2000. Continental slope and deep-sea fisheries: implications for a fragile ecosystem. ICES J. Mar. Sci. 57: 548-557.
Le Goff-Vitry, M.C., O.G. Pybus and A.D. Rogers. 2004. Genetic structure of the deep-sea coral *Lophelia pertusa* in the northeast Atlantic revealed by microsatellites nad internal transcribed spacer sequences. Molecular Ecol. 13: 537-549.
Masson, D.G., B.J. Bett, D.S.M. Billett, C.L. Jacobs, A.J. Wheeler and R.B. Wynn. 2003. The origin of deep-water, coral topped mounds in the northern Rockall Trough, Northeast Atlantic. Mar. Geol. 194: 159-180.
McDonough, J.J. and K.A. Puglise. 2003. Summary: Deep-sea corals workshop. International planning and collaboration workshop for the Gulf of Mexico and the North Atlantic Ocean. Galway, Ireland, January 16-17, 2003. NOAA Tech. Memo. NMFS-SPO-60, 51 p.
Menzies, R.J., R.Y. George, and G.T. Rowe. 1973. Abyssal Environment and Ecology of the World Oceans. John Wiley and Sons, New York.
Messing, C.G., A.C. Neumann and J.C. Lang. 1990. Biozonation of deep-water lithoherms and associated hardgrounds in the northeastern Straits of Florida. Palaios 5: 15-33.
Mikkelsen, N., H. Erlenkeuser, J.S. Killingley and W.H. Berger. 1982. Norwegian corals: radiocarbon and stable isotopes in *Lophelia pertusa*. Boreas 11: 163-171.
Miller, C.A. 2001. Marine protected area framework for deep-sea coral conservation. p. 145-155. In: Willison, J.H.M., J. Hall, S.E. Gass, E.L.R. Kenchington, M. Butler and P. Doherty (eds.). 2001. Proceedings of the First International symposium on Deep-Sea Corals. Ecology Action Centre. Nova Scotia Museum. Halifax, Nova Scotia. 231 p.
Milliman, J.D., F.T. Manheim, R.M. Pratt and E.F.K. Zarudzki. 1967. Alvin dives on the continental margin off the southeastern United States July 2-13, 1967. Woods Hole Oceanographic Inst. Tech. Rept. Ref. No. 67-80.
Morgan, L.E. and M. Pizer (eds.). 2005. Deep Sea Corals. Current 21(4).
Mortensen, P.B. and H.T. Rapp. 1998. Oxygen and carbon isotope ratios related to growth line patterns in skeletons of *Lophelia pertusa* (L) (Anthozoa, Scleractinia): implications for determination of linear extension rates. Sarsia 83: 433-446.
Neumann, A.C. and M.M. Ball. 1970. Submersible observations in the Straits of Florida: geology

and bottom currents. Geol. Soc. Amer. Bull. 81: 2861-2874.
Neumann, A.C., J.W. Kofoed and G. Keller. 1977. Lithoherms in the Straits of Florida. Geology 5: 4–10.
Paull, C.K., A.C. Neumann, B.A. am Ende, W. Ussler III and N.M. Rodriguez. 2000. Lithoherms on the Florida-Hatteras slope. Mar. Geol. 166: 83-101.
Pinet, P.R., P. Popenoe, M.L. Otter and S.M. McCarthy. 1981. An assessment of potential geologic hazards of the northern and central Blake Plateau. p. 8-1-8-48. In: Popenoe, P. (ed.). Environmental geologic studies on the southeastern Atlantic outer continental shelf. USGS Open File Rept. 81-582-A.
Popenoe, P. 1994. Bottom character map of the northern Blake Plateau. USGS Open File Rept. 93-724.
Popenoe, P. and F.T. Manheim. 2001. Origin and history of the Charleston Bump-geological formations, currents, bottom conditions, and their relationship to wreckfish habitats on the Blake Plateau. P. 43-93. In: G.R. Sedberry (ed.). Island in the Stream: oceanography and fisheries of the Charleston Bump. Amer. Fish. Soc., Symp. 25. Bethesda, MD.
Pratt, R.M. 1968. Atlantic continental shelf and slope of the United States - physiography and sediments of the deep-sea basin. Geol. Surv. Prof. Pap. 529-B. 44 p.
Puglise, K.A., R.J. Brock and J.J. McDonough, III. 2005. Identifying critical information needs and developing institutional partnerships to further the understanding of Atlantic deep-sea coral ecosystems. p. 1129-1140. In: Freiwald, A. and J.M. Roberts (eds.). Cold-Water Corals and Ecosystems. Springer-Verlag. Berlin Heidelberg.
Reed, J.K. 2002a. Comparison of deep-water coral reefs and lithoherms off southeastern U.S.A. Hydrobiologia 471: 57-69.
Reed, J.K. 2002b. Deep-water *Oculina* coral reefs of Florida: biology, impacts, and management. Hydrobiologia 471: 43-55.
Reed, J.K. and S.W. Ross. 2005. Deep-water reefs off the southeastern U.S.: recent discoveries and research. Current 21(4): 33-37.
Reed, J.K., S.A. Pomponi, D. Weaver, C.K. Paull and A.E. Wright. 2005. Deep-water sinkholes and bioherms of south Florida and the Pourtales Terrace-habitat and fauna. Bull. Mar. Sci. 77: 267-296.
Reed, J.K., D.C. Weaver and S.A. Pomponi. 2006. Habitat and fauna of deep-water *Lophelia pertusa* coral reefs off the southeastern U.S.: Blake Plateau, Straits of Florida, and Gulf of Mexico. Bull. Mar. Sci. 78: 343–375.
Roberts, S. and M. Hirshfield. 2003. Deep Sea Corals: out of sight, but no longer out of mind. Oceana. Washington, DC.
Rogers, A.D. 1994. The biology of seamounts. Advances Mar. Biol. 30: 306-350.
Rogers, A.D. 1999. The biology of *Lophelia pertusa* (Linnaeus 1758) and other deep-water reef-forming corals and impacts from human activities. Internat. Rev. Hydrobiol. 84: 315-406.
Ross, S.W. and M.S. Nizinski. in press. State of the U.S. Deep Coral Ecosystems in the Southeastern United States Region: Cape Hatteras to the Florida Straits. NOAA Tech. Memo. NMFS-OPR-29. NOAA Ecosystem Assessment Division. Silver Spring, MD.
Rowe, G.T. and R.J. Menzies. 1968. Deep bottom currents off the coast of North Carolina. Deep-Sea Res. 15: 711-719.
Rowe, G.T. and R.J. Menzies. 1969. Zonation of large benthic invertebrates in the deep-sea off the Carolinas. Deep-Sea Res. 16: 531-537.
Roberts, C.M. 2002. Deep impact: the rising toll of fishing in the deep sea. Trends Ecol. Evol. 17:

242-245.
Sedberry, G.R. (ed.). 2001. Island in the Stream: oceanography and fisheries of the Charleston Bump. Amer. Fish. Soc., Symp. 25. Bethesda, MD. 240 p.
SGCOR. 2004. Report of the study group on cold-water corals (SGCOR). ICES Advisory Committee on Ecosystems, ICES CM 2004/ACE:07 ref. E.
Squires, D.F. 1959. Deep sea corals collected by the Lamont Geological Observatory. I. Atlantic corals. Amer. Mus. Novitates No. 1965: 1-42.
Stetson, T.R. 1961. Report on Atlantis cruise # 266, June-July 1961. Woods Hole Oceanographic Inst. Ref. No. 61-35.
Stetson, T.R., D.F. Squires and R.M. Pratt. 1962. Coral banks occurring in deep water on the Blake Plateau. Amer. Mus. Novitates 2114: 1-39.
Stetson, T.R., E. Uchupi and J.D. Milliman. 1969. Surface and subsurface morphology of two small areas of the Blake Plateau. Trans. Gulf Coast Assoc. Geol. Soc. 19: 131-142.
Uchupi, E. 1967. The continental margin south of Cape Hatteras, North Carolina: shallow structure. SE Geol. 8: 155-177.
Uchupi, E. and A.R. Tagg. 1966. Microrelief of the continental margin south of Cape Lookout, North Carolina. Geol. Soc. Amer. Bull. 77: 427-430.
Vaughan, D.S., C.S. Manooch, III and J.C. Potts. 2001. Assessment of the wreckfish fishery on the Blake Plateau. p. 105-119. In: Sedberry, G.R. (ed.). Island in the Stream: oceanography and fisheries of the Charleston Bump. Amer. Fish. Soc., Symp. 25. Bethesda, MD. 240 p.
Wenner, E.L. and C.A. Barans. 2001. Benthic habitats and associated fauna of the upper- and middle-continental slope near the Charleston Bump. p. 161-175. In: G.R. Sedberry (ed.). Island in the Stream: oceanography and fisheries of the Charleston Bump. Amer. Fish. Soc., Symp. 25. Bethesda, MD.
Williams, B., M.J. Risk, S.W. Ross and K.J. Sulak. in press. Deep-water Antipatharians: proxies of environmental change. Geol.
Wilson, J.B. 1979. “Patch” development of the deep-water coral *Lophelia pertusa* (L.) on Rockall Bank. J. Mar. Biol. Assoc. U.K. 59: 165-177.
Zarudzki, E.F.K. and E. Uchupi. 1968. Organic reef alignments on the continental margin south of Cape Hatteras. Geol. Soc. Amer. Bull. 79: 1867-1870.

APPENDIX E. Alternatives the Council considered but eliminated from detailed study and a brief discussion of the reasons for their elimination

Pursuant to the FMP for Coral, Coral Reefs and Live/hard bottom habitat of the South Atlantic Region (GMFMC & SAFMC 1982), the Council may designate Coral Habitat Areas of Particular Concern (CHAPCs) to primarily protect habitat from the impact of fishing. In 1998 the Comprehensive Essential Fish Habitat Amendment (SAFMC 1998) established a framework procedure whereby technical advisors would provide the Council with a science-based report on recommendations for designation of any new CHAPCs. In 2004, 2006 and 2007, the Habitat and Coral Advisory Panels met jointly, reviewed available information on the occurrence and characterization of deepwater habitat and provided the Council with summary reports presented in **Appendices A, B, C, and D**. The Council adopted the five alternatives for consideration at public hearings that were held in May 2008. These alternatives were brought to public hearing along with alternatives to address potential fishery impacts on the deepwater habitat from trawling and trapping. Subsequently, the alternatives presented in **Section 4.0** are the result of a long-term process to create new deepwater CHAPCs. In addition, the alternatives as refined are a result of cooperation and collaboration with the royal red shrimp fishermen and the golden crab fishermen to identify traditional fishing grounds and select measures which provide for traditional fishing operations in areas which will not impact deepwater bottom habitat. The following are alterative considered but eliminated for designation of deepwater coral HAPCS; regulation of the deepwater shrimp fishery operations relative to the proposed CHAPCs; regulation of the golden crab fishery relative to the proposed CHAPCs; and monitoring of the golden crab fishery.

A. OTHER ALTERNATIVES CONSIDERED FOR DEEPWATER CHAPCS

Other Possible Alternative 1A. Establish six deepwater Coral Habitat Areas of Particular Concern; 1) Cape Lookout Lophelia Banks HAPC, 2) Cape Fear Lophelia Banks HAPC, 3) the Stetson Reefs HAPC, 4) Savannah and East Florida Lithoherms HAPC; 5) Miami Terrace HAPC; and 6) Pourtales Terrace HAPC.

This alternative (**Figure E-1**) was based on a previously adopted recommendation to the Council submitted by the Habitat and Coral Advisory Panels and supported by information in 2004 reports to SAFMC on deepwater coral habitat distribution in the South Atlantic Region. The alternative was removed from consideration after new information on deepwater habitat distribution and characterization was provided in updated technical reports (Reed 2006 and Ross 2006) to the Council. The new information served as the foundation for adoption of the combined CHAPC proposals by the Council for further consideration and analyses. In addition, the area was recommended by advisors as a network of CHAPCs. This alternative was eliminated from detailed consideration in lieu of analyzing each as a sub-alternative. **Figures E-2 and E-3** present new dive and other habitat distribution and research that provided the foundation to expand and consolidate the initially proposed CHAPCs.

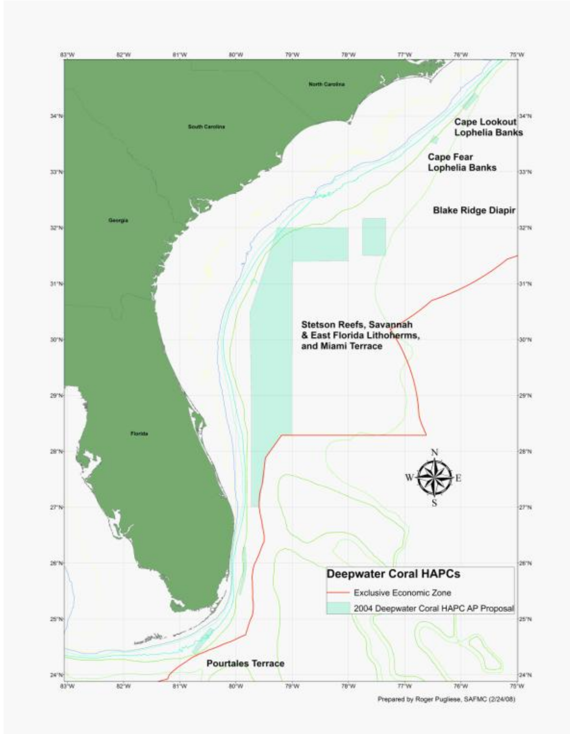
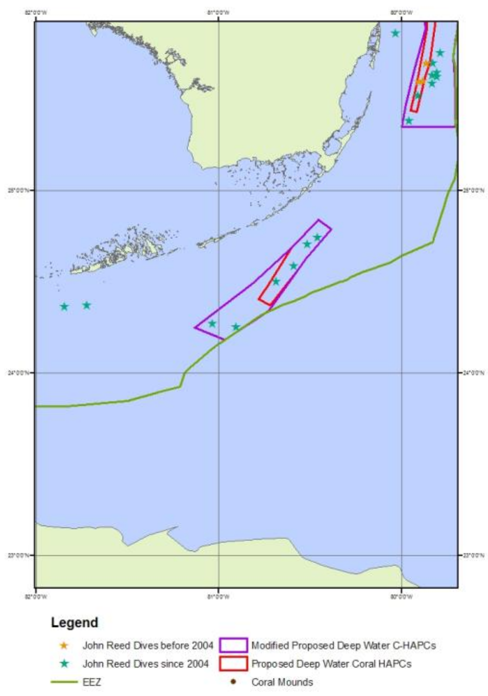
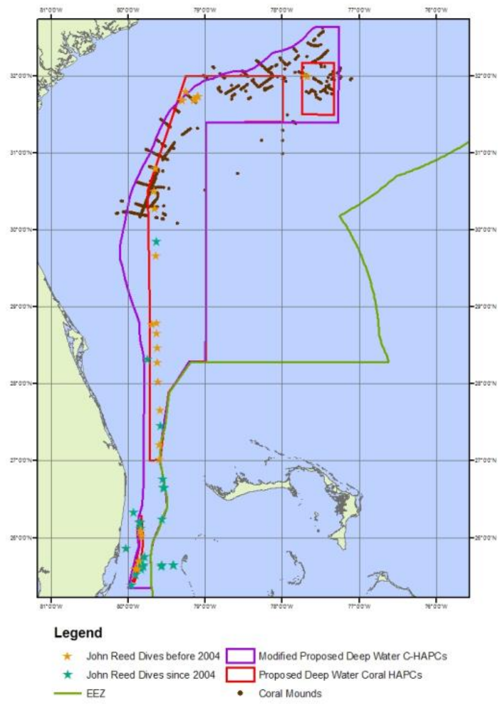


Figure E-1. Initial Recommendation for Deepwater CHAPCs. October 2004.





Figures E-2 and E-3. Submersible dives and other habitat distribution and research that provided the foundation to expand and consolidate the initially proposed CHAPCs.
(Note: Proposed DWCHAPCs do not include additional AP recommended modifications to use 300 meter contour for Miami Terrace area of CHAPC and extension of western boundary to cover special habitats identified in Popenoe maps).

The above maps show the original deepwater CHAPC proposal and the revision developed at the June 2006 Joint Habitat and Coral Advisory Panel Meeting to reflect habitat-driven consolidation of six areas into four deepwater CHAPC proposals.

Other Possible Alternative 2A. Establish the Cape Lookout Lophelia Banks HAPC. The alternative was removed from consideration and eliminated from detailed study after new information on deepwater habitat distribution and characterization was provided in technical reports (Ross 2006) to the Council. New information provided the Habitat and Coral Advisory Panels and the Council with more detailed information on distribution and characterization of deepwater habitat off North Carolina. Alternatives considered subsequently more accurately represent the known distribution of deepwater coral habitat offshore of Cape Lookout.

Other Possible Alternative 3A. Establish the Cape Fear Lophelia Banks HAPC. The alternative was removed from consideration and eliminated from detailed study after new information on deepwater habitat distribution and characterization was provided in technical reports (Ross 2006) to the Council. New information provided the Habitat and Coral Advisory Panels and Council with more detailed information on distribution and characterization of deepwater habitat off North Carolina. Alternatives considered subsequently more accurately represent the known distribution of deepwater coral habitat offshore of Cape Fear.

Other Possible Alternative 4A. Establish the Stetson Reefs HAPC. The alternative was removed from consideration and eliminated from detailed study after new information on deepwater habitat distribution and characterization was provided in technical reports (Reed 2006 and Ross 2006) to the Council. New information provided the Habitat and Coral Advisory Panels and Council with more detailed information on distribution and characterization of deepwater habitat off South Carolina and Georgia. Subsequently, later alternatives considered more accurately represent the known distribution of deepwater coral habitat offshore of these states. In addition, merging this alternative with Alternative 5B provides a more complete representation of known deepwater coral habitat distribution from the Stetson Reefs, through the Savannah and East Florida Lithoherms and the Miami Terrace. This alternative was rejected because it would not address the Council's intent to protect the known distribution of deepwater coral habitat.

Other Possible Alternative 5A. Establish the Savannah and East Florida Lithoherms HAPC. The alternative was removed from consideration and eliminated from detailed study after new information on deepwater habitat distribution and characterization was provided in technical reports (Reed 2006 and Ross 2006) to the Council. In addition, merging this alternative with Alternative 5B provides a more complete representation of known deepwater coral habitat distribution from the Stetson Reefs, through the Savannah and East Florida Lithoherms and the Miami Terrace. This alternative was rejected because it would not address the Councils' intent to protect known distribution of deepwater coral habitat.

Other Possible Alternative 6A. Establish the Pourtales Terrace HAPC. The alternative was removed from consideration and eliminated from detailed study after new information on deepwater habitat distribution and characterization was provided in technical reports (Reed 2006 and Ross 2006) to the Council. This alternative was rejected because it would not address the Councils' intent to protect known distribution of deepwater coral habitat.

B. OTHER ALTERNATIVES CONSIDERED FOR REGULATING THE DEEPWATER SHRIMP FISHERY OPERATIONS RELATIVE TO THE PROPOSED CHAPCS

Other Possible Alternative 1B. Amend the Shrimp FMP to Regulate Fishing for or Possession of Shrimp in the Deepwater Coral HAPCs.

The Council considered regulating fishing for deepwater shrimp through the Shrimp FMP but determined a more effective method to address the main action to protect deepwater habitat would be accomplished through gear regulation under the Coral FMP. In addition, regulating the royal red shrimp fishery directly would require adding the species to the management unit and development of SFA parameters for royal red shrimp which could possibly significantly delay implementation of proposed coral protection measures. Therefore, this alternative was considered but eliminated from detailed study.

Other Possible Alternative 2B. Prohibit fishing for or possession of deepwater shrimp in or from the deepwater coral HAPCs.

In the area encompassed by the deepwater CHAPCs the following additional regulation would apply: (1) Fishing for or possession of deepwater shrimp (rock shrimp, and royal red shrimp) in or from the HAPCs is prohibited.

The Council considered regulating fishing for deepwater shrimp through the Shrimp FMP but determined a more effective method to address the main action to protect deepwater habitat would be accomplished through gear regulation under the Coral FMP. In addition, regulating the royal red shrimp fishery directly would require adding the species to the management unit and development of SFA parameters for royal red shrimp which could possibly significantly delay implementation of proposed coral protection measures. Therefore, this alternative was considered but eliminated from detailed study.

Other Possible Alternative 3B. Prohibit fishing for or possession of shrimp in or from the deepwater coral HAPCs.

In the area encompasses by the deepwater coral HAPCs the following additional regulation would apply: (1) Fishing for or possession of shrimp (white shrimp, brown shrimp, pink shrimp, rock shrimp, and royal red shrimp) in or from the HAPCs is prohibited.

The Council considered regulating fishing for deepwater shrimp through the Shrimp FMP but determined a more effective method to address the main action to protect deepwater habitat would be accomplished through gear regulation under the Coral FMP. In addition, regulating the royal red shrimp fishery directly would require adding the species to the management unit and development of SFA parameters for royal red shrimp which could possibly significantly delay implementation of proposed coral protection measures. Therefore, this alternative was considered but eliminated from detailed study.

Other Possible Alternative 4B. Amend the Shrimp FMP to Establish Allowable Gear Areas and Regulate Fishing for or Possession of Shrimp in the Deepwater Coral HAPCs.

In October 2004 the Council's Habitat and Coral Advisory Panels developed consensus recommendations on measures to be included in the Comprehensive Ecosystem-based Amendment. The Habitat and Coral Advisory Panels indicated that adequate information should be available to define the fishing area from the VMS system required for the rock shrimp fishery. The consensus was that measure could enhance protection of unique habitat values of deepwater coral/habitat including the proposed deepwater CHAPCs and deepwater EFH-HAPCs including the Charleston Bump EFH-HAPC.

Creation of allowable gear areas outside the CHAPC for the shrimp fishery was considered but eliminated from further consideration. In part, this determination was the result of preliminary VMS information indicating the rock shrimp fishery did not occur in depths even close to the deepwater habitat under consideration. In addition, further analyses of VMS data by NMFS provided the Council with a characterization of royal red shrimp fishing activity which showed virtually all fishing occurred in waters shallower than the proposed CHAPCs. In addition, regulating the royal red shrimp fishery directly would require adding the species to the management unit and development of SFA parameters for royal red shrimp which could possibly significantly delay implementation of proposed coral protection measures. Subsequently, the need to create gear areas for the rock shrimp was not necessary to address gear concerns that could be addressed directly under the Coral FMP.

Other Possible Alternative 5B. Establish an Allowable Gear Area for deepwater trawls for the harvest of rock shrimp based on fishing operation area as defined by data from the approved Vessel Monitoring System.

This alternative addressed harvest of rock shrimp which subsequently were found not to occur or be harvested in depths or habitat associated with proposed deepwater CHAPCs. Therefore, this alternative was considered but eliminated from detailed study.

Other Possible Alternative 6B. Establish an Allowable Gear Area for deepwater trawls for the harvest of rock shrimp based on fishing operation area as defined by data from the approved Vessel Monitoring System and historic fishing grounds.

This alternative addressed harvest of rock shrimp which subsequently were found not to occur or be harvested in depths or habitat associated with proposed deepwater CHAPCs. Therefore, this alternative was considered but eliminated from detailed study.

Other Possible Alternative 7B. Move the west boundary of the proposed CHAPC eastward to exclude all VMS points from the CHAPC.

The Deepwater Shrimp Advisory Panel met formally and informally between January and March 2008 to develop proposals for Council consideration that would allow the fishery to continue to operate while avoiding damaging deepwater coral habitat. The Council approved bringing the alternatives (**Figure E-4**) developed by the Deepwater Advisory Panel to public hearing to collect additional information and input on the proposals. The Council determined that this alternative would allow the fishery to expand and operate in areas of both high and low profile habitat. This alternative would eliminate the minimal impact to the fishery but would potentially allow fishing on known deepwater habitat. The Council, at their June 2008, meeting re-evaluated this alternative after the May 2008 public hearings and approved a motion to eliminate it from further analyses.

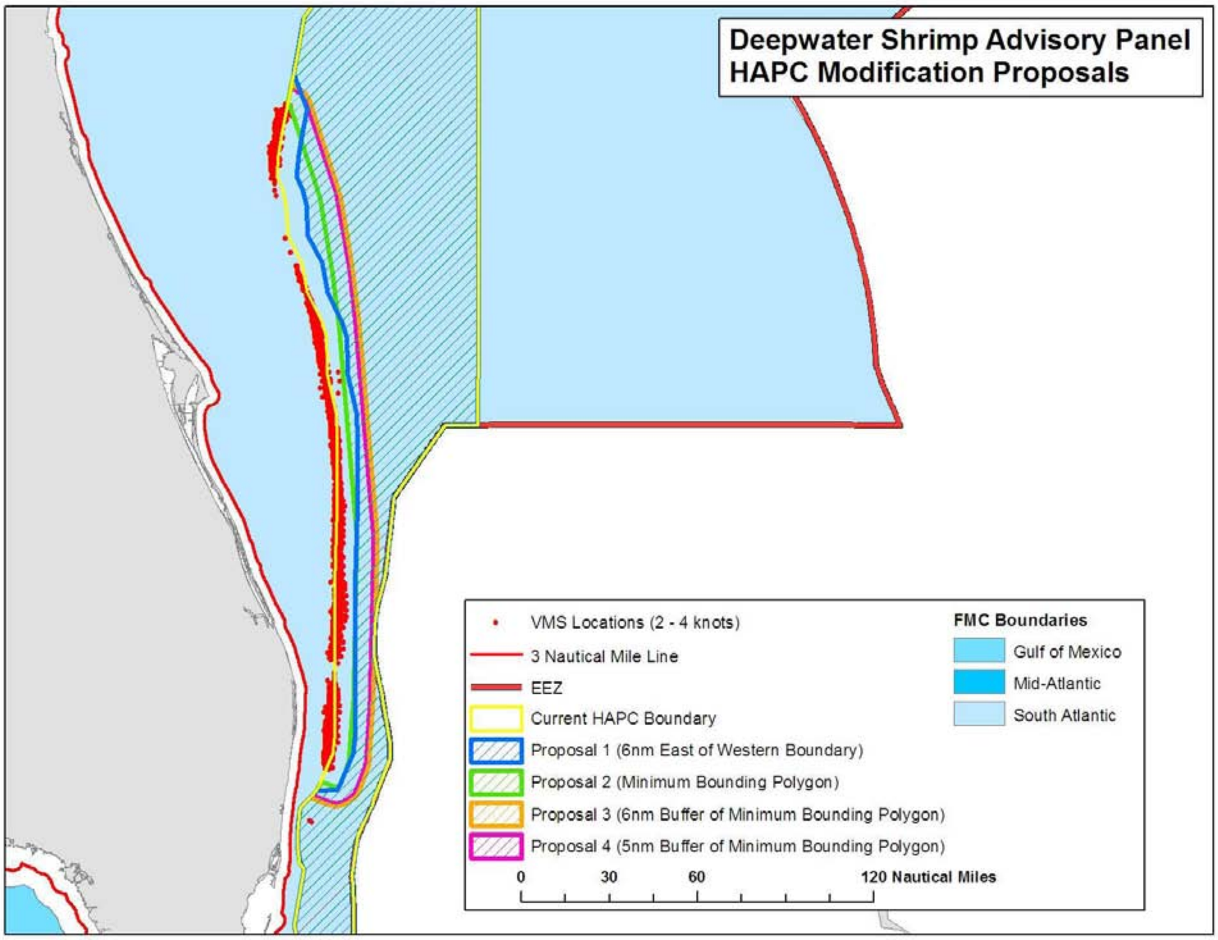


Figure E-4. Alternatives for the Shrimp Fishery Access Area developed by the Deepwater Shrimp Advisory Panel.

Other Possible Alternative 8B. Move the west boundary of the proposed CHAPC eastward 5 nautical miles from the eastern boundary of the polygon from Alternative 2.

The Deepwater Shrimp Advisory Panel met formally and informally between January and March 2008 to develop proposals for Council consideration that would allow the fishery to continue to operate while avoiding damaging deepwater coral habitat. The Council approved bringing the alternatives (**Figure E-4**) developed by the Deepwater Advisory Panel to public hearing to

collect additional information and input on the proposals. The Council determined that this alternative would allow the fishery to expand and operate in areas of both high and low profile deepwater coral habitat. This alternative would eliminate the minimal impact to the fishery but would potentially allow fishing on known deepwater habitat. The Council, at their June 2008 meeting, re-evaluated this alternative after the May 2008 public hearings and approved a motion to eliminate from further analyses.

Other Possible Alternative 9B. Move the west boundary of the proposed CHAPC eastward 6 nautical miles from the eastern boundary of the polygon from Alternative 2.

The Deepwater Shrimp Advisory Panel met formally and informally between January and March 2008 to develop proposals for Council consideration that would allow the fishery to continue to operate while avoiding damaging deepwater coral habitat. The Council approved bringing the alternatives (**Figure E-4**) developed by the Deepwater Advisory Panel to public hearing to collect additional information and input on the proposals. The Council determined that this alternative would allow the fishery to expand and operate in areas of both high and low profile deepwater coral habitat. This alternative would eliminate the minimal impact to the fishery but would potentially allow fishing on known deepwater habitat. The Council, at their June 2008 meeting, re-evaluated this alternative after the May 2008 public hearings and approved a motion to eliminate from further analyses.

C. OTHER ALTERNATIVES CONSIDERED FOR REGULATING THE GOLDEN CRAB FISHERY OPERATIONS RELATIVE TO THE PROPOSED CHAPCS

Other Possible Alternative 1C. Northern area where fishing is taking place – continue the eastern boundary north from the middle area boundary along the 700 meter depth contour up to 28 degrees 38 minutes, then along the 600 meter contour northwards to 29 degrees. Eastern boundary along the 500 meter contour starting at about 79 degrees 41 minutes; 28 degrees moving northwards. This is a box within a box except that the southernmost boundary must be extended westward to the boundary of the proposed CHAPC.

The Golden Crab AP met on January 27-28, 2008 to review the CHAPC proposal and discuss fishing operations relative to these proposals. Subsequently, Council staff met informally with a number of golden crab fishermen, including some AP members, on February 26, 2008 to help in the refinement of these proposals for consideration at the March Council meeting (**Figures E-5 and E-6**).

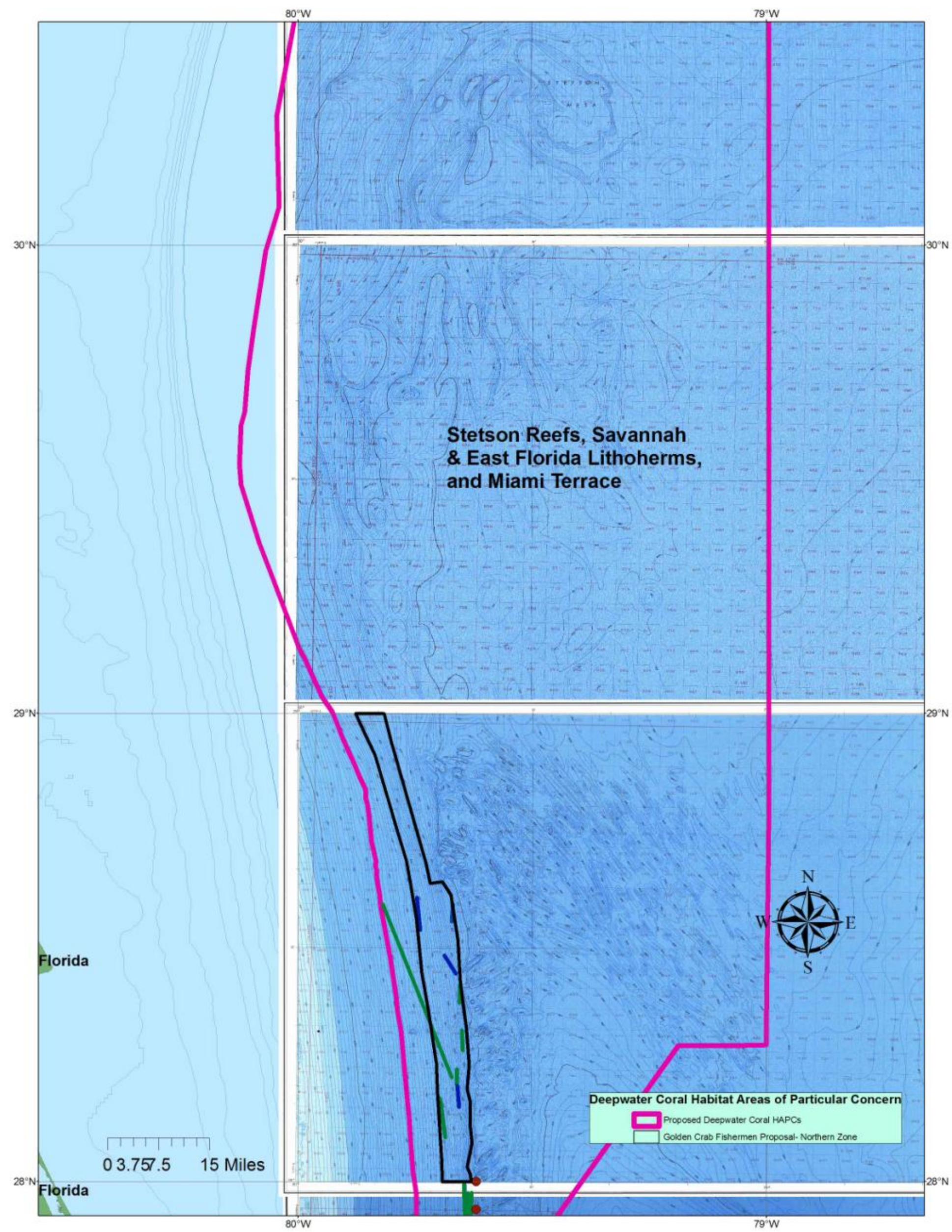


Figure E-5. Alternatives for Allowable Golden Crab Fishing Areas proposed by the Golden Crab Advisory Panel.

Fishing areas and **Other Possible Alternative 1C** for allowable gear area for golden crab fishing in the CHAPC in the Northern Zone (Data Source: Traps set locations represented by short colored lines, were provided by Golden Crab Fishermen).

Other Possible Alternative 2C. Middle area: Move the western boundary towards the east as shown by the latitude/longitude points provided and move the eastern boundary as shown by the latitude/longitude points provided. Create an "allowable golden crab fishing area" within the proposed CHAPC boundaries.

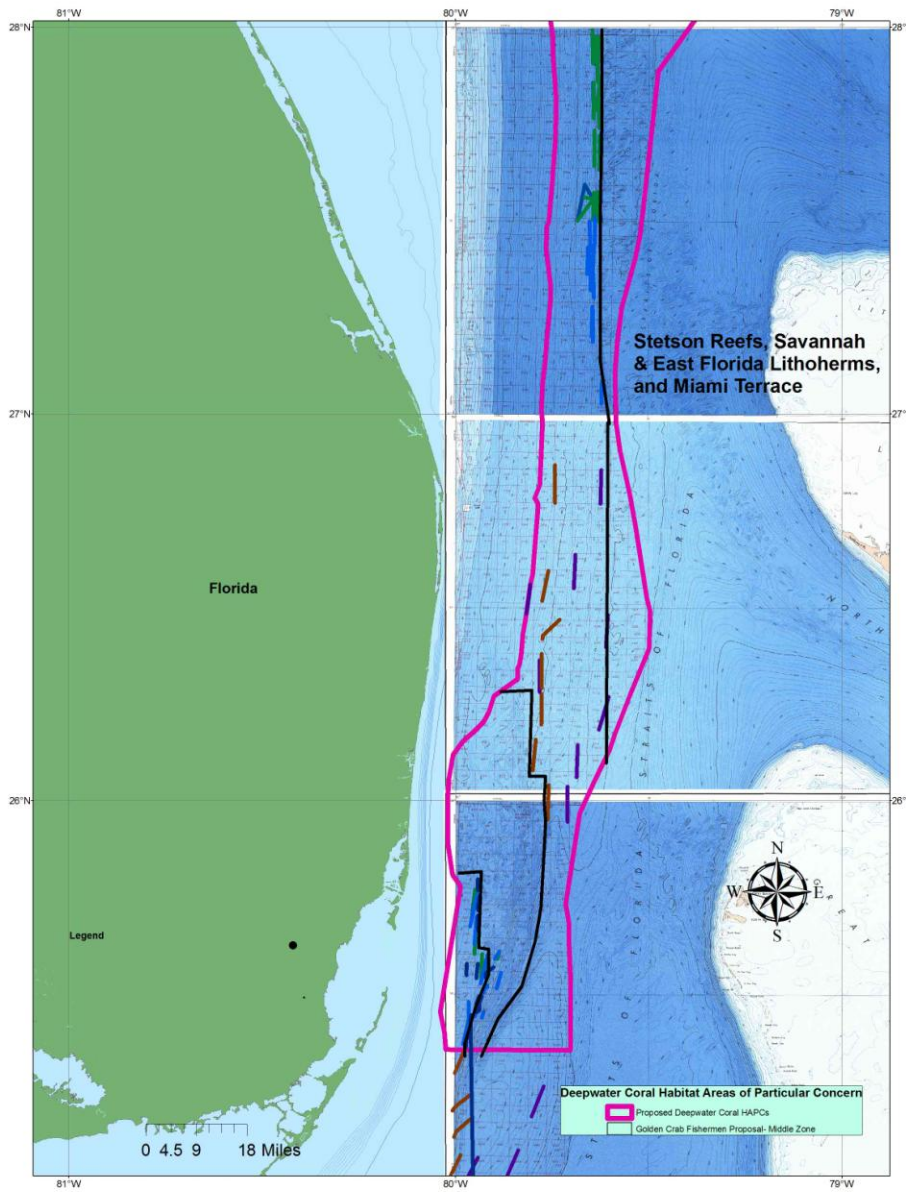


Figure E-6. Alternatives for Allowable Golden Crab Fishing Areas proposed by the Golden Crab Advisory Panel.

Fishing areas and **Other Possible Alternative 2C** for allowable gear areas for golden crab fishing in the Coral HAPC in the Middle Zone (Data Source: Traps set locations represented by short colored lines, were provided by Golden Crab Fishermen).

Other Possible Alternative 3C. Northern Zone – include provision for areas to be designated as "allowable golden crab areas" after research shows habitat allows fishing (e.g., cooperative research projects).

By eliminating this alternative from detailed consideration the Council reaffirmed their intent to focus action on providing for the traditional fishery.

Other Possible Alternative 4C. Create an "allowable golden crab fishing area" in the sand/mud zone in the northern zone.

By eliminating this alternative from detailed consideration the Council reaffirmed their intent to focus action on providing for the traditional fishery. Much of the area proposed would overlap with deepwater habitat and there was not sufficient data to identify it as traditional fishing grounds.

Other Possible Alternative 5C. Northern zone: preserve traditional golden crab fishing grounds.

The Advisory Panel chairman clarified at the March 2008 Council meeting that the Panel was recommending the establishment of allowable gear areas for golden crab fishing which lie within the deepwater CHAPC versus moving the proposed boundaries. The Council requested comment on the industry proposal to establish fishing areas where the traditional fishery has operated. The Advisory Panel provided a revised recommendation for the Northern Zone at public hearing (**Figure E-7**). Panel members collaborated with Council staff to further refine those proposals to focus on traditional fishing grounds and areas which would not impact deepwater coral habitat. The Council, at the June 2008, meeting adopted the alternative for the Northern Zone presented in **Section 4.0** as preferred. Therefore, this alternative was considered but eliminated from further detailed study.

Other Possible Alternative 6C. Middle zone: preserve traditional golden crab fishing grounds. Revised Alternative- see detailed summary for boundary modifications.

The Advisory Panel chairman clarified at the March 2008 Council meeting that the Panel was recommending the establishment of allowable gear areas for golden crab fishing which lie within the deepwater CHAPC versus moving the boundaries. The Council requested comment on the industry proposal to establish fishing areas where the traditional fishery has operated can continue to operate without impacting deepwater coral habitat. The Advisory Panel provided a revised recommendation for the Middle Zone at public hearing (**Figure E-7**). Panel members collaborated with Council staff to further refine those proposals to focus on traditional fishing grounds and areas which would not impact deepwater coral habitat. The Council, at the June 2008 meeting, adopted the alternative for the Middle Zone presented in **Section 4.0** as preferred. Therefore, this alternative was considered but eliminated from further detailed study.

Other Possible Alternative 7C. Southern zone: preserve traditional golden crab fishing grounds. Revised Alternative- see detailed summary for boundary modifications.

The Advisory Panel chairman clarified at the March 2008 Council meeting that the Panel was recommending the establishment of allowable gear areas for golden crab fishing which lie within the deepwater CHAPC versus moving the boundaries. The Council requested comment on the industry proposal to establish fishing areas where the traditional fishery has operated can continue to operate without impacting deepwater coral habitat. The Advisory Panel provided a revised recommendation for the Southern Zone at public hearing (see figure below). Panel members collaborated with Council staff to further refine those proposals to focus on traditional fishing grounds and areas which would not impact deepwater coral habitat. The Council, at the June 2008 meeting adopted the alternative for the Southern Zone presented in Section 4.0 as preferred.   Therefore, this alternative was considered but eliminated from further detailed study.

Other Possible Alternative 8C. Make the entire portion of the proposed CHAPC between 28 degrees and 29 degrees latitude and east of 79 degrees 30 minutes longitude "an allowable golden crab fishing area".

Much of the area proposed would overlap with deepwater habitat and do not have sufficient data to be identified as traditional fishing grounds. Figures below present maps of the proposals and the evaluation of the alternative relative to deepwater habitat information were reviewed with golden crab fishermen and by the Council at the June 2008 Council meeting. The Council concluded eliminating this alternative from detailed consideration would reaffirm the intent to focus present action on providing for the traditional fishery.

Other Possible Alternative 9C. Make the entire portion of the proposed CHAPC between 31 degrees and 31 degrees 23 minutes 28 seconds latitude "an allowable golden crab fishing area".

Much of the area proposed would overlap with deepwater habitat and do not have sufficient data to be identified as traditional fishing grounds. Figures below present maps of the proposals and the evaluation of the alternative relative to deepwater habitat information were reviewed with golden crab fishermen and by the Council at the June 2008 Council meeting. The Council concluded eliminating this alternative from detailed consideration would reaffirm the intent to focus present action on providing for the traditional fishery.

Other Possible Alternative 10C. In the extreme northern portion of the CHAPC create a "C" shaped "allowable golden crab fishing area.

The Council concluded by eliminating this alternative from detailed consideration would reaffirm the intent to focus present action on providing for the traditional fishery. Much of the area proposed would overlap with deepwater habitat and have sufficient data to be identified as traditional fishing grounds. The following maps present the proposals and the evaluation of the alternative relative to deepwater habitat information reviewed with golden crab fishermen and at the June 2008 Council meeting.

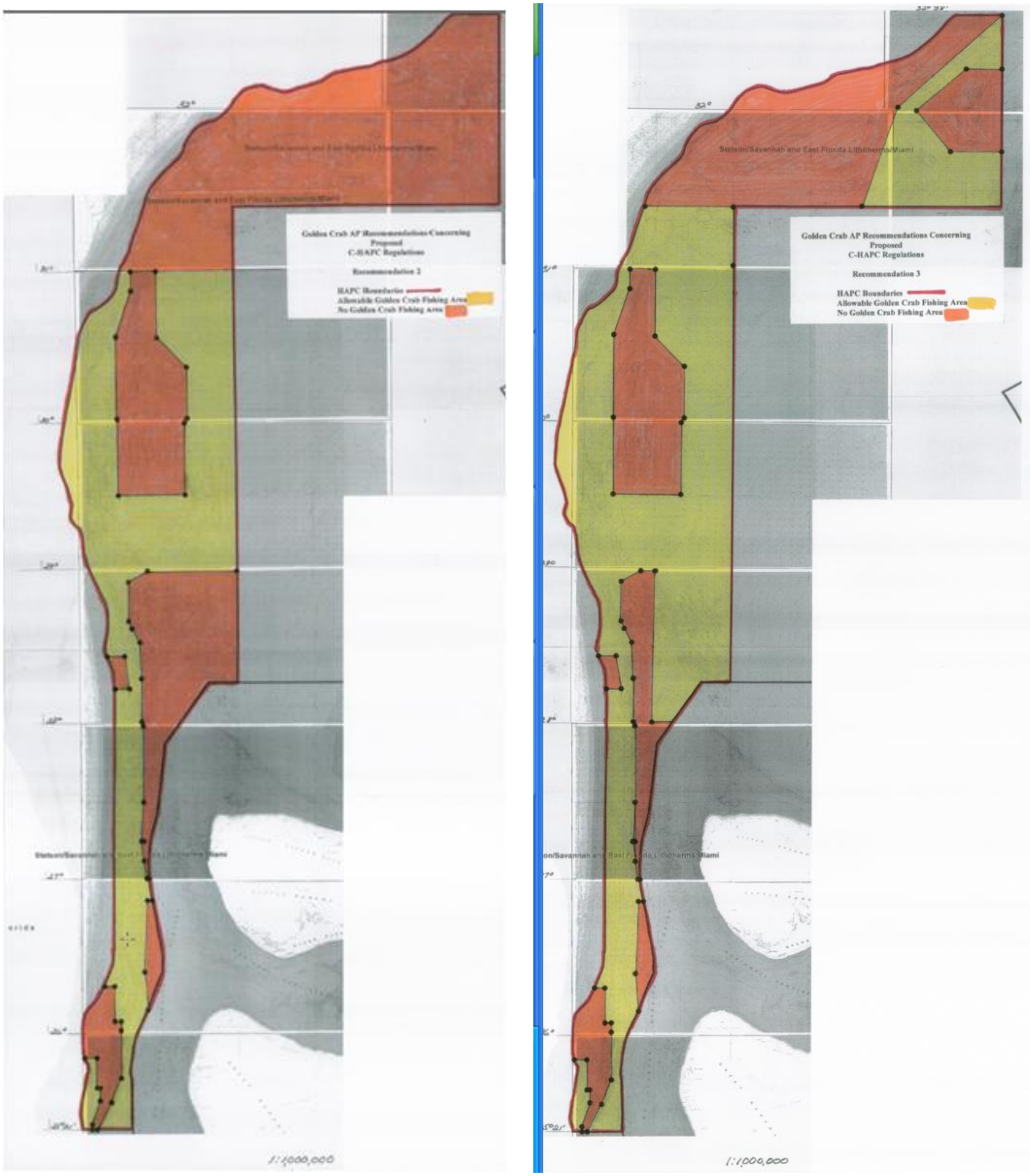
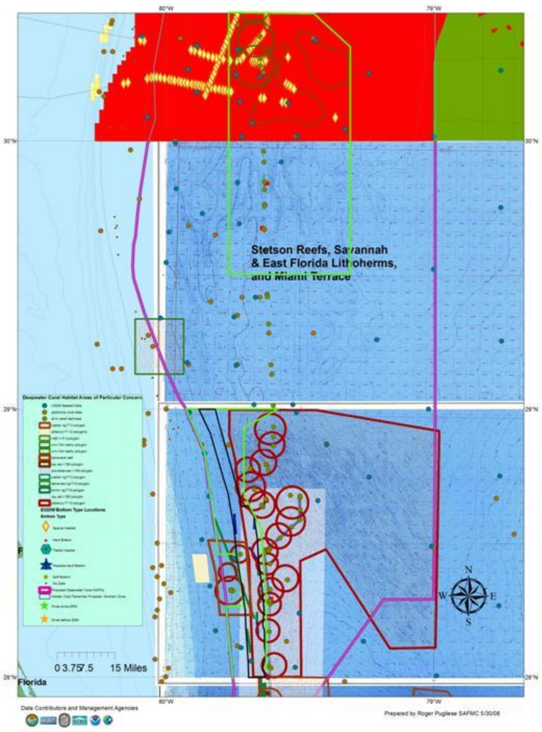
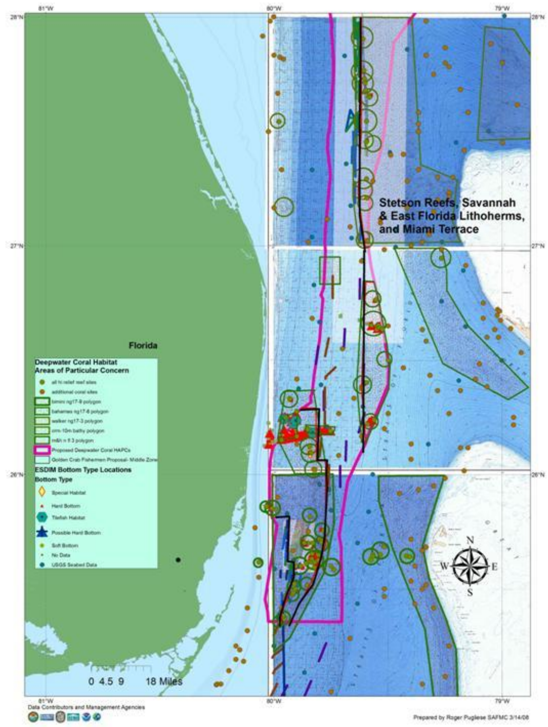
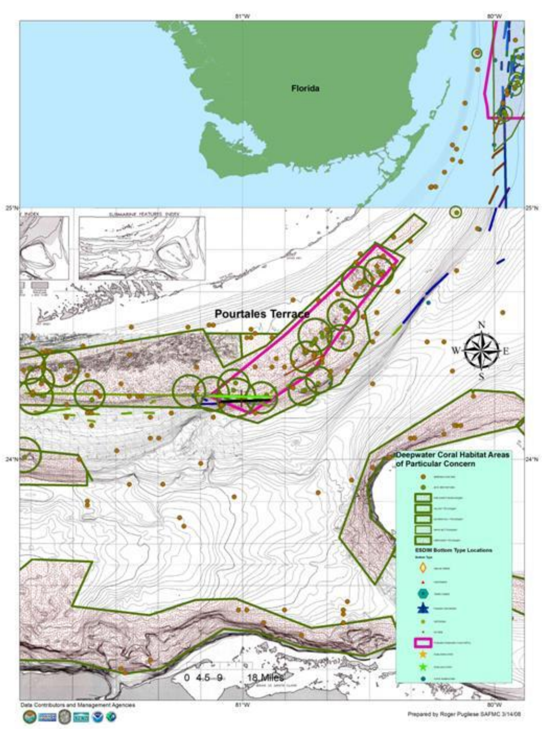


Figure E-7. Golden Crab Advisory Panel's revised recommendation for the Northern Zone.

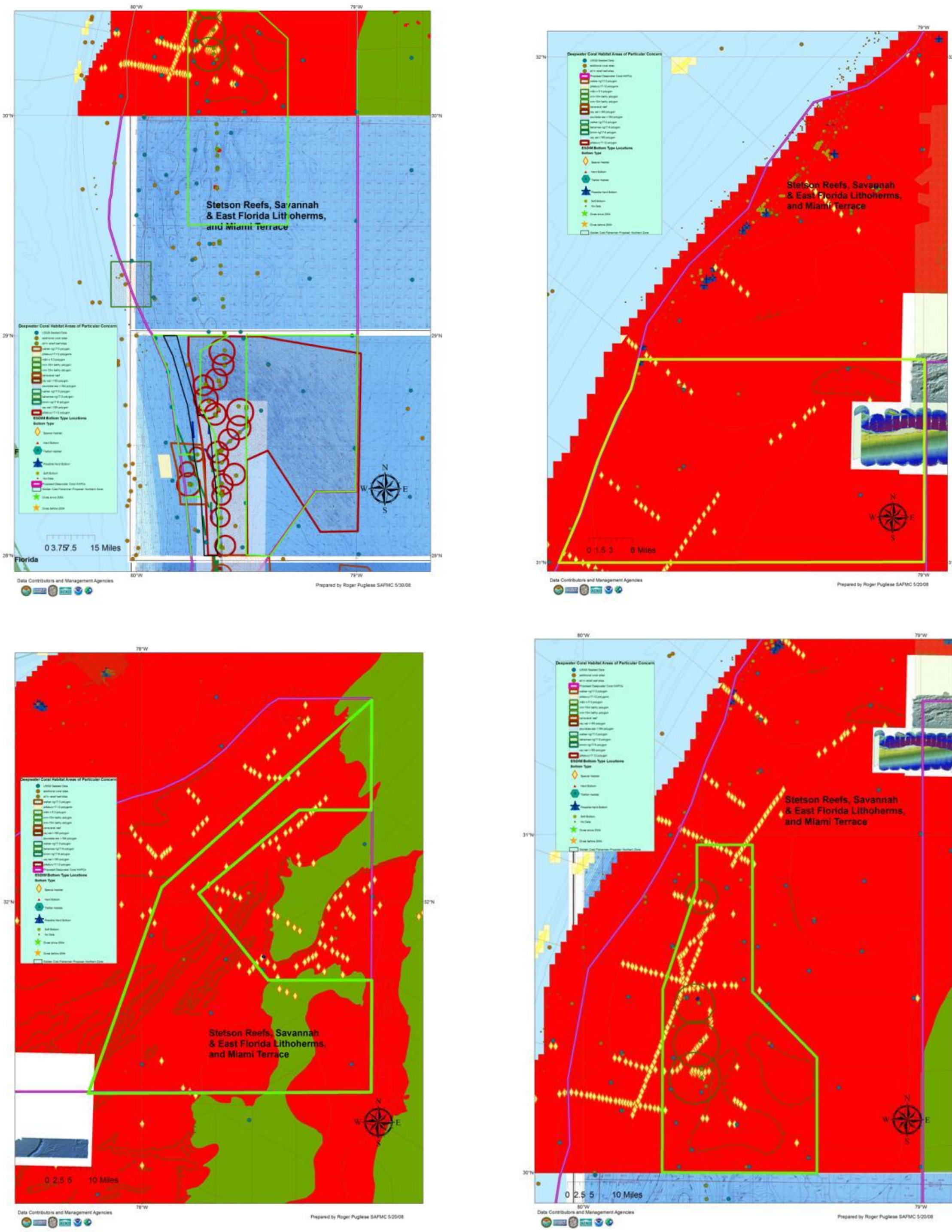
Other Possible Options 5C-10C presented by the Golden Crab Advisory Panel at the May 2008 Public Hearings







Habitat distribution associated with **Other Possible Alternatives 5C-7C**



Habitat distribution associated with **Other Possible Alternatives 8C, 9C and 10C**

D. OTHER ALTERNATIVES CONSIDERED FOR MONITORING THE GOLDEN CRAB FISHERY

Other Possible Alternative 1D. Require monitoring of golden crab vessels using acoustic monitoring. The monitoring of vessels and/or trap sets using acoustics was discussed with the Advisory Panel recommending it be considered for public hearing.

This alternative would provide enforcement of CHAPC and limit golden crab fishing to areas which did not impact habitat. This alternative was brought to public hearing however, while sensors may exist to monitor gear and or the vessel, the network of fixed buoys to hold such monitors and transmission capabilities necessary to monitor the fishery do not exist at this time. In addition, acoustic monitoring in the deep ocean is very limited and even sensors may need to be developed to handle extreme depths or distances signals must travel. Subsequently, the Council at the June 2008 meeting eliminated this alternative from consideration for detailed study and identified it as a future research need.

APPENDIX F. Coordinates for the five proposed deepwater CHAPCs (Source: Roger Pugliese, SAFMC and Tina Udouj, FWRI).

(Note: Shape-files, Metadata, Tables and KMZ files for proposed CHAPCs area available for download from the Habitat and Ecosystem Internet Map Server: http://www.safmc.net/EcosystemManagement/EcosystemBoundaries/MappingandGISData/tabid/62/Default.aspx)

Table 1. Coordinates for the proposed Cape Fear CHAPC.

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
1	33° 38' 49"	76° 29' 32"
2	33° 32' 21"	76° 32' 38"
3	33° 29' 49"	76° 26' 19"
4	33° 36' 9"	76° 23' 37"

Table 2. Coordinate table for the proposed Cape Lookout CHAPC.

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
1	34° 24' 37"	75° 45' 11"
2	34° 10' 26"	75° 58' 44"
3	34° 5' 47"	75° 54' 54"
4	34° 21' 2"	75° 41' 25"

Table 3. Coordinate table for the proposed Blake Ridge Diapir CHAPC.

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
1	32° 32' 28"	76° 13' 16"
2	32° 30' 44"	76° 13' 24"
3	32° 30' 37"	76° 11' 21"
4	32° 32' 21"	76° 11' 13"

Table 4. Coordinate table for the proposed Stetson-Miami Terrace CHAPC.

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
1	28° 17' 10"	79° 0' 0"
2	31° 23' 37"	79° 0' 0"
3	31° 23' 37"	77° 16' 21"
4	32° 38' 37"	77° 16' 21"
5	32° 38' 21"	77° 34' 6"
6	32° 35' 24"	77° 37' 54"
7	32° 32' 18"	77° 40' 26"

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
8	32° 28' 42"	77° 44' 10"
9	32° 25' 51"	77° 47' 43"
10	32° 22' 40"	77° 52' 5"
11	32° 20' 58"	77° 56' 29"
12	32° 20' 30"	77° 57' 50"
13	32° 19' 53"	78° 0' 49"
14	32° 18' 44"	78° 4' 35"
15	32° 17' 35"	78° 7' 48"
16	32° 17' 15"	78° 10' 41"
17	32° 15' 50"	78° 14' 9"
18	32° 15' 20"	78° 15' 25"
19	32° 12' 15"	78° 16' 37"
20	32° 10' 26"	78° 18' 9"
21	32° 4' 42"	78° 21' 27"
22	32° 3' 41"	78° 24' 7"
23	32° 4' 58"	78° 29' 19"
24	32° 6' 59"	78° 30' 48"
25	32° 9' 27"	78° 31' 31"
26	32° 11' 23"	78° 32' 47"
27	32° 13' 9"	78° 34' 4"
28	32° 14' 8"	78° 34' 36"
29	32° 12' 48"	78° 36' 34"
30	32° 13' 7"	78° 39' 7"
31	32° 14' 17"	78° 40' 1"
32	32° 16' 20"	78° 40' 18"
33	32° 16' 33"	78° 42' 32"
34	32° 14' 26"	78° 43' 23"
35	32° 11' 14"	78° 45' 42"
36	32° 10' 19"	78° 49' 8"
37	32° 9' 42"	78° 52' 54"
38	32° 8' 15"	78° 56' 11"
39	32° 5' 0"	79° 0' 30"
40	32° 1' 54"	79° 2' 49"
41	31° 58' 40"	79° 4' 51"
42	31° 56' 32"	79° 6' 48"
43	31° 53' 27"	79° 9' 18"
44	31° 50' 56"	79° 11' 29"
45	31° 49' 7"	79° 13' 35"
46	31° 47' 56"	79° 16' 8"
47	31° 47' 11"	79° 16' 30"
48	31° 46' 29"	79° 16' 25"
49	31° 44' 31"	79° 17' 24"
50	31° 43' 20"	79° 18' 27"
51	31° 42' 26"	79° 20' 41"
52	31° 41' 9"	79° 22' 26"
53	31° 39' 36"	79° 23' 59"
54	31° 37' 54"	79° 25' 29"
55	31° 35' 57"	79° 27' 14"
56	31° 34' 14"	79° 28' 24"

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
57	31° 31' 8"	79° 29' 59"
58	31° 30' 26"	79° 29' 52"
59	31° 29' 11"	79° 30' 11"
60	31° 27' 58"	79° 31' 41"
61	31° 27' 6"	79° 32' 8"
62	31° 26' 22"	79° 32' 48"
63	31° 24' 21"	79° 33' 51"
64	31° 22' 53"	79° 34' 41"
65	31° 21' 3"	79° 36' 1"
66	31° 20' 0"	79° 37' 12"
67	31° 18' 34"	79° 38' 15"
68	31° 16' 49"	79° 38' 36"
69	31° 13' 6"	79° 38' 19"
70	31° 11' 4"	79° 38' 39"
71	31° 9' 28"	79° 39' 9"
72	31° 7' 44"	79° 40' 21"
73	31° 5' 53"	79° 41' 27"
74	31° 4' 40"	79° 42' 9"
75	31° 2' 58"	79° 42' 28"
76	31° 1' 3"	79° 42' 40"
77	30° 59' 50"	79° 42' 43"
78	30° 58' 27"	79° 42' 43"
79	30° 57' 15"	79° 42' 50"
80	30° 56' 9"	79° 43' 28"
81	30° 54' 49"	79° 44' 53"
82	30° 53' 44"	79° 46' 24"
83	30° 52' 47"	79° 47' 40"
84	30° 51' 45"	79° 48' 16"
85	30° 48' 36"	79° 49' 2"
86	30° 45' 24"	79° 49' 55"
87	30° 41' 36"	79° 51' 31"
88	30° 38' 38"	79° 52' 23"
89	30° 35' 29"	79° 52' 54"
90	30° 32' 55"	79° 54' 19"
91	30° 31' 5"	79° 55' 27"
92	30° 28' 9"	79° 56' 6"
93	30° 26' 57"	79° 56' 34"
94	30° 25' 25"	79° 57' 36"
95	30° 23' 3"	79° 58' 25"
96	30° 21' 27"	79° 59' 24"
97	30° 18' 22"	80° 0' 9"
98	30° 16' 34"	80° 0' 33"
99	30° 14' 55"	80° 0' 23"
100	30° 12' 36"	80° 1' 44"
101	30° 12' 0"	80° 1' 49"
102	30° 6' 52"	80° 1' 58"
103	29° 59' 16"	80° 4' 11"
104	29° 49' 12"	80° 5' 44"
105	29° 43' 59"	80° 6' 24"

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
106	29° 38' 37"	80° 6' 53"
107	29° 36' 54"	80° 7' 18"
108	29° 31' 59"	80° 7' 32"
109	29° 29' 14"	80° 7' 18"
110	29° 21' 48"	80° 5' 1"
111	29° 20' 25"	80° 4' 29"
112	29° 8’ 0”	79° 59' 43"
113	29° 6' 56"	79° 59' 7"
114	29° 5' 59"	79° 58' 44"
115	29° 3' 34"	79° 57' 37"
116	29° 2' 11"	79° 56' 59"
117	29° 0' 0"	79° 55' 32"
118	28° 56' 55"	79° 54' 22"
119	28° 55' 0"	79° 53' 31"
120	28° 53' 35"	79° 52' 51"
121	28° 51' 47"	79° 52' 7"
122	28° 50' 25"	79° 51' 27"
123	28° 49' 53"	79° 51' 20"
124	28° 49' 1"	79° 51' 20"
125	28° 48' 19"	79° 51' 10"
126	28° 47' 13"	79° 50' 59"
127	28° 43' 30"	79° 50' 36"
128	28° 41' 5"	79° 50' 4"
129	28° 40' 27"	79° 50' 7"
130	28° 39' 50"	79° 49' 56"
131	28° 39' 4"	79° 49' 58"
132	28° 36' 43"	79° 49' 35"
133	28° 35' 1"	79° 49' 24"
134	28° 30' 37"	79° 48' 35"
135	28° 14' 0"	79° 46' 20"
136	28° 11' 41"	79° 46' 12"
137	28° 8' 2"	79° 45' 45"
138	28° 1' 20"	79° 45' 20"
139	27° 58' 13"	79° 44' 51"
140	27° 56' 23"	79° 44' 53"
141	27° 49' 40"	79° 44' 25"
142	27° 46' 27"	79° 44' 22"
143	27° 42' 0"	79° 44' 33"
144	27° 36' 8"	79° 44' 58"
145	27° 30' 0"	79° 45' 29"
146	27° 29' 4"	79° 45' 47"
147	27° 27' 5"	79° 45' 54"
148	27° 25' 47"	79° 45' 57"
149	27° 19' 46"	79° 45' 14"
150	27° 17' 54"	79° 45' 12"
151	27° 12' 28"	79° 45' 0"
152	27° 7' 45"	79° 46' 7"
153	27° 4' 47"	79° 46' 29"
154	27° 0' 43"	79° 46' 39"

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
155	26° 58' 43"	79° 46' 28"
156	26° 57' 6"	79° 46' 32"
157	26° 49' 58"	79° 46' 54"
158	26° 48' 58"	79° 46' 56"
159	26° 47' 1"	79° 47' 9"
160	26° 46' 4"	79° 47' 9"
161	26° 35' 9"	79° 48' 1"
162	26° 33' 37"	79° 48' 21"
163	26° 27' 56"	79° 49' 9"
164	26° 25' 55"	79° 49' 30"
165	26° 21' 5"	79° 50' 3"
166	26° 20' 30"	79° 50' 20"
167	26° 18' 56"	79° 50' 17"
168	26° 16' 19"	79° 54' 6"
169	26° 13' 48"	79° 54' 48"
170	26° 12' 19"	79° 55' 37"
171	26° 10' 57"	79° 57' 5"
172	26° 9' 17"	79° 58' 45"
173	26° 7' 11"	80° 0' 22"
174	26° 6' 12"	80° 0' 33"
175	26° 3' 26"	80° 1' 2"
176	26° 0' 35"	80° 1' 13"
177	25° 49' 10"	80° 0' 38"
178	25° 48' 30"	80° 0' 23"
179	25° 46' 42"	79° 59' 14"
180	25° 27' 28"	80° 2' 26"
181	25° 24' 6"	80° 1' 44"
182	25° 21' 4"	80° 1' 27"
183	25° 21' 4"	79° 42' 4"

Following Point 183 area boundary follows the EEZ northward to Point 1.

Table 5. Coordinate table for the proposed Pourtales Terrace CHAPC.

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
1	24° 20' 12"	80° 43' 50"
2	24° 33' 42"	80° 34' 23"
3	24° 37' 45"	80° 31' 20"
4	24° 47' 18"	80° 23' 8"
5	24° 51' 8"	80° 27' 58"
6	24° 42' 52"	80° 35' 51"
7	24° 29' 44"	80° 49' 45"
8	24° 15' 4"	81° 7' 52"
9	24° 10' 55"	80° 58' 11"

Following Point 9, area boundary follows the EEZ northward to Point 1.

APPENDIX G. Coordinates for the proposed Shrimp Fishery Access Area. (Source: Roger Pugliese, SAFMC and Tina Udouj, FWRI).

(Note: Shapefiles, Metadata, Tables and KMZ files for proposed SFAA available for download from the Habitat and Ecosystem Internet Map Server: http://www.safmc.net/EcosystemManagement/EcosystemBoundaries/MappingandGISData/tabid/62/Default.aspx)

Table 1a. Coordinate table for the proposed Shrimp Fishery Access Area (SFAA1).

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
1	30° 12' 0"	80° 1' 49"
2	30° 6' 52"	80° 1' 58"
3	29° 59' 16"	80° 4' 11"
4	29° 49' 12"	80° 5' 44"
5	29° 43' 59"	80° 6' 24"
6	29° 38' 37"	80° 6' 53"
7	29° 36' 54"	80° 7' 18"
8	29° 31' 59"	80° 7' 32"
9	29° 29' 14"	80° 7' 18"
10	29° 21' 48"	80° 5' 1"
11	29° 20' 25"	80° 4' 29"
12	29° 20' 25"	80° 3' 11"
13	29° 21' 48"	80° 3' 52"
14	29° 29' 14"	80° 6' 8"
15	29° 31' 59"	80° 6' 23"
16	29° 36' 54"	80° 6' 0"
17	29° 38' 37"	80° 5' 43"
18	29° 43' 59"	80° 5' 14"
19	29° 49' 12"	80° 4' 35"
20	29° 59' 16"	80° 3' 1"
21	30° 6' 52"	80° 0' 46"
22	30° 12' 0"	80° 0' 42"

Table 1b. Coordinate table for the proposed Shrimp Fishery Access Area (SFAA2).

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
1	29° 8' 0"	79° 59' 43"
2	29° 6' 56"	79° 59' 7"
3	29° 5' 59"	79° 58' 44"
4	29° 3' 34"	79° 57' 37"
5	29° 2' 11"	79° 56' 59"
6	29° 0' 0"	79° 55' 32"
7	28° 56' 55"	79° 54' 22"
8	28° 55' 0"	79° 53' 31"
9	28° 53' 35"	79° 52' 51"
11	28° 51' 47"	79° 52' 7"
12	28° 50' 25"	79° 51' 27"
13	28° 49' 53"	79° 51' 20"
14	28° 49' 1"	79° 51' 20"
14	28° 48' 19"	79° 51' 10"
15	28° 47' 13"	79° 50' 59"
16	28° 43' 30"	79° 50' 36"
17	28° 41' 5"	79° 50' 4"
18	28° 40' 27"	79° 50' 7"
19	28° 39' 50"	79° 49' 56"
20	28° 39' 4"	79° 49' 58"
21	28° 36' 43"	79° 49' 35"
22	28° 35' 1"	79° 49' 24"
23	28° 30' 37"	79° 48' 35"
24	28° 30' 37"	79° 47' 27"
25	28° 35' 1"	79° 48' 16"
26	28° 36' 43"	79° 48' 27"
27	28° 39' 4"	79° 48' 50"
28	28° 39' 50"	79° 48' 48"
29	28° 40' 27"	79° 48' 58"
30	28° 41' 5"	79° 48' 56"
31	28° 43' 30"	79° 49' 28"
32	28° 47' 13"	79° 49' 51"
33	28° 48' 19"	79° 50' 1"
34	28° 49' 1"	79° 50' 13"
35	28° 49' 53"	79° 50' 12"
36	28° 50' 25"	79° 50' 17"
37	28° 51' 47"	79° 50' 58"
38	28° 53' 35"	79° 51' 43"
39	28° 55' 0"	79° 52' 22"
40	28° 56' 55"	79° 53' 14"
41	29° 0' 0"	79° 54' 24"
42	29° 2' 11"	79° 55' 50"
43	29° 3' 34"	79° 56' 29"
44	29° 5' 59"	79° 57' 35"
45	29° 6' 56"	79° 57' 59"

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
46	29° 8' 0"	79° 58' 34"

Table 1c. Coordinate table for the proposed Shrimp Fishery Access Area (SFAA3).

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
1	28° 14' 0"	79° 46' 20"
2	28° 11' 41"	79° 46' 12"
3	28° 8' 2"	79° 45' 45"
4	28° 1' 20"	79° 45' 20"
5	27° 58' 13"	79° 44' 51"
6	27° 56' 23"	79° 44' 53"
7	27° 49' 40"	79° 44' 25"
8	27° 46' 27"	79° 44' 22"
9	27° 42' 0"	79° 44' 33"
10	27° 36' 8"	79° 44' 58"
11	27° 30' 0"	79° 45' 29"
12	27° 29' 4"	79° 45' 47"
13	27° 27' 5"	79° 45' 54"
14	27° 25' 47"	79° 45' 57"
15	27° 19' 46"	79° 45' 14"
16	27° 17' 54"	79° 45' 12"
17	27° 12' 28"	79° 45' 0"
18	27° 7' 45"	79° 46' 7"
19	27° 4' 47"	79° 46' 29"
20	27° 0' 43"	79° 46' 39"
21	26° 58' 43"	79° 46' 28"
22	26° 57' 6"	79° 46' 32"
23	26° 57' 6"	79° 44' 52"
24	26° 58' 43"	79° 44' 47"
25	27° 0' 43"	79° 44' 58"
26	27° 4' 47"	79° 44' 48"
27	27° 7' 45"	79° 44' 26"
28	27° 12' 28"	79° 43' 19"
29	27° 17' 54"	79° 43' 31"
30	27° 19' 46"	79° 43' 33"
31	27° 25' 47"	79° 44' 15"
32	27° 27' 5"	79° 44' 12"
33	27° 29' 4"	79° 44' 6"
34	27° 30' 0"	79° 43' 48"
35	27° 30' 0"	79° 44' 22"
36	27° 36' 8"	79° 43' 50"
37	27° 42' 0"	79° 43' 25"
38	27° 46' 27"	79° 43' 14"
39	27° 49' 40"	79° 43' 17"
40	27° 56' 23"	79° 43' 45"
41	27° 58' 13"	79° 43' 43"

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
42	28° 1' 20"	79° 44' 11"
43	28° 4' 42"	79° 44' 25"
44	28° 8' 2"	79° 44' 37"
45	28° 11' 41"	79° 45' 4"
46	28° 14' 0"	79° 45' 12"

Table 1d. Coordinate table for the proposed Shrimp Fishery Access Area (SFAA4).

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
1	26° 49' 58"	79° 46' 54"
2	26° 48' 58"	79° 46' 56"
3	26° 47' 1"	79° 47' 9"
4	26° 46' 4"	79° 47' 9"
5	26° 35' 9"	79° 48' 1"
6	26° 33' 37"	79° 48' 21"
7	26° 27' 56"	79° 49' 9"
8	26° 25' 55"	79° 49' 30"
9	26° 21' 5"	79° 50' 3"
10	26° 20' 30"	79° 50' 20"
11	26° 18' 56"	79° 50' 17"
12	26° 18' 56"	79° 48' 37"
13	26° 20' 30"	79° 48' 40"
14	26° 21' 5"	79° 48' 8"
15	26° 25' 55"	79° 47' 49"
16	26° 27' 56"	79° 47' 29"
17	26° 33' 37"	79° 46' 40"
18	26° 35' 9"	79° 46' 20"
19	26° 46' 4"	79° 45' 28"
20	26° 47' 1"	79° 45' 28"
21	26° 48' 58"	79° 45' 15"
22	26° 49' 58"	79° 45' 13"

APPENDIX H. Coordinates for the proposed Allowable Golden Crab Fishing Areas (Source: Roger Pugliese, SAFMC and Tina Udouj, FWRI).

(Note: Shapefiles, Metadata, Tables and KMZ files for proposed AGCFAs area available for download from the Habitat and Ecosystem Internet Map Server: http://www.safmc.net/EcosystemManagement/EcosystemBoundaries/MappingandGISData/tabid/62/Default.aspx)

Table 1a. Coordinate table for the proposed Allowable Golden Crab Fishing Area - Middle Zone A.

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
1	26° 58' 45"	79° 35' 5"
2	27° 0' 39"	79° 36' 26"
3	27° 7' 55"	79° 37' 52"
4	27° 14' 52"	79° 37' 9"
5	27° 29' 21"	79° 37' 15"
6	28° 0' 0"	79° 38' 16"
7	28° 0' 0"	79° 43' 59"
8	27° 58' 13"	79° 43' 43"
9	27° 56' 23"	79° 43' 45"
10	27° 49' 40"	79° 43' 17"
11	27° 46' 27"	79° 43' 14"
12	27° 42' 0"	79° 43' 25"
13	27° 36' 8"	79° 43' 50"
14	27° 30' 0"	79° 44' 22"
15	27° 30' 0"	79° 43' 48"
16	27° 29' 4"	79° 44' 6"
17	27° 27' 5"	79° 44' 12"
18	27° 25' 47"	79° 44' 15"
19	27° 19' 46"	79° 43' 33"
20	27° 17' 54"	79° 43' 31"
21	27° 12' 28"	79° 43' 19"
22	27° 7' 45"	79° 44' 26"
23	27° 4' 47"	79° 44' 48"
24	27° 0' 43"	79° 44' 58"
25	26° 58' 43"	79° 44' 47"
26	26° 57' 6"	79° 44' 52"
27	26° 57' 6"	79° 42' 34"
28	26° 49' 58"	79° 42' 34"
29	26° 49' 58"	79° 45' 13"
30	26° 48' 58"	79° 45' 15"
31	26° 47' 1"	79° 45' 28"
32	26° 46' 4"	79° 45' 28"
33	26° 35' 9"	79° 46' 20"
34	26° 33' 37"	79° 46' 40"
35	26° 27' 56"	79° 47' 29"
36	26° 25' 55"	79° 47' 49"
37	26° 21' 5"	79° 48' 8"

38	26° 20' 30"	79° 48' 40"
39	26° 18' 56"	79° 48' 37"
40	26° 3' 38"	79° 48' 16"
41	26° 3' 35"	79° 46' 9"
42	25° 58' 33"	79° 46' 8"
43	25° 54' 27"	79° 45' 37"
44	25° 46' 55"	79° 44' 14"
45	25° 38' 4"	79° 45' 58"
46	25° 38' 5"	79° 42' 27"

Following Point 46, area boundary follows the EEZ northward to Point 47.

47	26° 7' 49"	79° 36' 7"
48	26° 17' 36"	79° 36' 6"
49	26° 21' 18"	79° 38' 4"
50	26° 50' 46"	79° 35' 12"
51	26° 50' 40"	79° 33' 45"

Following Point 51, area boundary follows the EEZ northward to Point 1.

Table 1b. Coordinate table for the proposed Allowable Golden Crab Fishing Area - Middle Zone B.

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
1	25° 49' 10"	80° 0' 38"
2	25° 48' 30"	80° 0' 23"
3	25° 46' 42"	79° 59' 14"
4	25° 27' 28"	80° 2' 26"
5	25° 24' 6"	80° 1' 44"
6	25° 21' 4"	80° 1' 27"
7	25° 21' 4"	79° 58' 12"
8	25° 23' 25"	79° 58' 19"
9	25° 32' 52"	79° 54' 48"
10	25° 36' 58"	79° 54' 46"
11	25° 37' 20"	79° 56' 20"
12	25° 49' 11"	79° 56' 0"

Table 1c. Coordinate table for the proposed Allowable Golden Crab Fishing Area - Middle Zone C.

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
1	25° 33' 32"	79° 42' 18"
2	25° 33' 32"	79° 47' 14"
3	25° 21' 4"	79° 53' 45"
4	25° 21' 4"	79° 42' 4"

Following Point 4, area boundary follows the EEZ northward to Point 1.

Table 2. Coordinates for the proposed Allowable Golden Crab Fishing Area - Northern Zone.

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
1	29° 0' 0"	79° 54' 24"
2	28° 56' 55"	79° 53' 14"
3	28° 55' 0"	79° 52' 22"
4	28° 53' 35"	79° 51' 43"
5	28° 51' 47"	79° 50' 58"
6	28° 50' 25"	79° 50' 17"
7	28° 49' 53"	79° 50' 12"
8	28° 49' 1"	79° 50' 13"
9	28° 48' 19"	79° 50' 1"
10	28° 47' 13"	79° 49' 51"
11	28° 43' 30"	79° 49' 28"
12	28° 41' 5"	79° 48' 56"
13	28° 40' 27"	79° 48' 58"
14	28° 39' 50"	79° 48' 48"
15	28° 39' 4"	79° 48' 50"
16	28° 36' 43"	79° 48' 27"
17	28° 35' 1"	79° 48' 16"
18	28° 30' 37"	79° 47' 27"
19	28° 30' 37"	79° 42' 12"
20	28° 14' 0"	79° 40' 54"
21	28° 14' 0"	79° 45' 12"
22	28° 11' 41"	79° 45' 4"
23	28° 8' 2"	79° 44' 37"
24	28° 4' 42"	79° 44' 25"
25	28° 1' 20"	79° 44' 11"
26	28° 0' 0"	79° 43' 59"
27	28° 0' 0"	79° 38' 16"
28	28° 11' 42"	79° 38' 13"
29	28° 23' 2"	79° 38' 57"
30	28° 36' 50"	79° 40' 25"
31	28° 38' 33"	79° 41' 33"
32	28° 38' 20"	79° 43' 4"
33	28° 41' 0"	79° 43' 39"
34	28° 48' 16"	79° 44' 32"
35	28° 54' 29"	79° 45' 55"
36	29° 0' 0"	79° 45' 50"

Table 3. Coordinates for the proposed Allowable Golden Crab Fishing Area - Southern Zone.

Point	Latitude N (Degrees Minutes Seconds)	Longitude W (Degrees Minutes Seconds)
1	24° 14' 7"	80° 53' 27"
2	24° 13' 46"	81° 4' 54"
3	24° 10' 55"	80° 58' 11"

Following Point 3, area boundary follows the EEZ northward to Point 1.

Appendix I. Summary of monitoring methods

The intent of this summary is to provide the reader with more detailed technical information on various methods of fisheries monitoring. Depending on whether the fishery is being monitored for bycatch, overall characterization or compliance with regulations, these methods will vary in their appropriateness and effectiveness. Some of these methods may be appropriate ways to monitor the golden crab fishery in the South Atlantic.

Onboard Observers

Onboard observers are used in several U.S. fisheries to collect biological data. Usually only a portion of the trips conducted by the fleet are required to have observers on them. Some international fisheries have required 100% observer coverage and in some cases, the observers have also been responsible for reporting violations of regulations. Onboard observers are typically the most expensive means of collecting biological data. In the U.S. at-sea observers have usually been paid for through NMFS or fishermen or through a cost-sharing arrangement.

South Atlantic Snapper Grouper Pilot Program (4/06-5/07 and ongoing)

In 2006, the Gulf and South Atlantic Fisheries Foundation conducted a pilot study to characterize the catch and fate of discards in the snapper grouper vertical hook-and-line fishery of the South Atlantic. The major goals of this program were to gather catch, effort, and disposition data. Beginning in late 2006, two fishery observers were trained and began onboard observation. So far, this research has placed observers on board over 19 different commercial fishing vessels and accumulated over 130 observed sea days. Although formal data analysis has not begun, preliminary analysis shows an average of 7 days per trip and 55 sets per trip. However, there was considerable variance depending upon the size of the vessel with a range of trip length from 2 to 11 days and number of sets from 14 to 113. Analysis of catch and discard fate began in the Fall of 2007 and a presentation was made to the South Atlantic Fishery Management Council at their June 2008 meeting. The intent of this project was not to form a stand-alone dataset, but to augment currently available datasets (Jepson, 2007). Catch characterization trips were completed in all four South Atlantic states with eight (8) trips in NC, ten (10) in SC, six (6) in GA and four (4) in FL. Trip lengths ranged from 2 to 13 days with an average of 7 days per trip overall. The number of sets per trip ranged from 14 to 142 with an overall average of 61 sets per trip. Trip length varied with vessels from North Carolina making shorter day trips averaging 4 days in length, while vessels in the three other South Atlantic states averaging longer trips closer to the overall average of 7 days. A final report for this project is currently under development.

Electronic Monitoring (EM)

Electronic (video) monitoring has been used in the British Columbia Limited Access Program fisheries, some Alaskan fisheries (crab), the Pacific whiting fishery, among others. Pilot programs to determine the feasibility of using EM in general and the *data review issues. While such an approach is necessary when testing the applicability of a given technology, it does serve to possibly over-inflate the total cost of an effective EM program.*

The document by Kinsolving (2006) includes an overview of the 2005 Kodiak electronic monitoring project where two video monitoring systems are compared. Cost projections were based on the assumption of 18 boats, where each boat fishes an average of 7 trips, and trip length will average 3 days, of which there is 24 hours of activity to review. Total minimum and maximum costs are laid out in the document. Total equipment costs (including installation and maintenance) per vessel ranged from $5,875 to $13,325 per year. The cost of maintenance and storage was estimated at $100 per trip. Although data review costs could vary enormously depending on how much data are reviewed, the document assumes that a full review would cost approximately $50,000 per year for all vessels together (see table below).

2) McElderry et al. (2003) conducted a large scale deployment of electronic monitoring systems on the 2002 BC halibut longline fishery to evaluate the feasibility of EM as an alternative to observer-based at-sea monitoring. Two cameras per vessel were used for this project. In some cases, at-sea observers were deployed on the same vessels as the EM system. In these cases, comparisons could be made between observer and reviewed EM video to determine accuracy of recorded information. The authors note that overall, EM and observer catch estimates agreed within 2% and individual identifications by hook agreed in over 90% of the catch records. They also note that there was close agreement between EM and observers regarding whether a fish was kept or discarded and the time, location, and depth at the set start and finish. The authors concluded that EM is a promising tool for at-sea monitoring applications depending on specific fishery management objectives regarding monitoring. They also note it would have a substantially lower cost than at-sea observers. They suggest two ways to use EM for the BC longline fishery: 1) an integrated EM-observer program using both methods in a complimentary fashion to achieve fleet sampling objectives; and 2) using EM and an electronic fishing log as an at-sea monitoring audit tool. While at-sea observers cost ca.$320 per vessel per day for fishermen and ca.$130 per day for the federal government, EM cost about $210 per vessel per day (see table below).

3) McElderry et al. (2004) assessed the feasibility of electronic monitoring for the Cape Cod longline haddock fishery where bycatch rates of cod must be closely monitored. The primary objectives of the project were to evaluate the effectiveness of electronic monitoring in estimating the at-sea catch of haddock and cod, assess the suitability of EM systems for various components of the fleet, obtain skipper and crew feedback on EM suitability, and foster fleet education on EM monitoring as well as verify EM derived catch information by comparison with like data from observers. Two cameras per vessel were used for this pilot program. Costs were estimated at $1,200 per vessel per day for the pilot project (see table below). A full EM program cost per vessel is suspected to be much less. In general, McElderry (2003) estimated that EM programs run between 20-60% of the cost of an at-sea observer program.

McElderry et al. (2004) provide information on an EM program for the British Columbia groundfish longline fishery that involves less than full data review requirements. They write:

One possible fleet monitoring design might involve large-scale deployment of EM systems on the fleet with image data selectively analyzed according to a specific sample design. In this way, the analysis effort changes from full interpretation of all imagery from a fishing trip to sampling the fleet, monitoring imagery for sets or portions of sets. British Columbia's groundfish longline fishery is adopting this approach to provide full catch accountability in their 17,000-seaday fishery. Fishing vessels will carry EM systems on a fishing trip and fishers will keep a careful record of catch in an electronic fishing log (included as part of the EM system). The logbook data will be audited with catch data from EM imagery and the level of agreement will prescribe the amount of image viewing required. This unique monitoring approach provides cost effective monitoring, more actively engages industry in data collection, and, when analysis cost is applied individually, provides a positive stimulus for accurate catch accounting by industry.

Table Summarizing Pilot Program Evaluation of the Use of Electronic Monitoring (EM) for Various Fisheries.

Type of fishery	Discard concerns?	Equipment costs	Data review costs
Alaska Rockfish Trawl	Yes	$5,900-$13,300 per vessel annually	$50,000 for all vessels per year
Cape Cod Longline for Haddock	Yes, cod	(two cameras) $1,200 per vessel per day for pilot project, developed EM program would be less costly	Not specified, paid for by federal government
BC Halibut Longline Fishery (LAP fishery)	Yes, various rockfish species	(two cameras) ca.$210 per vessel per day	Not specified, paid for by federal government

References

Kinsolving, Alan. 2006. "Discussion Paper on Issues Associated with Large Scale Implementation of Video Monitoring". National Marine Fisheries Service.

McElderry, H. 2003. Sustainable Fisheries Management Using Electronic Fisheries Monitoring. Seafood NZ. 11(6).

McElderry, H. J. Schrader, and J. Illingworth. 2003. The Efficacy of Video-Based Electronic Monitoring for the Halibut Longline Fishery. Fisheries and Oceans Canada Research Document 2003/042.

McElderry, H., J. Illingworth, D. McCullough, and J. Schrader. 2004. Electronic Monitoring of the Cape Cod Haddock Fishery in the United States – A Pilot Study. Unpublished report prepared for Cape Cod Commercial Hook Fishermen's Association (CCCHFA) by Archipelago Marine Research Ltd., Victoria, BC Canada.

Electronic Logbooks

Electronic logbooks improve the accuracy of data collection at the species level by allowing fishermen to report catch data at sea throughout a fishing day rather than reporting pounds of fish as determined by the dealer. The electronic logbooks also enable the collection of more accurate bycatch information by allowing the reporting of bycatch while at sea at the time of the actual discard. Additionally, electronic logbooks also offer practical business benefits for the user (fishermen) in that all data that are recorded are available for the fishermen; they can see their data overlaid on nautical charts by species, by area, and by time period. Fishermen also have the ability to see their own catch per unit effort statistics for different time periods.

South Atlantic Electronic Logbook Pilot Project

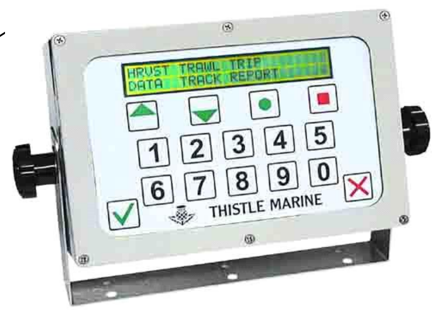
Electronic logbooks have been used in several fisheries in the U.S. including fisheries in New England. As required by Amendment 4 to Snapper Grouper Fishery Management Plan, commercial fishermen fishing for South Atlantic snapper grouper have been required to fill out a paper logbook since 1992. In 2002, the SAFMC and Technology Planning and Management Corporation (TPMC) (now Perot Systems Government Services [PSGS]) tested the use of electronic logbook reporting using the Thistle Marine™ electronic logbook. This device is "ruggedized" for small boat fisheries and is designed specifically for fisheries logbook recording and biological sampling during fishing operations. The project examined the proposition that an electronic logbook can collect all of the data elements presently required by the paper logbook program and can collect more accurate and comprehensive bycatch and catch location information.

The Thistle Marine HMS-110, (Thistle box), is an off-the-shelf device that is ideally suited to electronic data collection on small, open wheelhouse vessels such as those in the snapper/grouper fishery. The device is totally self-contained, weatherproof, and can be operated with a gloved hand. Power is supplied through a cable that is plugged into the back of the device and connected to the boat's 12-volt power supply. The same cable also interfaces the Thistle box with the vessel's GPS unit using a standard NMEA (National Marine Electronics Association) connection. After a fishing trip, the fisherman brings the unit home, connects it to the phone line, and sends and saves the data on Thistle Marine's secure website. The unit's ease of installation and durability make it ideal for small fishing vessels where 110-volt power is not available for a PC or an open wheelhouse precludes having a computer onboard.

The 2002 project was implemented on two commercial snapper/grouper vessels in South Carolina and North Carolina from May, 2002 through November, 2002. The electronic logbook pilot program recorded:

- Number of fish caught (although pounds can be recorded instead, number of fish was more expeditious in this case)
- Number of fish discarded
- Number of crew
- Number of lines
- Number of hooks per line
- Date (when interfaced with vessel's GPS)
- Time (when interfaced with vessel's GPS)
- Location (when interfaced with vessel's GPS)

The second major goal of this project was to examine the feasibility of using an electronic logbook to record biological



information on the catch that is retained and on the component that is discard. A final presentation was given to the Council and Snapper Grouper Advisory Panel at their December 2002 meeting and the results were well received by the fishermen involved, members of the Snapper Grouper Advisory Panel, and by Council members[1].

By far, the greatest challenge to implementing an electronic logbook on a commercial fishing vessel is integrating the data collection flow into the vessel's

[1] The pilot project collected over four thousand data points representing nineteen commercial snapper grouper trips aboard two bandit vessels. Thirteen hundred catch observations were recorded representing just over five hundred anchor sets. Both landed catch and discards were recorded in numbers of fish for twenty-nine different species. In addition, the electronic logbook recorded nearly twice as many species landed per trip than the paper logs. The reason for this is most likely a result of recall error when filling out paper logs and the seafood dealer's practice of combining smaller quantities of fish of different species and reporting them as one.

fishing operations. Almost all of the time spent on this pilot project and most of the programming changes made to the Thistle box were to fit data collection into the workflow of the fishermen during fishing operations.

When interfaced with the vessel's GPS, the Thistle box can be viewed as an "event" recorder. Each event that is entered is stamped with the date, time, and location from the GPS receiver. In the lobster fishery where the system was first conceived, an event is each time a trap is hauled or a string of traps is hauled. For the snapper/grouper fishery pilot project, TPMC identified the events associated with the way bandit fishermen fish their gear. When the fisherman identifies where they want to fish, they drop anchor and remain in that location until they are done fishing and prepare to move on to another location.

After dropping anchor, the fisherman will record the event on the Thistle box, noting the date, time, and location of the event. When fishing is complete, the fisherman will note that event by recording the pounds of fish kept by species and the number of fish discarded by species. The date, time, and location would again be recorded to complete the overall fishing record for this site. A trip would be composed of a number of these two events at each fishing site.

drop anchor ⟶ **fish** ⟶ **haul anchor** ⟶ **record data**

This pilot program was funded again in 2004 and 2005 and applied to a larger number of vessels.

It should be noted that all participants found the charting capabilities of the P-Sea WindPlot software to be an excellent addition to their standard electronic navigation equipment. However, the use of these computer systems has not been without a few minor issues, considering the corrosive environment in which they have been deployed.

Although not yet developed for the electronic logbook pilot programs in the South Atlantic, it has been suggested that electronic logbook data could be submitted via a VMS satellite transmission. This would enable real-time data collection.

Appendix J. Summary of Scoping Comments on Comprehensive Ecosystem-Based Amendment 1

The Council, with assistance NMFS staffs, held a series of public meetings from February to June 2005 to seek input regarding ecosystem objectives for fisheries management in the South Atlantic region. The meetings were intended to facilitate wide-ranging discussions with stakeholder groups and the general public in eight topic areas:

i. views regarding the adequacy of current approaches for addressing ecosystem considerations;
ii. the nature of ecosystem-based management and the goals to be achieved in addressing ecosystem issues;
iii. the nature of the public decision making processes within the FMCs for addressing management tradeoffs, consistent with identified goals;
iv. mechanisms for considering activities outside the FMC's purview but influencing ecosystem productivity;
v. the boundaries of sub-regional ecosystems within the areas of the various FMCs;
vi. the types of management measures that would be incorporated into ecosystem approaches for fishery management, consistent with the identified goals;
vii. the specific regional issues that need to be addressed in a fishery ecosystem plan (FEP);
viii. techniques for determining success of ecosystem-based management; and
ix. other issues considered important to the stakeholders in any particular region.

Summary of Comments:

The vast majority of comments were in support of implementing an ecosystem-based approach to fisheries management in the South Atlantic region.

Conservation organizations strongly supported the Council's approach to ecosystem-based management of fishery resources. One conservation representative stated two main reasons for his agency's support:

1. The importance of an ecosystem-based approach in the South Atlantic region in particular, given the disproportionate importance of food chains and a diversity of habitats and life histories of managed species, and
2. The potential for the region to serve as a model for the nation on how to pursue effective ecosystem-based management.

Suggestions:

- The relevance of accurate, timely social science information as a framework for this process is essential.
- The state-of-the-art information about the way the energy flows through these ecosystems and the degree to which different habitats function to sustain and alter production of target species is a key ingredient.
- Perform a comprehensive assessment of the overall governance framework itself to look at identifying key policy gaps or key governance gaps.
- Perform cost-benefit analyses.
- "Map" all NMFS and NOS individuals working on ecosystem projects; this should identify their location, contact information, description of project, level of funding and so forth.
- Specify, to the extent it can be done, the necessary freshwater inflows for sustaining spawning and nursery habitats, as well as nearshore ocean habitats.
- Model the impacts of coastal development on the fisheries, i.e., highlight the connection between habitat degradation, and the loss of fishery productivity, noting that all the management measures in the world will be ineffective, unless habitat quantity and quality are maintained.
- Develop indicators of ecosystem health that can be used throughout the Council's jurisdiction.
- Develop habitat-production relationships for all species, especially for species associated with deepwater corals.
- Identify those habitats for which mapping is incomplete or non-existent, and identify resources and strategies for obtaining the information. This should include mapping of subtidal oyster bed habitats, and Submerged Aquatic Vegetation habitats.

Several commenters reiterated the importance of "getting the science right" underlying the human uses of the ecosystem. They felt at the time that we fell short on knowing how fishing activity and shifts in effort affected ecological cascades that ramify into others.

One commenter stated that agencies have not done a very good job historically of addressing cumulative impacts. An ecosystem-based approach is really the only way to have any success; taking a comprehensive look at the entire system and interrelated species.

One commenter noted that there are currently many deepwater species that are not managed at all and a framework for managing those species was needed.

One commenter stated that episodic kill events should be considered in the plan as well. She noted in the recent hurricanes, there were some relatively massive kills attributed to low DO and these events would certainly have impacts on efforts to quantify biomass.

It was noted that deepwater habitats have huge holes in the data. It will be a challenge to put together an ecosystem management approach, when we are just discovering what lives there. We don't know how deepwater species use the habitat. The first step should be to map the habitat, the different communities and the species using them. Indices of ecosystem health, which appear to be relatively easy to define, will be challenging for deepwater coral areas.

It was noted that the political challenges to management in the coastal areas are very different that in deepwater. We should feel no compulsion whatsoever to repeat any of the mistakes we have made in the coastal areas. We shouldn't let habitats get severely impacted before there is any action. We should be in a proactive mode. We should view this as an opportunity and a challenge, not to repeat mistakes that have been made in the coastal zone.

One commenter asked how exotic species would be handled. He noted this is important in the inshore areas (i.e. *Phragmites*) as well as offshore (i.e. lionfish)

It was noted that fishery-independent data, especially for inshore ecosystems, were lacking.

One commenter noted that NMFS has refused to designate EFH for anadromous fish, despite the request they do so.

It was noted that blackbelly rosefish are landed incidental to the wreckfish and snowy grouper fisheries. It is a small fishery, for a very slow-growing fish. The same is true for red bream and barrelfish, both of which are widely-distributed species. The commenter noted that the orange roughy fishery used paired trawls in deepwater habitats, so he is aware that it can be done. There is concern that fisheries for deepwater species could develop in the South Atlantic region.

One commenter asked whether there were any incentives for commercial fishermen to develop less damaging gear to fish in deep water. He noted that TEDs and other gear for reducing bycatch were developed primarily by commercial fishermen.