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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TABLE OF CONTENTS

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

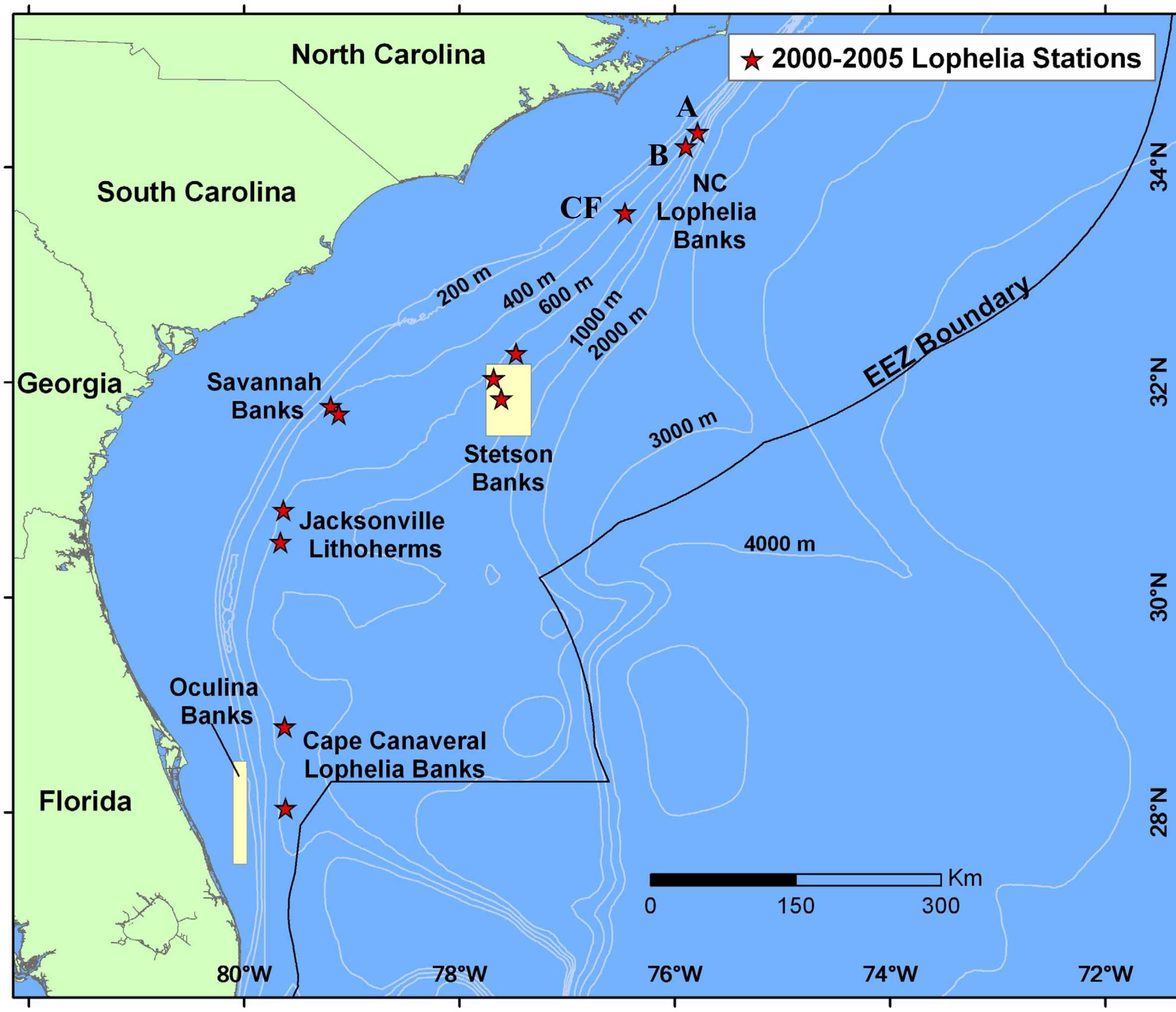

Figure 1. Ross et al. deep coral study sites (red stars), 2000-2005. CF=Cape Fear.

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

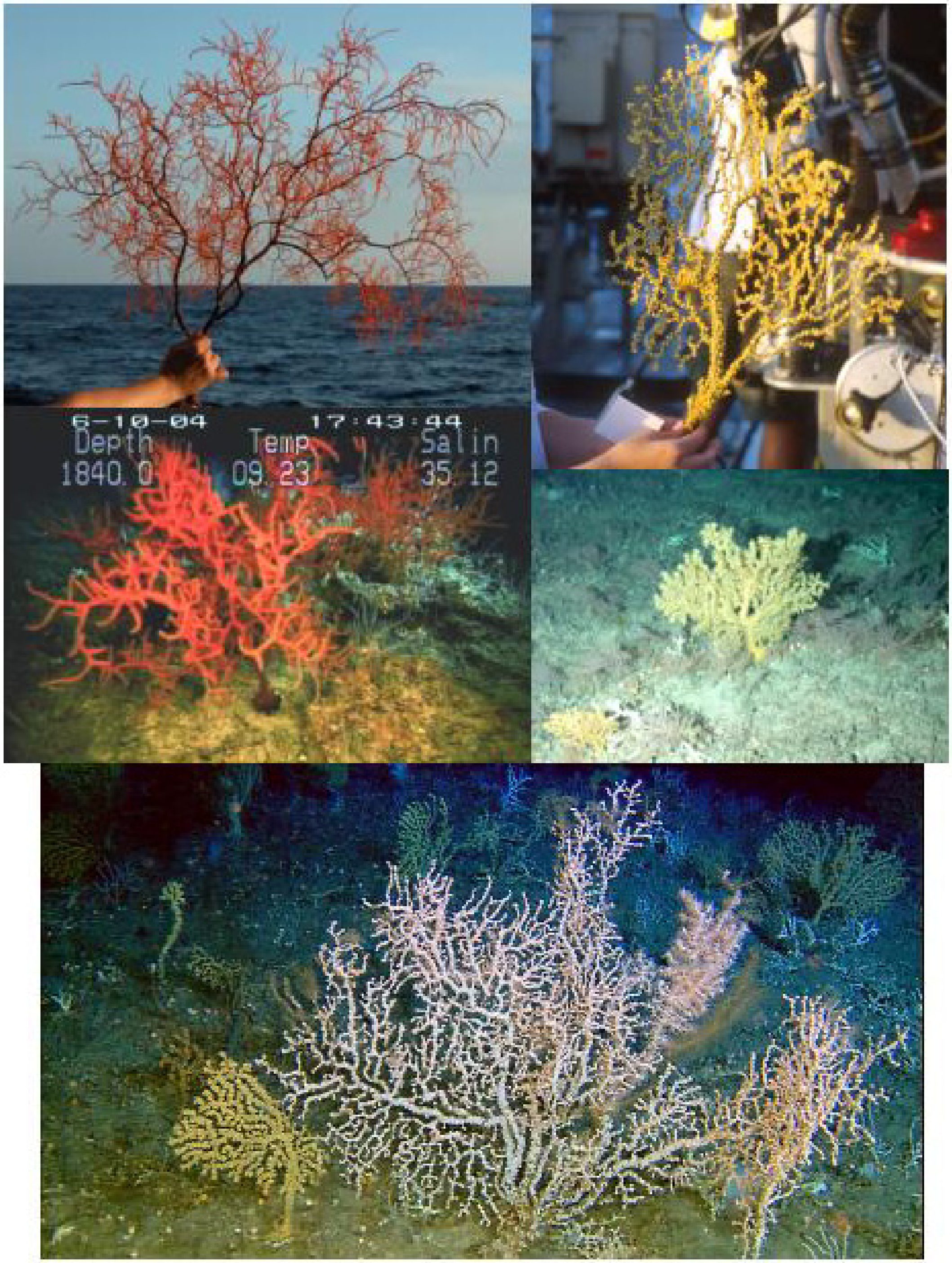

Figure 2. Selected views of Black corals and Bamboo corals on the Blake Plateau (Ross et al., unpubl. data).

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

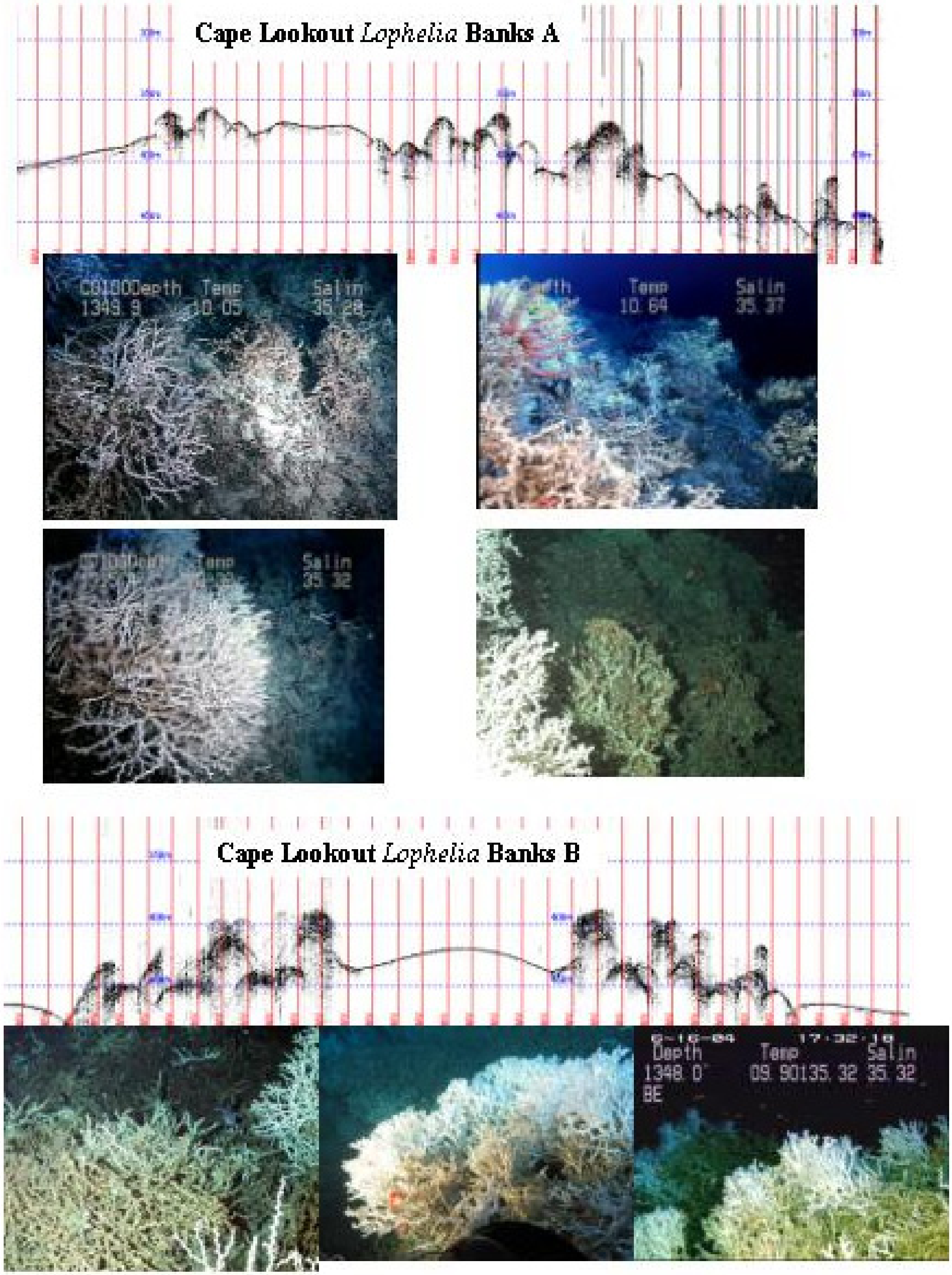

Figure 3. Selected views of *Lophelia pertusa* habitat and depth sounder recordings for the two deep coral mounds off Cape Lookout, NC (Ross et al., unpubl. data).

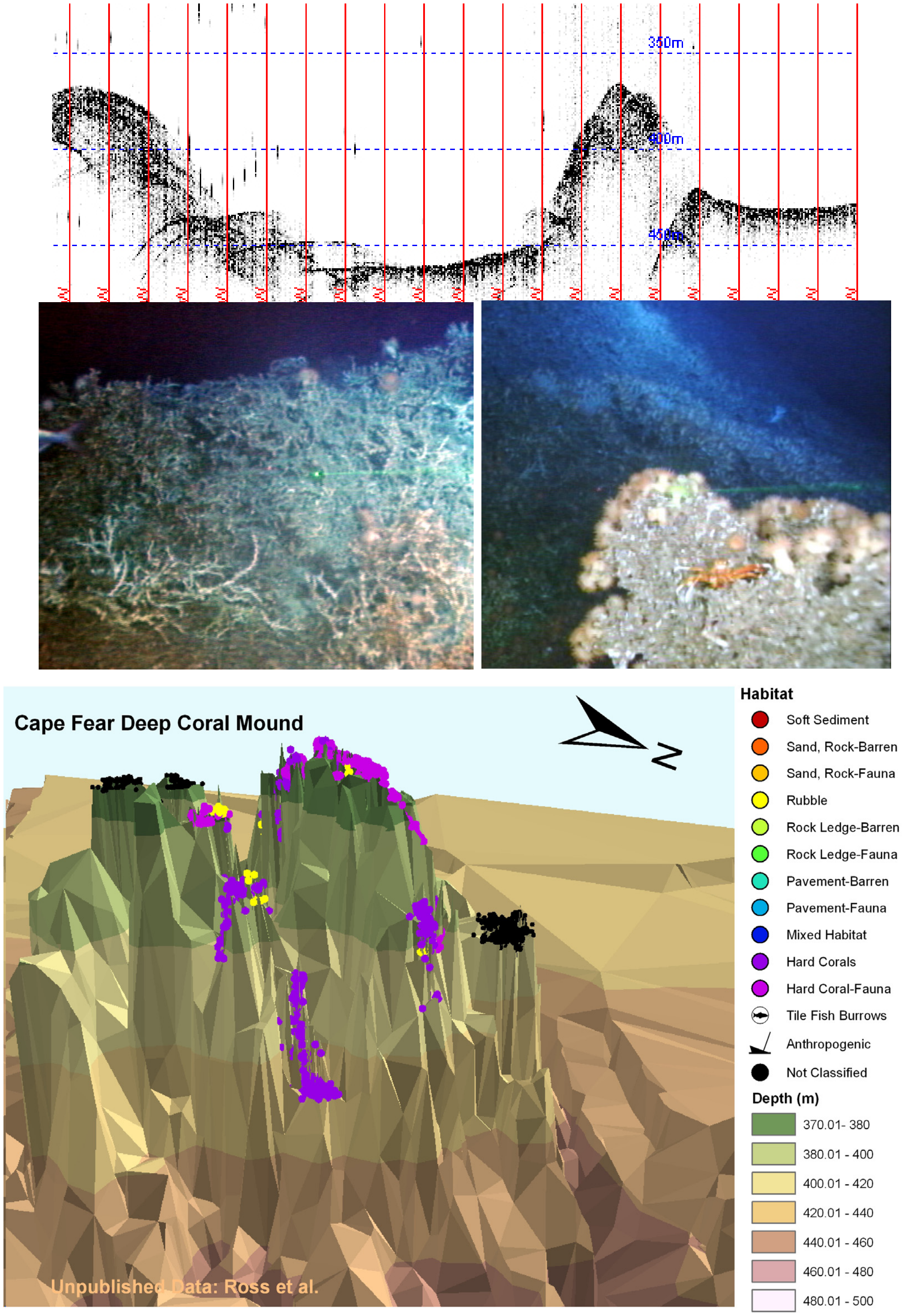

Figure 4. Selected views of the deep coral mound off Cape Fear, NC. Bottom panel is a 3-D reconstruction of this feature with general habitat classifications (SEADESC) from JSL dives (S.W. Ross, unpubl. data).

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

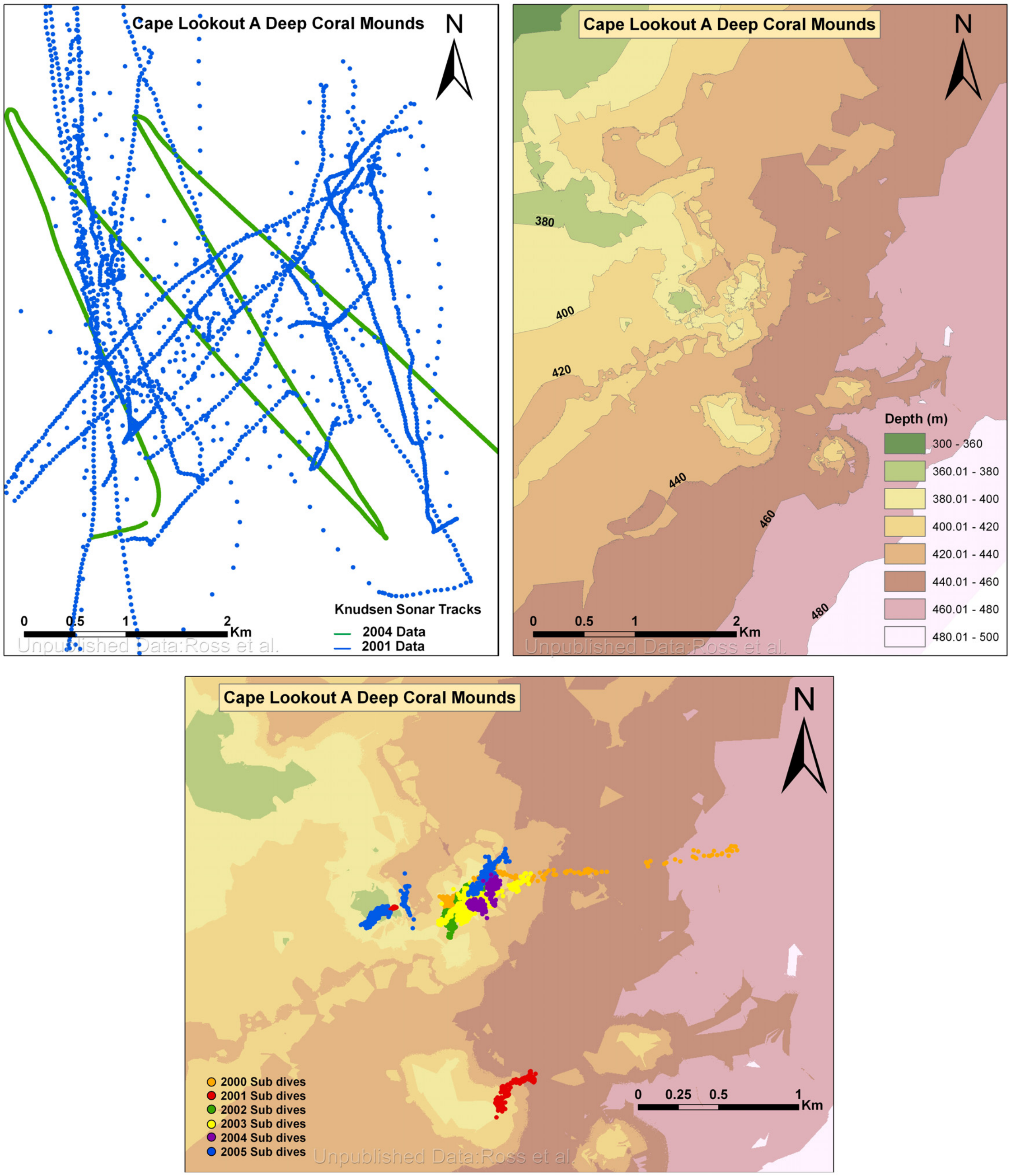

Figure 6. Ship collected sonar tracks (top left) and resulting bathymetry maps (top right) from the deep coral area off Cape Lookout, NC (A). In this area additional data from our files were added for the bathymetry map. Bottom panel shows JSL submersible dive tracks in this area from 2000-2005. All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 (unpublished).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

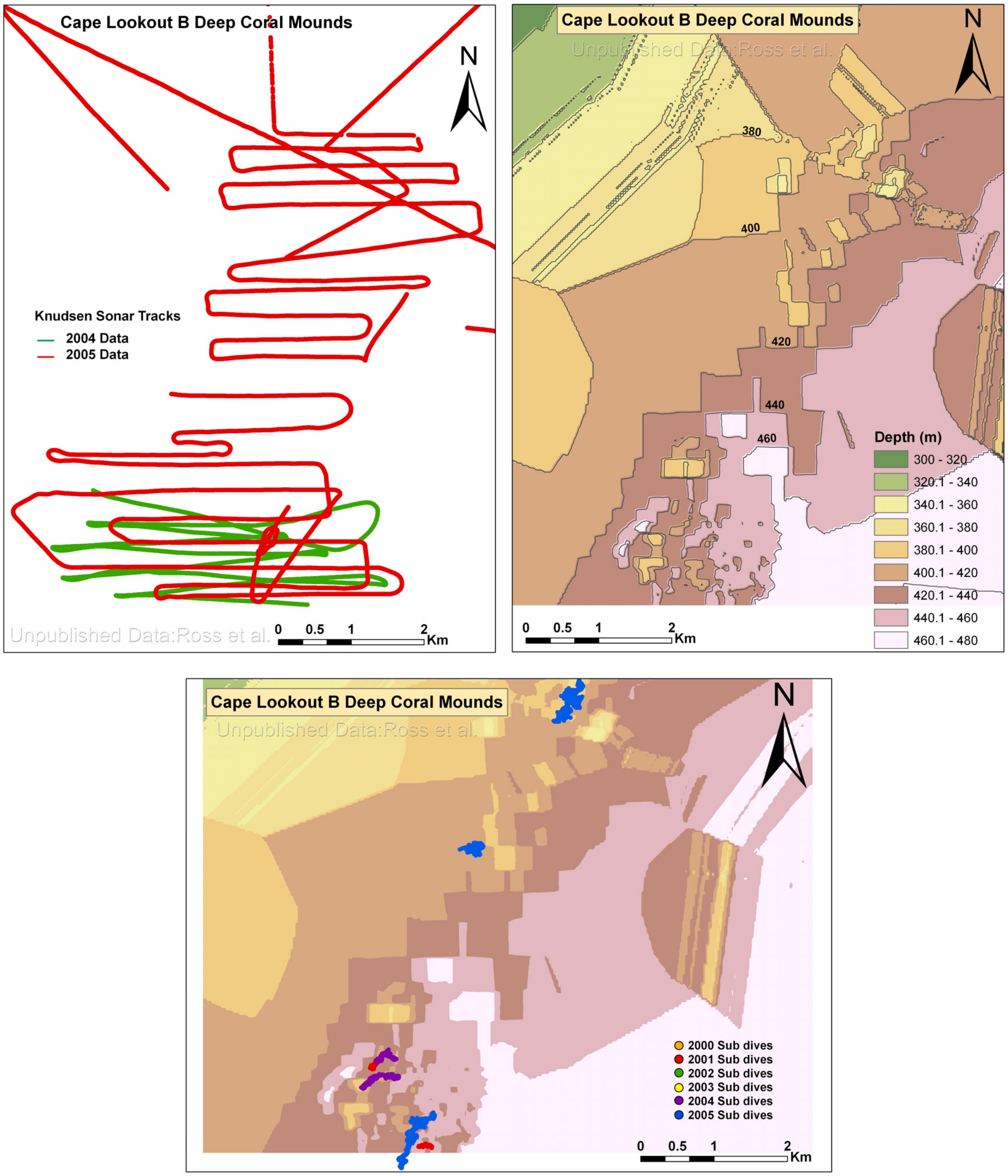

Figure 7. Ship collected sonar tracks (top left) and resulting bathymetry maps (top right) from the deep coral area off Cape Lookout, NC (B). Bottom panel shows JSL submersible dive tracks in this area from 2000-2005. All data are from Ross et al. (unpublished). See Fig. 1 to locate this area.

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

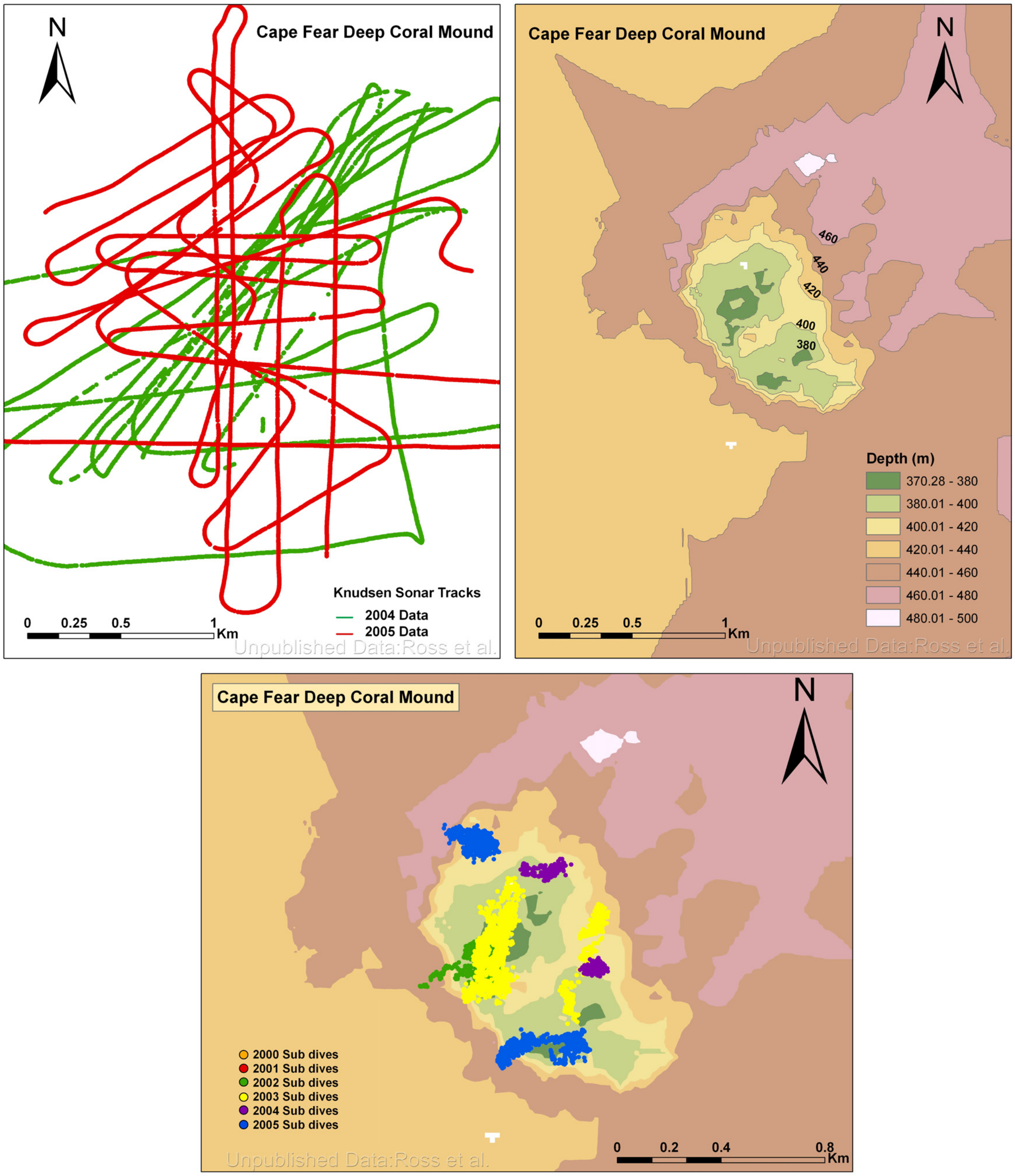

Figure 8. Ship collected sonar tracks (top left) and resulting bathymetry maps (top right) from the deep coral area off Cape Fear, NC. Bottom panel shows JSL submersible dive tracks in this area from 2000-2005. All data are from Ross et al. (unpublished). See Fig. 1 to locate this area and Fig. 4 for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

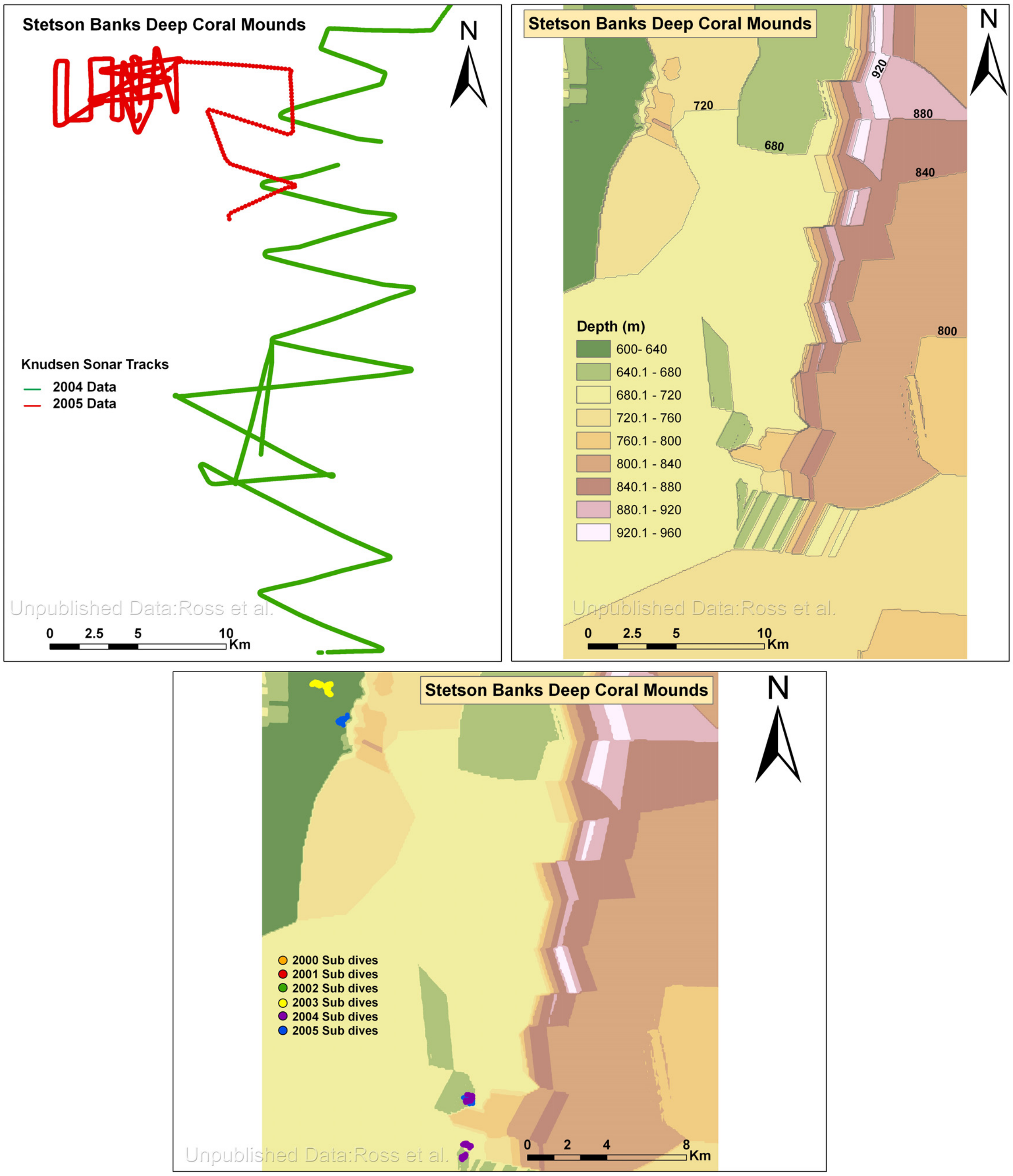

Figure 9. Ship collected sonar tracks (top left) and resulting bathymetry maps (top right) from the Stetson deep coral area off of SC. Bottom panel shows JSL submersible dive tracks in this area from 2000-2005. All data are from Ross et al. (unpublished). See Fig. 1 to locate this area.

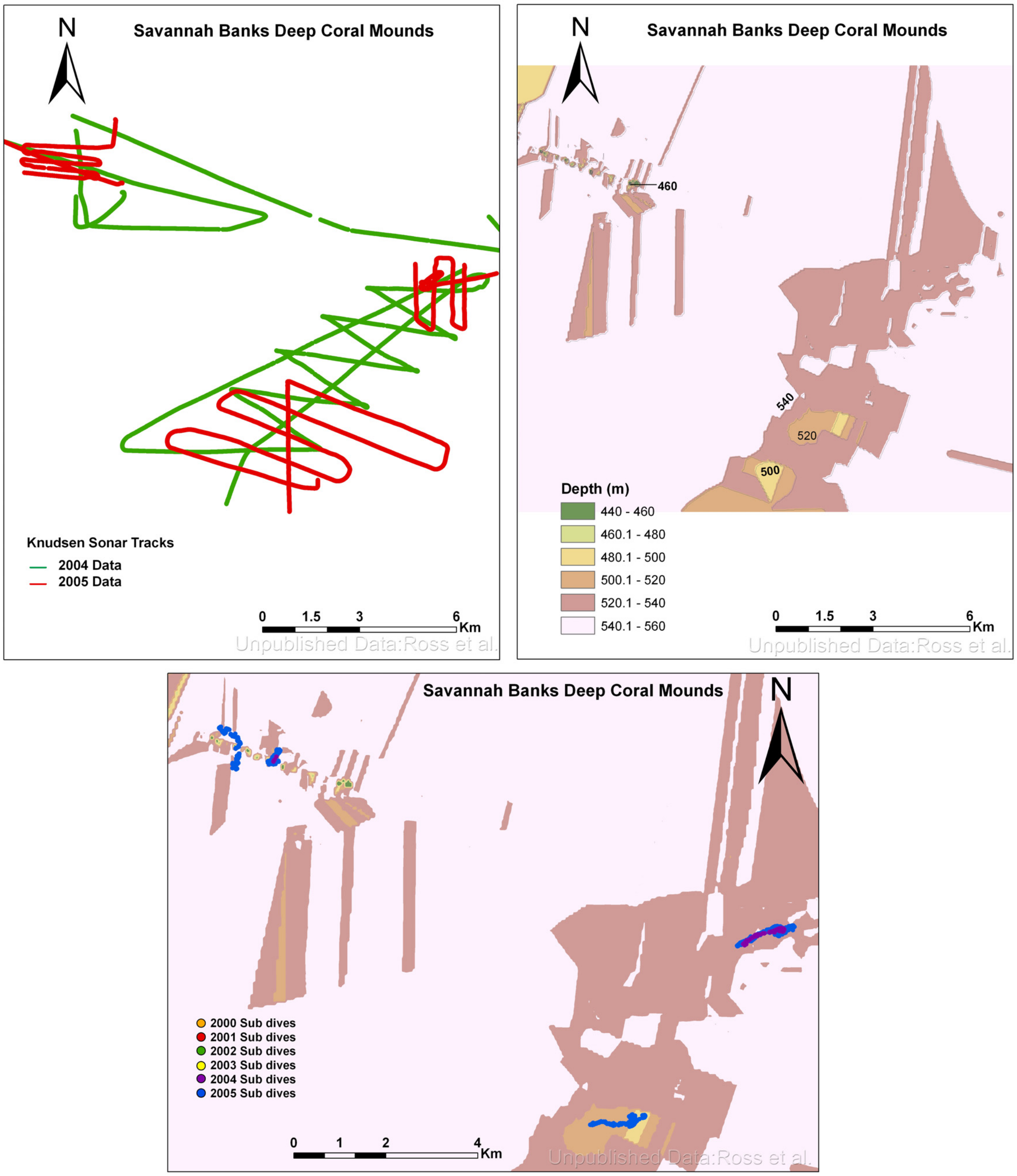

Figure 10. Ship collected sonar tracks (top left) and resulting bathymetry maps (top right) from the Savannah Banks deep coral area off of SC-GA. Bottom panel shows JSL submersible dive tracks in this area from 2000-2005. All data are from Ross et al. (unpublished). See Fig. 1 to locate this area.

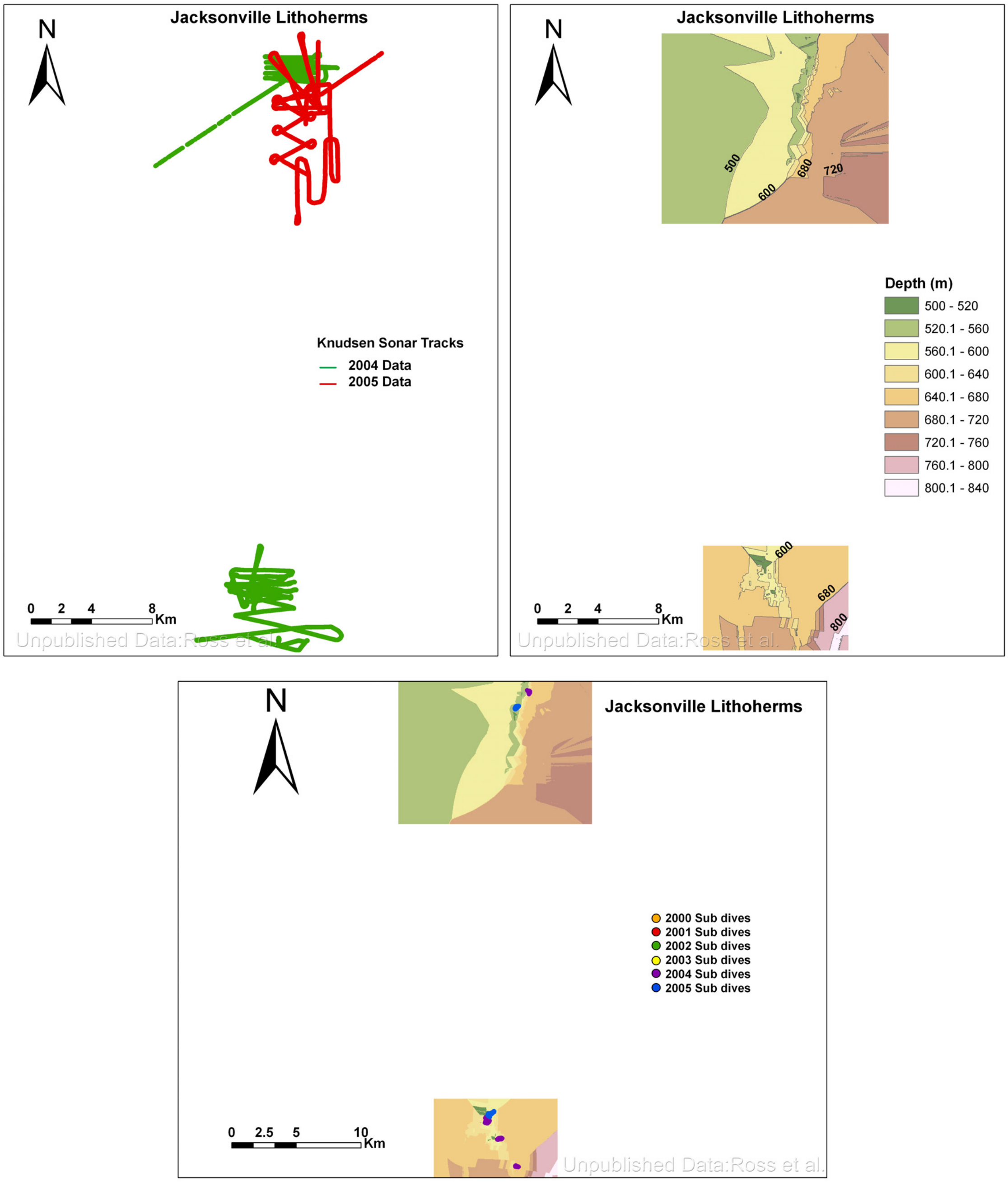

Figure 11. Ship collected sonar tracks (top left) and resulting bathymetry maps (top right) from the Jacksonville Banks deep coral area off of GA-FL. Bottom panel shows JSL submersible dive tracks in this area from 2000-2005. All data are from Ross et al. (unpublished). See Fig. 1 to locate this area.

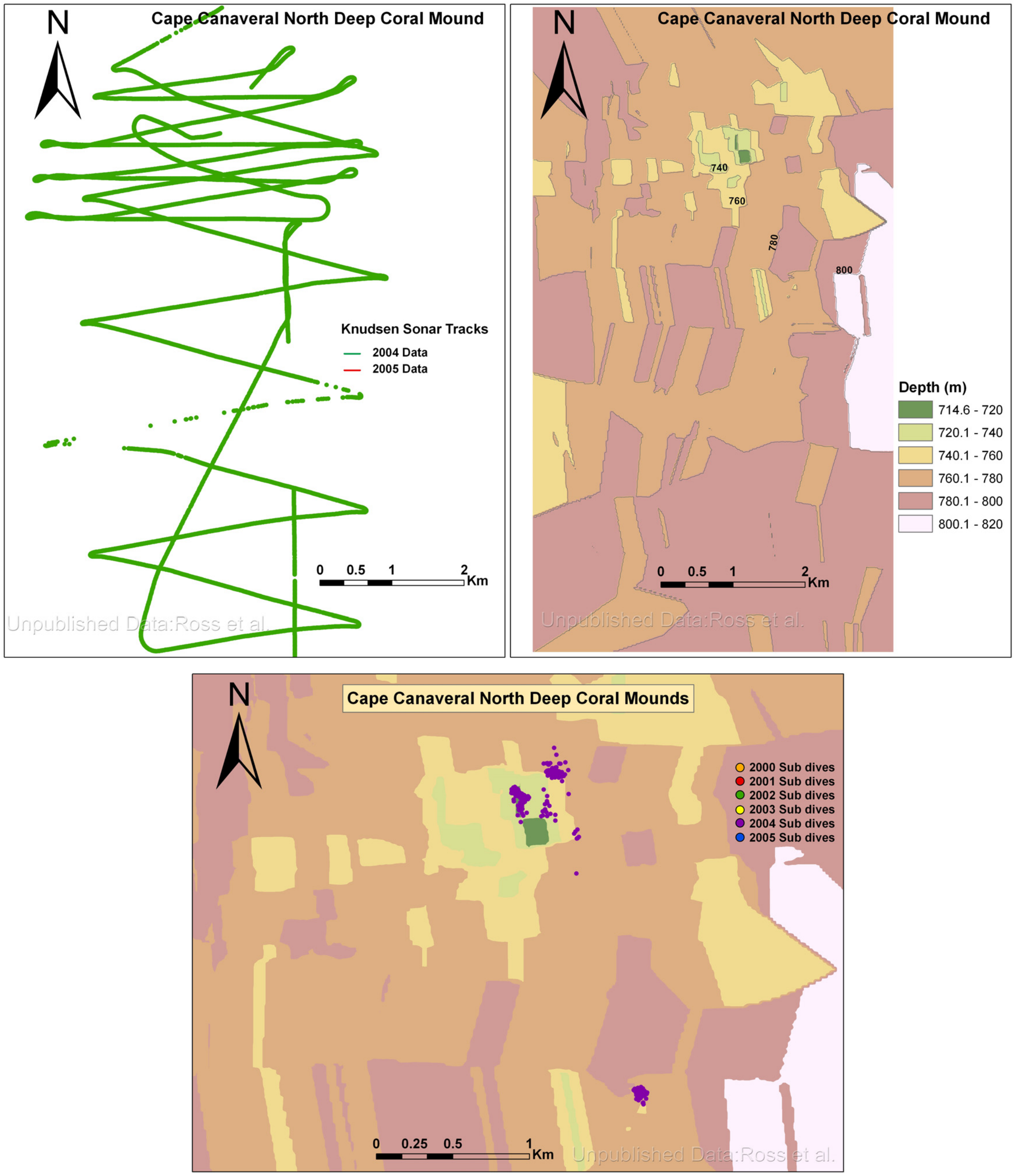

Figure 12. Ship collected sonar tracks (top left) and resulting bathymetry maps (top right) from the deep coral area just north of Cape Canaveral, FL. Bottom panel shows JSL submersible dive tracks in this area from 2000-2005. All data are from Ross et al. (unpublished). See Fig. 1 to locate this area.

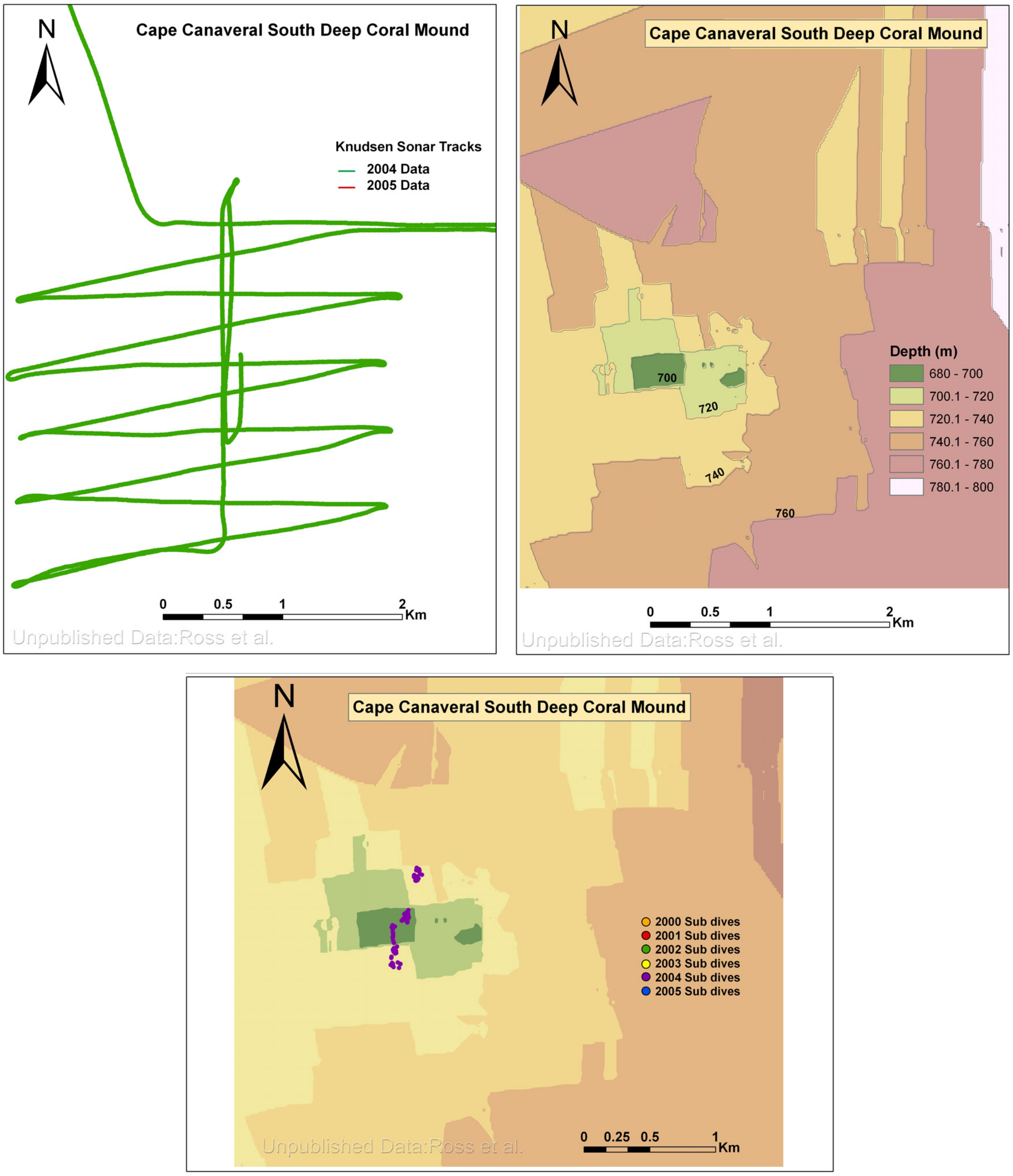

Figure 13. Ship collected sonar tracks (top left) and resulting bathymetry maps (top right) from the deep coral area just south of Cape Canaveral, FL. Bottom panel shows JSL submersible dive tracks in this area from 2000-2005. All data are from Ross et al. (unpublished). See Fig. 1 to locate this area.

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

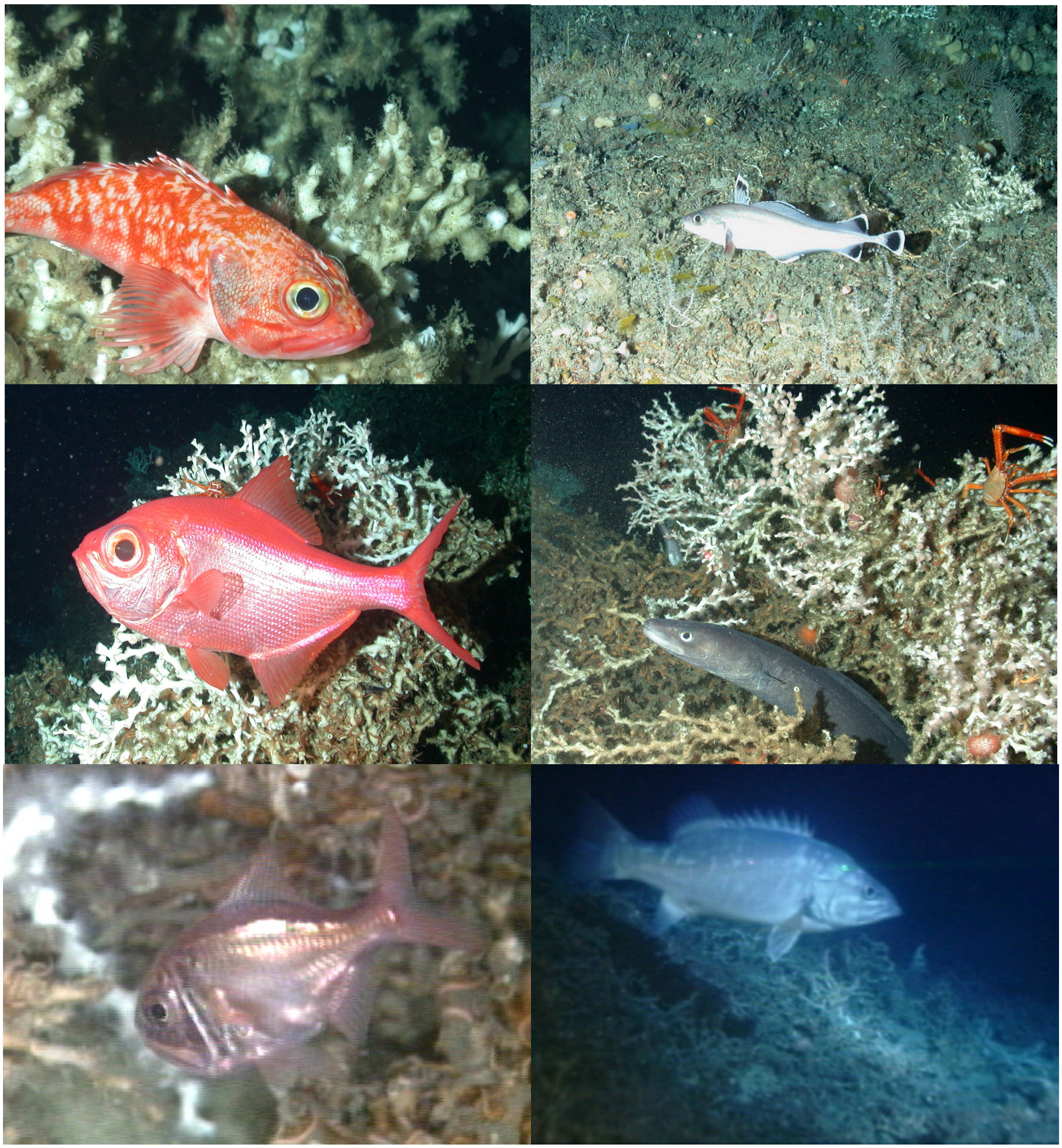

Figure 14. Selected deep reef fishes from coral banks off the southeastern United States. From left to right and top to bottom: *Helicolenus dactylopterus, Laemonema melanurum, Beryx decadactylus, Conger oceanicus, Hoplostethus occidentalis, Polyprion americanus.* All photos from Ross et al. (unpubl.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