Mounds, Depressions, Scarps and Caves: Exploration of Habitat and Species Diversity on the Charleston Bump and Blake Plateau

Final Project Report

by

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EXECUTIVE SUMMARY

This final project report summarizes field and laboratory activities aimed at exploration and description of unique, unusual and common habitat features on the Charleston Bump, adjacent Blake Plateau and nearby continental shelf-edge reefs, in depths from 46 - 567 m. We used a variety of technological tools and methods to map and describe bottom features and to observe and collect associated fish and invertebrate assemblages of those bottom habitats. Exploration was aimed at exploring poorly-known deep reef formations and habitats, and at investigation of benthic organisms living on hard substrates in deep water under a swift Gulf Stream with its associated variable hydrography. The habitats observed and sampled included hard pavements, scarps and associated caves and overhangs; scour depressions and deepwater coral reefs. We used historical data and shipboard sonar to map these bottom features, and examined, via submersible observations and collections, how sponges, corals, crustaceans, fishes, sessile and vagile organisms utilize coral mounds (and their associated sediments), caves, scour depressions, and scarps. Additional goals included comparison of faunas associated with these different habitat features, and to examine poorly-sampled habitats for new species. A submersible and associated oceanographic and sampling gear were used to collect data, specimens, photographs and videotaped transects that can be used to describe habitats, features, oceanography, and fish and invertebrate assemblages associated with bottom formations that varied in composition and topography. Fishes and large sessile epifauna were observed along videotaped transects. Suction and grab (scoop) samples were made of smaller invertebrates and cryptic fishes associated with complex bottom. Collections of sessile invertebrates such as sponges and corals were made to describe faunal assemblages that are intimately associated with these invertebrates. We obtained samples that can be used to compare faunas from sheltered habitats that are formed biogenically (e.g. coral mounds) or physically (e.g. caves), and unsheltered habitats (e.g. manganese-phosphorite pavements). In addition to coral mounds and caves, we explored scour depressions, overhangs, low outcrops, pavements, low-relief sponge/coral communities and other microhabitats and to make observations on their faunas. Fish and invertebrate communities sampled during this project will eventually be described in relation to biotic and abiotic factors that create habitat complexity and may influence biodiversity. Collections of corals were also obtained to determine growth rates for deepwater corals, because they are often subject to destructive fishing practices in other locations where they are important fish habitats. Corals were aged to develop growth models that will assist in conservation and restoration of deepwater coral banks. DNA samples were collected from corals and other taxa to contribute to existing libraries for future work on relationships and recruitment patterns of deepwater corals and other deep hard-bottom organisms in the western North Atlantic.

Fishes observed along videotaped transects were low in abundance and diversity, compared to similar surveys conducted at shallower (50-60 m) shelf-edge reefs. Video surveys also indicated that large sponges are dominant constituents of deep-water hard bottom communities in the Blake Plateau. Some deep-water sponge specimens may represent species new to science. Average abundances of sponges were estimated at approximately 0.05 per m^2 ($\pm$ 0.01), and included various sponge morphotypes such as vase sponges, “cake” sponges, and “cantaloupe” sponges.

The deepwater sponge *Chondrilla* sp. was dissected to remove faunal associates. A total of 163 organisms representing six taxonomic groups were identified. These faunal associates included several known commensal organisms. Comparisons of faunal associates on *Chondrilla* sp. from 2002, 2003 and 2004 Ocean Exploration cruises found similarities in dominant taxa, which could be attributed to the internal morphology of that sponge species. This represents the first study ever conducted on faunal associates of deep-water sponges.

Based on staffing and funding availability, future efforts will focus on more detailed taxonomic identifications and descriptions of invertebrate faunal assemblages associated with all of the habitats sampled. Eventually, we will have data to compare these deep assemblages to those from the coastal to outer continental shelf of the region.

Living colonial branching corals collected from a depth of approximately 600m on the Charleston Bump were ontogenetically microsampled. Coral specimens contained stable carbon and oxygen isotope and Sr:Ca profiles that often oscillated in tandem with visible growth bands apparent in cross section. Otherwise sinusoidal geochemical profiles were interrupted by zones of abrupt variation, suggesting periods of growth diminishment or cessation. This observed elemental and isotopic cyclicity may enable coral growth rate analysis and therefore facilitate future development of these corals as paleoclimate proxies. Preliminary data analysis suggests vertical extension rates of at least 1mm/y in some of these corals. This growth rate permits sub-annual isotopic and elemental sampling resolution.

Abundant fossil corals were present in the study area and the isotopic and elemental data contained in these fossils may represent valuable paleoclimate archives. The Charleston Bump is an area of significant relief and is situated so as to deflect the Gulf Stream, causing large-scale eddies and upwelling, such as the biologically productive Charleston Gyre. Therefore, unlike many other deepwater coral habitats, the Charleston Bump is comparatively dynamic with respect to temperature, current flow, and other climate-related variables. As such, coral climate proxies from this region may be sensitive indicators of past Gulf Stream variation.

A large number of educational web sites, news articles, popular articles and presentations have been based on some of the observations and results of this project. Several scientific publications and student theses are in preparation or have been completed.

PURPOSE

Project Rationale and Purpose

The Charleston Bump is a deepwater rocky bottom feature on the Blake Plateau southeast of Charleston, South Carolina (Fig. 1). It includes a shoaling ramp and ridge/trough features on which the seafloor rises from 700 m to shallower than 400 m within a relatively short distance and at a transverse angle to both the general isobath pattern of the upper slope, and to Gulf Stream currents (Brooks and Bane 1978). The Bump includes areas of nearly vertical, 100-200-m high rocky scarps with carbonate outcrops and overhangs; other complex bottom such as coral mounds; and flat hard bottom consisting of phosphorite-manganese pavement (Fig. 2; Popenoe and Manheim 2001; Sedberry et al., 2001). The bottom relief is important to deep reef species and supports the wreckfish (*Polyprion americanus*) fishery (Sedberry et al. 1999). It is also an important pelagic longlining area (Cramer 1996; Sedberry et al. 2001).

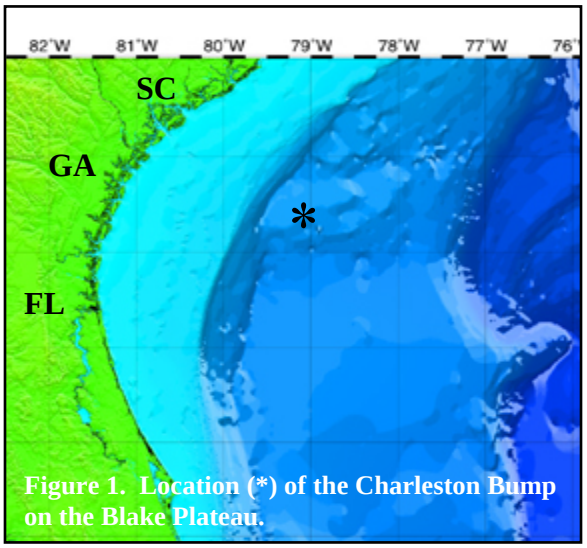


Figure 1. Location (*) of the Charleston Bump on the Blake Plateau.

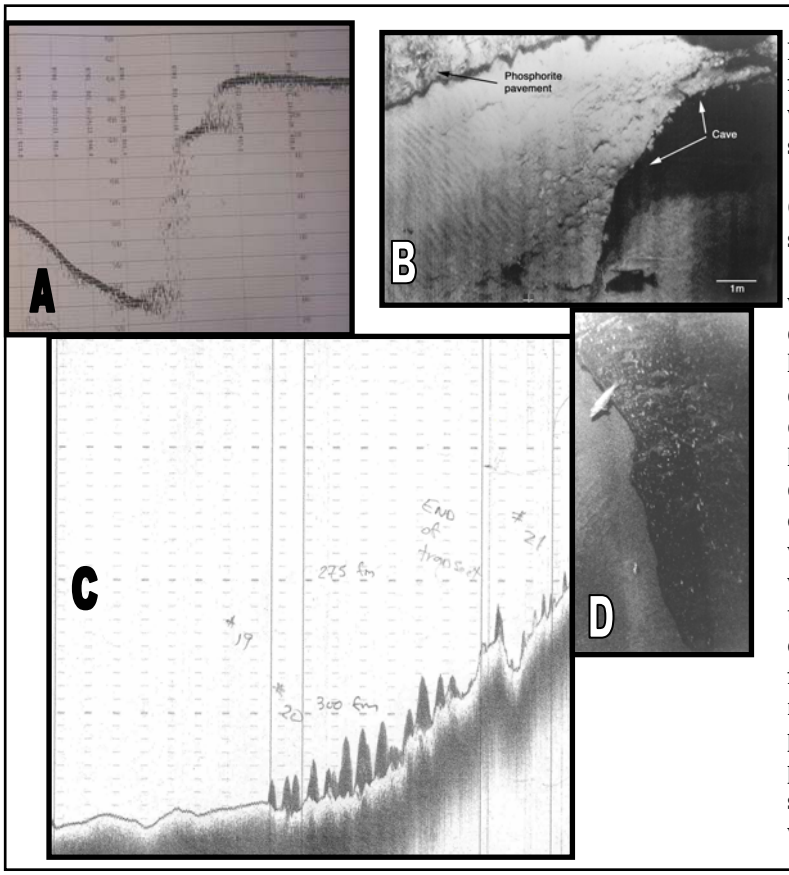


Figure 2. Bottom features observed with sonar and submersible (*NR-1*, 1990) on the Charleston Bump. A) sonar record of "Wreckfish Scarp" with caves and overhangs; vertical lines represent 200 m of horizontal distance; horizontal lines represent 12 m of depth. B) image of cave, overhangs and wreckfish associated with scarps such as that depicted in A; C) coral mounds seen on fathometer trace; D) manganese-phosphorite pavement (right) and sand (left), with a wreckfish.

The feature was first described by Brooks and Bane (1978), who noted that it deflected the Gulf Stream offshore. This deflection and the subsequent downstream eddies, gyres and upwellings may increase productivity and concentrate

fishes and other organisms along thermal fronts downstream from the Bump (McGowan and Richards 1985; Dewar and Bane 1985; Haney 1986; Collins and Stender 1987; Lee et al., 1991). Similar increases in productivity have been noted around other deepwater bottom features. The restriction of Gulf Stream flow between the shoaling bottom and the Florida-Hatteras Slope causes swift and variable flows in the Gulf Stream, and subsequent wide-ranging and unpredictable variation in bottom temperatures (Sedberry et al. 1999; Sedberry et al. 2004). These variable oceanographic conditions and swift currents undoubtedly make life a challenge for benthic organisms, particularly sessile species. Complex bottom features, however, might provide shelter from the current for many of these, and such features could harbor a number of unique species.

The Charleston Bump occurs on the Blake Plateau, a feature that dominates the continental slope off the southeastern U.S. The Blake Plateau has a relatively smooth topography from 700 to 1100 m depth, in contrast to the Bump itself, and to the steep continental slopes to the north, east and west. Relatively little is known about the deep continental slope of the U.S., relative to the shelf; however, important progress was made in the last quarter of the twentieth century in our understanding of community ecology and oceanographic processes in the waters beyond the continental shelf. Much effort since 1970 has concentrated on continental slopes and the adjacent rise. Some of this increased research effort has coincided with, or resulted from, development of deepwater fisheries for groupers (Serranidae), wreckfish (Polyprionidae) ocean perches (Scorpaenidae), tilefishes (Malacanthidae), alfonsins (Berycidae), roughies (Trachichthyidae), rattails (Macrouridae), medusafishes (Centrolophidae) and other groups. Ecological studies have concentrated on relatively dynamic and productive seamounts and submarine canyons (e.g. Rowe 1972; Haefner and Musick 1973; Able et al. 1982; Greene et al. 1988). Comparisons have been made of biomass and productivity between these relatively energetic areas to more tranquil open slope areas (Musick et al. 1975; Crabtree et al. 1991). Studies have compared more productive soft bottom slope and rise habitats of the Middle Atlantic Bight (Cape Cod to Cape Hatteras) with subtropical deep soft bottom habitats of the Bahamas and Caribbean, and have included community comparisons, and comparisons of feeding habits of fishes from temperate and subtropical regions (Sedberry and Musick 1978; Anderson et al. 1986; Crabtree et al. 1991). Differences in species composition and trophic structure of fish communities, and morphology of the deep-sea fish faunas have been attributed to differing levels of nutrient and/or oxygen concentrations between demersal habitats of the two regions and other attributes associated with the presence of bottom topography such as canyons, seamounts, ridges and hard bottom (Sulak and Ross 1996). The Blake Plateau, in the area of the Charleston Bump, presents additional challenges to adaptation and morphology, as organisms encounter swift and variable currents, low-productivity tropical waters, and scoured hard bottom. Complex features that occur on the Charleston Bump may enable many species to exist on the Blake Plateau, by providing shelter and mechanisms for trapping limited productivity and food. However, these complex bottom habitats and faunas have been poorly explored because of the difficulty of sampling complex bottom in deep water with currents that make deployment of gear from the surface difficult. The fish fauna of the Charleston Bump and the Blake Plateau has been poorly studied because of the difficulties in sampling deep water under the Gulf Stream. Additional sampling on the Blake Plateau is needed to describe the deepwater fish assemblages and determine their ecological relationship with more intensively studies fish faunas of the

region.

Although hard bottom habitats, consisting of rock outcrops and living coral patches, are scattered along the continental slope of the southeastern U.S., little research effort has been directed at deep-water rocky habitats (Anonymous, 1985). Hard bottom habitat on the continental shelf and upper slope of the South Atlantic Bight (SAB) supports drastically different fish and invertebrate faunas than do soft bottom habitats in similar depths and thermal regimes (Wenner 1983; Wenner et al. 1983; Sedberry and Van Dolah 1984). It is likely that these differences extend to the deeper waters of the Blake Plateau, Florida-Hatteras Slope and the Charleston Bump. Thus, deepwater rocky bottom habitats such as the Charleston Bump may support greater biomass and diversity of fishes than that found on adjacent soft bottom areas; however, this needs investigation.

The hard bottom of the continental shelf of the SAB supports populations of tropical and subtropical reef fishes and invertebrates that find suitable reef habitat in the form of rock outcrops. Many of these are species that have extended their ranges northward from centers of abundance in the Caribbean, taking advantage of rocky reef habitat, and relatively warm thermal regimes on the middle continental shelf. It is unknown if the fauna associated with deep hard bottom of the Caribbean extends its range northward along the hard bottom habitat of the Blake Plateau to the Charleston Bump. Similarly, the faunal affinities between the rocky bottom of the Blake Plateau and rocky North Atlantic islands such as Bermuda and the Azores is not known, although fishery landings (e.g. wreckfish; blackbelly rosefish, *Helicolenus dactylopeterus*; red porgy, *Pagrus pagrus*; etc.) indicate many similarities. "Islands" of suitable habitat, such as the Charleston Bump on the Blake Plateau, may provide "stepping stones" to extend the distribution of rocky bottom deepwater fishes, corals and other species from the Caribbean to the eastern Atlantic, assuming that water temperatures and other conditions are favorable. Faunal study of deep hard bottom habitats in the Caribbean, SAB, and farther northward are needed to address these questions.

Recent studies have shown decreasing average size of species and individuals within species of deep-sea fishes from north to south along the middle continental slope (Sulak and Ross 1996). An obvious contradiction to this trend is found in the occurrence of large populations of a large species, the wreckfish, on middle-slope depths (450-650 m) on the Blake Plateau. This species occurs in large numbers, in the only documented spawning aggregation (Sedberry et al. in press) in the western North Atlantic, and has supported moderate fishery landings [in excess of 4 million lbs in 1990 until limited by quotas set by the South Atlantic Fishery Management Council (Sedberry et al. 1999)]. This high concentration of biomass on the Blake Plateau corresponds to the location of the high relief bottom topography of the Charleston Bump. It is unknown if similar populations of this or other large species occur on deep hard bottom habitats farther to the south, in the Caribbean, although a small recreational fishery for wreckfish occurs in the Bahamas (Olander, 1997).

Extensive geological observations have been made on the Blake Plateau, and surveys of the wreckfish grounds were conducted to determine population sizes of wreckfish and other fishes, and to examine possible trophic pathways that may support populations of such a large species in a food-poor environment (Popenoe and Manheim 2001; Weaver and Sedberry 2001). Unfortunately, the submersible *NR-1* used in those surveys, while very useful for making observations that require extended submergence, is not ideal for observing small fishes.

Additional observations are needed to describe the ichthyofauna of the Charleston Bump and the ecosystem that supports it. Qualitative observations were made from *NR-1* on the occurrence of corals and sponges with various bottom features (Popenoe and Manheim, 2001). In order to fully understand the physical and biological mechanisms that structure these communities, detailed visual transects and collections are needed that were beyond the capabilities of the *NR-1*.

The variability in composition of Blake Plateau bottom features, that has been noted by geological investigators, poses the question of whether substrate type or profile and complexity of structure are the most important determinant of the density of wreckfish, other fishes and other benthic organisms. We know that commercial wreckfish fishery operates primarily on ledge systems with 75-100 m of relief and very steep slopes, but the bottom composition of these areas is not well known. Many fishes are attracted to high-relief bottom for a variety of reasons, but specific attributes of this deep-water complex bottom that attract a high demersal fish biomass are not well understood. In addition, high relief areas are easily located by fisherman and the apparent high density of wreckfish on very high relief scarps may be an artifact of the fishery, rather than the habits of the fish. Because the fishery is localized, the variety of habitats over which wreckfish occur cannot be easily ascertained. In order to determine potential stock size, available habitats and mean density for each habitat, the habitat type must be determined. An objective of this study is to determine the habitats and communities with which wreckfish associate. If fishable concentrations of wreckfish are not restricted to high profile habitats, the amount of potential fishing habitat on the western Blake Plateau may be significantly larger than previously considered.

In addition to wreckfish, the present fishery lands occasional red bream (*Beryx decadactylus*) and other large fishes. Population size estimates for these other species (e.g. roughies, *Hoplostethus* spp.; barrelfish, *Hyperoglyphe perciformis*) that co-exist with wreckfish are not available. Although the ichthyofauna of continental and insular slopes and adjacent deep-sea waters have been studied for areas to the north and south of the Blake Plateau (Sulak, 1982), no faunal surveys of fishes have been conducted on the Blake Plateau. This is due primarily to the rugged bottom topography and currents, which make traditional sampling impossible. Indeed, historical exploratory trawl surveys that have been used to describe ichthyofaunas of the U.S. (e.g. Goode and Bean 1896; Bullis and Thompson 1965; Berry and Drummond 1967) have bypassed the Blake Plateau because of the difficulty of sampling. Quantitative visual observations using newer technology is needed to describe fish assemblages of the Blake Plateau.

Few data are available on trophic and community relationships in the habitat that supports wreckfish and the apparently high biomass of this and other large fishes such as barrelfish and alfonsins. What behavioral interactions occur that result in high concentrations of large fishes in a small area, in spite of fishery removal of large wreckfish? What are the trophic pathways supporting these organisms? Little is known regarding the habitat requirements for wreckfish, and the mechanisms whereby an apparently large population of large fishes (many in excess of 1 m total length and 20 kg weight) exist in a relatively food-poor deep-sea environment. Studies of feeding habits of fishes of the Middle Atlantic Bight continental slope, including limited *in situ* observations, indicate that high demersal fish biomass on the slope is supported by food chains that incorporate migration of mesopelagic animals from productive

surface waters at night to the bottom during the day (Sedberry and Musick 1978). These nektonic organisms migrate downward to cool resting waters during the day in open ocean waters. On the continental slope, daytime depths for these species coincide with the bottom depth of the slope, and these vertically migrating animals become an important food source for demersal fishes (Sedberry and Musick, 1978). The expansive area of the Blake Plateau provides a broad area of impingement upon the sea floor of migrating meso- and bathypelagic animals. Limited observations by the investigators (Weaver and Sedberry 1991) indicated that deep-sea pelagic species are preyed upon by wreckfish, and the occurrence of a high biomass of wreckfish and other fishes on the Blake Plateau may be related to the enhanced food availability provided by migrating pelagic organisms. Because wreckfish and other large demersal fishes often regurgitate stomach contents upon capture, *in situ* observations are needed to determine the importance of mesopelagic fishes in the diet of demersal fishes on the Blake Plateau.

Wreckfish and other large fishes may be abundant on the Blake Plateau in the vicinity of the Charleston Bump because a high-energy food source, i.e. vertically migrating mesopelagic cephalopods and fishes, impinge upon the bottom and are concentrated by bottom topography and associated currents into an area where wreckfish feed upon them. Feeding behavior of bottom fishes like wreckfish might be important in transferring energy from pelagic production to benthic communities by feeding upon vertically migrating organisms and depositing organic matter (feces) on the bottom. Such feeding behavior may be essential to maintaining some benthic communities. Observations of demersal fish behavior and habitat preferences can determine the sources of energy for productive bottom habitats on the Blake Plateau. This is particularly important since substantial number of wreckfish and other fishes that feed similarly are removed by the fishery.

In addition to communities that are structured by predation and other biological interactions, the biomass, abundance and diversity of fishes and other organisms on the Blake Plateau may be controlled by specific habitat characteristics, particularly substrate orientation (i.e. flat surfaces versus vertical walls; degree of protection from currents) or slope. Visual observations from submersible can be used to delineate specific habitat preferences of large organisms, can collections of macrofauna can be compared with orientation of the substrate from which they are collected.

There is considerable genetic exchange between Charleston Bump wreckfish and wreckfish inhabiting the North Atlantic Islands of Bermuda, Azores and Madeira (Sedberry et al. 1996; Ball et al. 2000). It is thought that such genetic exchange is caused by long-lived pelagic juvenile stages, and migration of adult fish. However, population structure and recruitment patterns of sessile species such as corals are poorly understood. Little is known about their reproduction and recruitment, but examination of genetic population structure can provide information on gene flow relative to oceanographic features of the Atlantic. Deep corals are difficult to collect for these analyses; however, submersibles have successfully been used to collect corals for genetic study on deep seamounts and on the Charleston Bump. Additional collections are needed to resolve genetic population structure of deep corals in the North Atlantic. Deepwater coral banks such as those observed on the Charleston Bump have been shown to be important habitats and spawning grounds for fishes and other organisms (e.g. Reed et al. 1982), and we need to understand how they are formed and maintained.

Hard bottom habitats on the continental shelf, slope and Blake Plateau off the

southeastern U.S. (South Atlantic Bight or SAB) support populations of tropical and subtropical reef fishes, and perhaps constitute a bridge for such faunal components to extend from tropical centers of high diversity to other rocky habitats in the Middle Atlantic Bight (MAB) and eastern North Atlantic. Deep reef habitats and associated reef fish and invertebrate faunas of the continental slope in the southeast have been described, but most programs have concentrated on exploratory fishery surveys and life history of fishery species such as wreckfish, snowy grouper and blackbelly rosefish (White et al. 1998; Sedberry et al. 1999; Wyanski et al. 2000; Sedberry et al. 2001). Others studies have concentrated on economically valuable crustaceans and cephalopods (Rowell and Trites 1985; Wenner and Barans 1990; Wenner et al. 1992; Wenner and Barans 2001; Vecchione 2001). There has been little exploration of cryptic fauna associated with complex substrates or with the complexity provided by sessile epifauna (Wendt et al. 1985), and very little is known about regarding invertebrate communities associated with reefs deeper than 200 m (Anonymous 1985). This is particularly true on the Blake Plateau, where periodic swift Gulf Stream currents, deep water and rugged bottom topography have prevented traditional sampling. Indeed, large scale faunal surveys (Bullis and Thompson 1965; Berry and Drummond 1967) have reported a paucity of samples collected from the Blake Plateau.

Because of the complexity of deep reef habitats, special technology is needed to locate, describe, and collect specimens from deep reefs (e.g. Pyle 1996, 2001). When new sampling technology has been applied to marine habitats, new species are often discovered, especially on deep reefs and in complex habitats (Colin 1974; Starck and Colin 1978; Gore 1981; Pyle 1996, 2001). Recent studies of deepwater coral banks in the eastern Atlantic and Pacific have shown that these complex habitats harbor a number of obligate and facultative symbionts, and many new species have been discovered living among deepwater corals. Deepwater coral banks harbor a diverse fauna (800 species in *Lophelia* banks in the eastern North Atlantic), but biological interactions and community dynamics are poorly understood (Mortensen 2001). Additional investigation is needed, particularly in deep coral banks off the southeastern U.S.

Deepwater corals often possess associated assemblages that help maintain coral bank integrity by strengthening coral reef structure (e.g. tube-building worms) or that prey upon coral predators (Mortensen 2001). In some respects, these coral banks function like tropical coral reefs or rainforests, with many biological interactions that serve to maintain the integrity of the system. While many species have been found associated with deep coral banks, it is uncertain how many of these are obligate symbionts (Mortensen 2001). While studies from the eastern North Atlantic indicate that associations may not be obligate, systems in the subtropical western North Atlantic, such as those on the Blake Plateau, may be more structured, as they are in the tropics.

The diversity of associated assemblages appears to be positively correlated with coral bank complexity (Reed et al. 1982). Variations in depth, habitat complexity and current flows are associated with changes in community and trophic structure (Thresher and Colin 1986). The Blake Plateau in the vicinity of the Charleston Bump provides much variation in depth, habitat complexity and current regimes, and probably supports a diverse fauna. Additional collecting is needed to confirm this.

In addition to a high diversity due to habitat complexity, intermediate disturbance caused by variable Gulf Stream flow (e.g. Bane et al. 2001; Sedberry et al. 2004) might also result in increase biodiversity in habitats on the Blake Plateau. Habitat complexity, intermediate

disturbance, recruitment from the tropical Atlantic and adaptation to complex niches and unique conditions might result in a high diversity and many unique species being discovered on the Blake Plateau. Sampling using submersible technology can elucidate associations of these and other species that have not previously been described. On the Blake Plateau, there exists the probability that many species seek shelter from swift currents, as well as symbiotic species to assist in making a living (e.g. Mortensen 2001), under such harsh conditions as deep water, strong currents and low-productivity tropical waters. Because of the specializations that are needed to live under such conditions and in such specialized habitats such as those found on the Blake Plateau, one would expect to find very specialized species, and perhaps many new ones.

Complex deepwater coral banks may harbor higher densities and diversities of fishes than adjacent simpler habitats, as has been shown in shallow water reefs (Wenner 1983; Sedberry and Van Dolah 1984; Sedberry and Carter 1993). However, this has been largely unexplored in deep water (Parrish et al. 2002). In addition to discovering new species and faunal associations, determining the associations of fishes with complex habitat can assist in bottom mapping efforts, by making faunal and fisheries survey data useful as indicators of bottom type (Van Dolah et al. 2001). Some fishes are clearly associated with deepwater corals (Parrish et al. 2002) and can serve as indicator species for mapping of coral habitat, but only if fish habitat preferences are known.

In summary, the Blake Plateau in the vicinity of the Charleston Bump comprises varied and complex habitats that include scarps, caves, rock outcrops and overhangs, hard pavements, soft sediments, and patches of sessile epifauna. Because of the habitat complexity and uniqueness, and the proximity to tropical sources of recruitment, the Charleston Bump should harbor a relatively high diversity of organisms relative to similar depths in the North Atlantic. However, the habitat complexity and current regime have prevented traditional sampling of the Charleston Bump. Trawls, fish traps and longline gear become fouled in the strong and variable currents or on the rough bottom, and traditional fishing and sampling gear is usually not recovered intact (Sedberry et al. 2004). Investigators of complex habitats such as deep coral reefs have had similar problems in other parts of the world; however, when non-traditional diving technology is employed, samples are successfully obtained. Such samples often include a high diversity and many undescribed species, even in relatively well-known taxa such as fishes (Colin 1974; Thresher and Colin 1986; Pyle 1996; Pyle 2001). A submersible and associated sampling gear are ideal for discovery and exploration of complex habitats on the Charleston Bump, in order make discoveries regarding the diversity of life found there.

This report describes the results of a study aimed at submersible exploration and description of diverse habitats and associated species of the Charleston Bump and adjacent Blake Plateau. This study is complementary of other fishery research efforts aimed at a better understanding of the ecology of the Charleston Bump and its influence on oceanography and fish populations of the region. We proposed research to use traditional fisheries and oceanographic sampling, as well as newer marine technologies, to describe deep reefs and other diverse habitats on the Blake Plateau. This research was designed to complement several other National Oceanic and Atmospheric Administration (NOAA) programs.

Objectives of the Project

The following objectives represent the original Scope of Work. Due to budget reductions

we did not attempt to meet all of the original objectives. However, we continue to seek additional funding for some additional post-project sample and data analysis.

The focus of this project was a description of microhabitats and faunas associated with steep rocky scarps, scour depressions and other hard bottoms of the Charleston Bump. Our goal was to map, explore and describe deep reef habitats, including description of their use by marine organisms and the adaptations these organisms have for these specialized habitats. We addressed this goal by establishing the following objectives:

1. Map habitat features of the Charleston Bump and adjacent Blake Plateau using sonar, fathometer and historical sounding data to direct subsequent submersible explorations.
2. Explore complex habitats such as caves, overhangs, depressions, coral mounds, pinnacles, and pavements with a submersible.
3. Visually document and describe habitats (bottom features, substrate composition, hydrographic features) in depths from 300-900 m; and describe assemblages of associated fishes, crustaceans, and large sessile epifauna.
4. Collect large sessile epifauna to describe assemblages of invertebrates associated with sponges and corals.
5. Collect (suction and scoop) macrofauna from microhabitats to compare assemblages for macroinvertebrates from caves, overhangs, sour depressions, pavements, sediments, sponges and corals, and to look for new and unusual species for taxonomic study and educational purposes.
6. Compare deep reef faunas associated with different bottom features and hydrographic regimes (e.g. current velocity), in terms of community structure, feeding guilds and morphological adaptations.
7. Determine from *in situ* observations, densities of fishes in relation to specific habitat characteristics such as substrate orientation and type, sessile benthic fauna and/or associated forage species.
8. Obtain coral samples for determining growth rates using thin-sectioning and ontogenetic isotopic and trace element analyses, in order to develop growth models that will assist in conservation and restoration of deepwater coral banks.
9. Collect DNA samples from corals and other organisms to elucidate patterns of recruitment of deep hard-bottom organisms to islands of favorable habitat such as the Charleston Bump and North Atlantic islands.
10. Develop educational materials from the research.

Budget limitations, technical problems at sea, and the weather prevented us from accomplishing all of these objectives; however we made significant progress toward completion, and have samples on hand for additional analyses in the future.

APPROACH

Site Selection

We examined historical data (e.g. Popenoe and Manheim 2001; Sedberry et al. 2001) and our unpublished data (e.g. Fig. 2, Fig. 3) to pick sites that contained complex bottom topography with varying amounts of vertical relief and the apparent presence of coral mounds, scour depressions, steep scarps, caves and overhangs. Unfavorable weather and current conditions at some of the sites prevented us from sampling some sites chosen prior to the expedition. However, additional sites were chosen that had favorable conditions. Also, the need to revisit some sites to retrieve experiments (carrion traps and current measuring devices) resulted in much overlap in dive sites (Fig 3).

Submersible Reconnaissance and Sampling

We used the Harbor Branch Oceanographic Institution (HBOI) Research Vessel *Seward Johnson* to deploy a variety of sampling gear at each reef site (Table 1, Fig. 3, Fig. 4). We used the submersible *Johnson Sea-Link2* (*JSL2*) to conduct visual reconnaissance of different types of habitats on the Charleston Bump and adjacent shelf-edge and Blake Plateau.

At each site, we used submersible dives to characterize habitats, describe faunas, and make video recordings. On each dive the sub descended to the bottom, obtained a position fix and began transects at slow speed. Timed transects began and ended with a position fix while the *JSL2* remained stationary on the bottom. During this time we also made collections of rocks, sediments and biota. Additional collections of benthic fauna were made from various habitats observed during a dive. These habitats included "Wreckfish scarp" (steep rocky slopes exceeding 25 m in height; manganese-phosphorite pavements without attached growth; areas of live sponge-coral on hard bottom pavement or rocky relief; broken pavement-rubble; low-relief outcrop habitats; soft bottom; and coral mounds. We attempted to use the submersible's collecting devices (suction, scoop, claw) to sample organisms from these major habitats and any other features (e.g. caves, depressions, overhangs), in an effort to obtain samples from the complete diversity of habitats observed. Samples were obtained as different habitats were encountered, without a set sampling design. On some dives we spent considerable time deploying clod cards for investigators from the University of South Carolina (to measure currents) and carrion traps. Additional details of submersible samples are described below, for each type of sample or analysis performed.

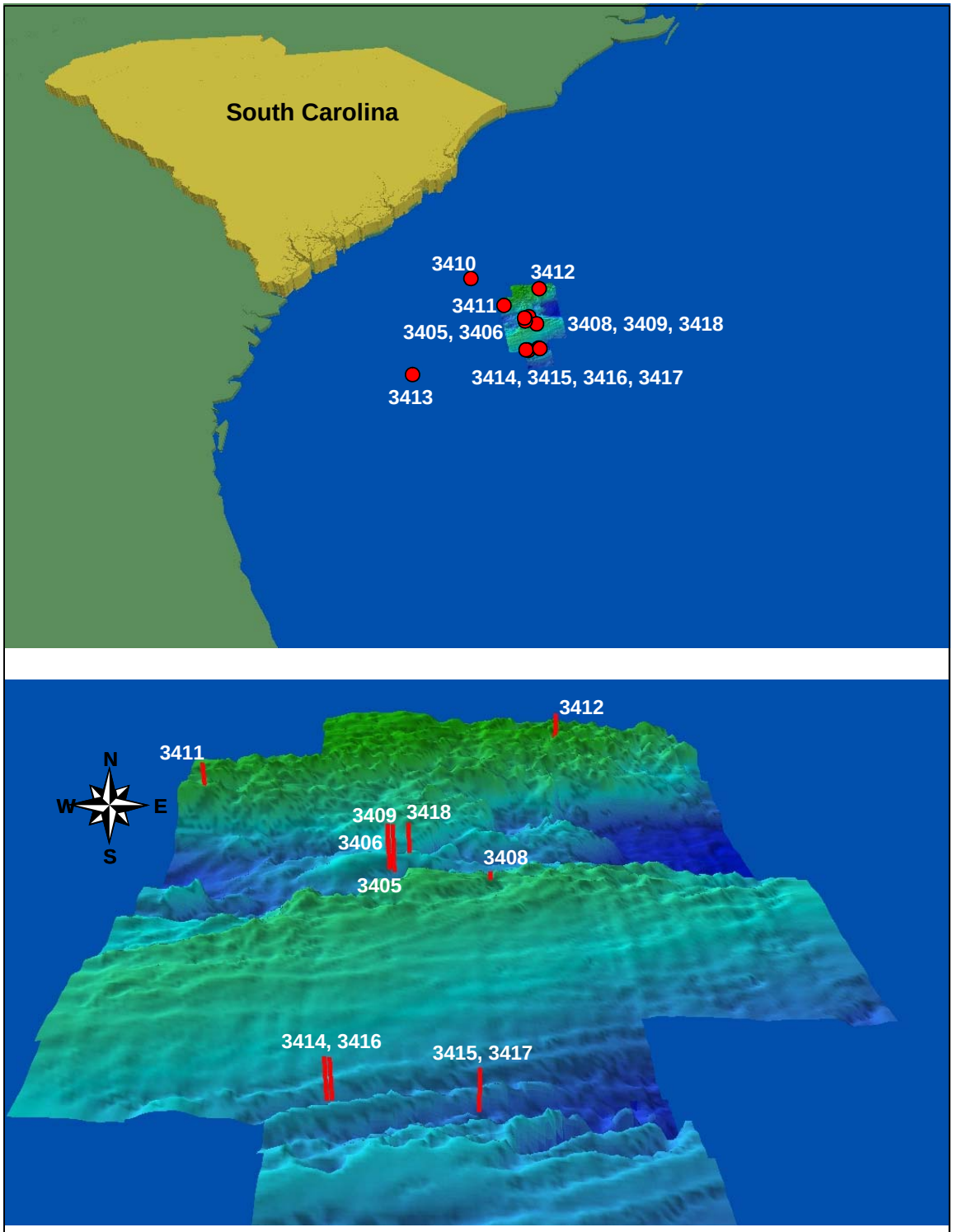


Figure 3. Location of actual dive sites (top map) and those dive sites (lower image) located on a previously mapped sonar image of the Charleston Bump. Numbers indicate JSL2 Dive Numbers (see Table 1).

Table 1. Collection data for samples colleted during the 2003 Ocean Exploration expedition to sites on the Charleston Bump and deepwater hardbottom and shelf edge habitats.

Location Designation Date	Latitude	Longitude	Sample Depth (m)	Bottom T (°C)	Gear (JSL2 Dive No.)
B-Cubed					
3-Aug	31.6944	-78.8197	552	13.56	submersible dive (3405)
3-Aug	31.7007	-78.8237	560	13.50	submersible dive (3406)
4-Aug	31.7012	-79.0026	0		1-mm neuston
4-Aug	31.7083	-78.66	505	11.57	ctd
4-Aug	31.6533	-78.7517	460	16.11	ctd
4-Aug	31.6483	-78.7633	545		pipe dredge
4-Aug	31.6483	-78.765	558		pipe dredge
5-Aug	31.6316	-78.7467	455		aborted sub dive
6-Aug	31.8967	-78.9033	395		pipe dredge
6-Aug	31.8933	-78.9	0		1-mm neuston
6-Aug	31.8883	-78.9067	400	8.35	ctd
6-Aug	31.8317	-78.855	0		1-mm neuston
6-Aug	31.83	-78.815	0		1-mm neuston
6-Aug	31.7617	-78.7867	0		1-mm neuston
6-Aug	31.7617	-78.79	489		pipe dredge
Neptune's Staircase SC					
6-Aug	31.7307	-78.8064	504	8.51	submersible dive (3408)
6-Aug	31.74	-78.795	484	8.58	ctd
6-Aug	31.7295	-78.8245	543	8.91	submersible dive (3409)
7-Aug	31.58	-78.6567	470		pipe dredge
7-Aug	31.575	-78.6517	476	12.36	ctd
7-Aug	31.5783	-78.66	0		1-mm neuston
7-Aug	31.619	-78.6998	0		1-mm neuston
Tattler Town SC					
7-Aug	32.0606	-79.2533	78	13.72	submersible dive (3410)
8-Aug	32.0733	-79.2633	0		pipe dredge
8-Aug	32.075	-79.2633	0		pipe dredge
8-Aug	32.08	-79.2533	67	14.46	ctd
8-Aug	32.0817	-79.2517	0		1-mm neuston
8-Aug	32.0067	-79.145	0		1-mm neuston
8-Aug	31.92	-79.0333	0		1-mm neuston
8-Aug	31.83	-78.9	0		1-mm neuston
8-Aug	31.8383	-78.8817	455		pipe dredge

Table 1. Continued.

Location Designation Date	Latitude	Longitude	Sample Depth (m)	Bottom T (°C)	Gear (JSL2 Dive No.)
Fathom Ridge SC					
8-Aug	31.8479	-78.9991	429	9.47	submersible dive (3411)
8-Aug	31.9283	-78.665	378		ctd
Sherwood Valley SC					
8-Aug	31.954	-78.6422	382	11.03	submersible dive (3412)
9-Aug	31.93	-78.6533	530	15.23	ctd
9-Aug	31.2817	-78.66	0		1-mm neuston
9-Aug	31.3233	-78.6917	0		1-mm neuston
9-Aug	31.3633	-78.7183	0		1-mm neuston
9-Aug	32.195	-79.1083	75	14.88	ctd
9-Aug	32.4383	-78.9667	36	16.25	ctd
10-Aug	31.0583	-79.8367	182	7.89	ctd
Razorback SC					
10-Aug	31.2117	-79.8922	46	15.43	submersible dive (3413)
11-Aug	31.5167	-78.98	0		1-mm neuston
11-Aug	31.4733	-78.9317	0		1-mm neuston
11-Aug	31.515	-78.985	404	14.19	ctd
11-Aug	31.4417	-78.8983	0		1-mm neuston
11-Aug	31.4117	-78.8467	0		1-mm neuston
Slab Garden SC					
11-Aug	31.408	-78.8593	530	14.18	submersible dive (3414)
Velvet Steps SC					
11-Aug	31.3964	-78.7769	567		submersible dive (3415)
12-Aug	31.5	-78.525	531		1-mm neuston
12-Aug	31.4967	-78.5283	507	14.66	ctd
12-Aug	31.4633	-78.64	0		1-mm neuston
12-Aug	31.4433	-78.7233	0		1-mm neuston
12-Aug	31.4067	-78.8583	0		1-mm neuston
Slab Garden SC					
12-Aug	31.4077	-78.8564	546	14.04	submersible dive (3416)

Table 1. Continued.

Location Designation Date	Latitude	Longitude	Sample Depth (m)	Bottom T (°C)	Gear (JSL2 Dive No.)
Velvet Steps SC					
12-Aug	31.3964	-78.7769	567		submersible dive (3417)
12-Aug	31.3983	-78.765	496	15.85	ctd
13-Aug	31.4817	-78.79	0		1-mm neuston
13-Aug	31.4933	-78.765	0		1-mm neuston
13-Aug	31.5567	-78.7883	444	14.27	ctd
13-Aug	31.5567	-78.8	0		1-mm neuston
13-Aug	31.6583	-78.7983	0		1-mm neuston
13-Aug	31.7317	-78.745	0		1-mm neuston
Neptune's Staircase SC					
13-Aug	31.7288	-78.8198	549	12.64	submersible dive (3418)
13-Aug	31.7517	-78.77	487	12.75	ctd

Table 2. Collection data for samples collected by the *JSL2* submersible during the 2003 Ocean Exploration expedition to sites on the Charleston Bump and deepwater hardbottom and shelf edge habitats.

Location Date	Dive Number	Duration (h:min)	Depth (m)	Number of Recordings	Transects	Samples Obtained, Comments
B-Cubed						
3-Aug	3405	2:15	554	2	5	Sponges, sediment, echinoderms, anemone, coral, wood, rock
3-Aug	3406	3:11	563	3	2	Sponges, sediment, misc. crustaceans, coral, fish, swordfish
4-Aug	3407	0:45	0	0		Aborted
Neptune's Staircase						
6-Aug	3408	2:58	504	3	11	Sponges, anemone, sea cucumber, urchin, coral, galatheid, rock
6-Aug	3409	1:43	548	2	5	Sponges, sediment, coral, urchins, tunicates, rock
Tattler Town						
7-Aug	3410	2:52	96	2	8	Sponges, coral, rock, starfish, fish
Fathom Ridge						
8-Aug	3411	2:53	433	3	10	Sponges, sediment coral, starfish
Sherwood Valley						
8-Aug	3412	2:54	383	3	7	Sponges, sediment, starfish
Razorback						
10-Aug	3413	2:18	46	3	7	Sponge, sediment, coral
Slab Garden						
11-Aug	3414	2:09	538	1	2	Sediment, rock, shrimp, crab
Velvet Steps						
11-Aug	3415	2:07	570	1	2	Sponge, sediment, rock, coral, carrion traps
Slab Garden						
12-Aug	3416	2:41	545	3	6	Sponges, sediment, crabs, shrimp
Velvet Steps						
12-Aug	3417	2:24	571	1	1	Sediment, coral, starfish, gastropod, crab, shrimp, fish
Neptune's Staircase						
13-Aug	3418	2:50	547	2	2	Sediment, crab, urchin, gastropod, rock

Habitat Characterization

Prior to the 2003 Expedition, mapping of bottom topography of the Charleston Bump was conducted from the NOAA Ships *Whiting* and *Thomas Jefferson*, during opportunities provided by NOAA Marine and Aviation Operations at no cost to the OE project. Several small surveys were conducted (April and June, 1999, April 2000, June 2001, April 2002, June 2003). Bottom mapping from the NOAA ships concentrated on the northern and southern wreckfish grounds and the bottom between them and to the north (Fig. 3, 7). Soundings were recorded continuously using an echosounder interfaced with GPS. From 1999 through 2001, GPS positions and single-beam echosoundings were recorded every 200 m along transects. Transects were spaced 500 m apart, and generally ran in a north-south direction. Occasional transects were conducted at an angle to the main transects, in order to cross-check previous soundings. Soundings were taken at a vessel speed of 18.5 km/h (10 knots), except in areas of steep relief, where the vessel speed was lowered to 9.25 km/h (5 knots). Single-beam sonar

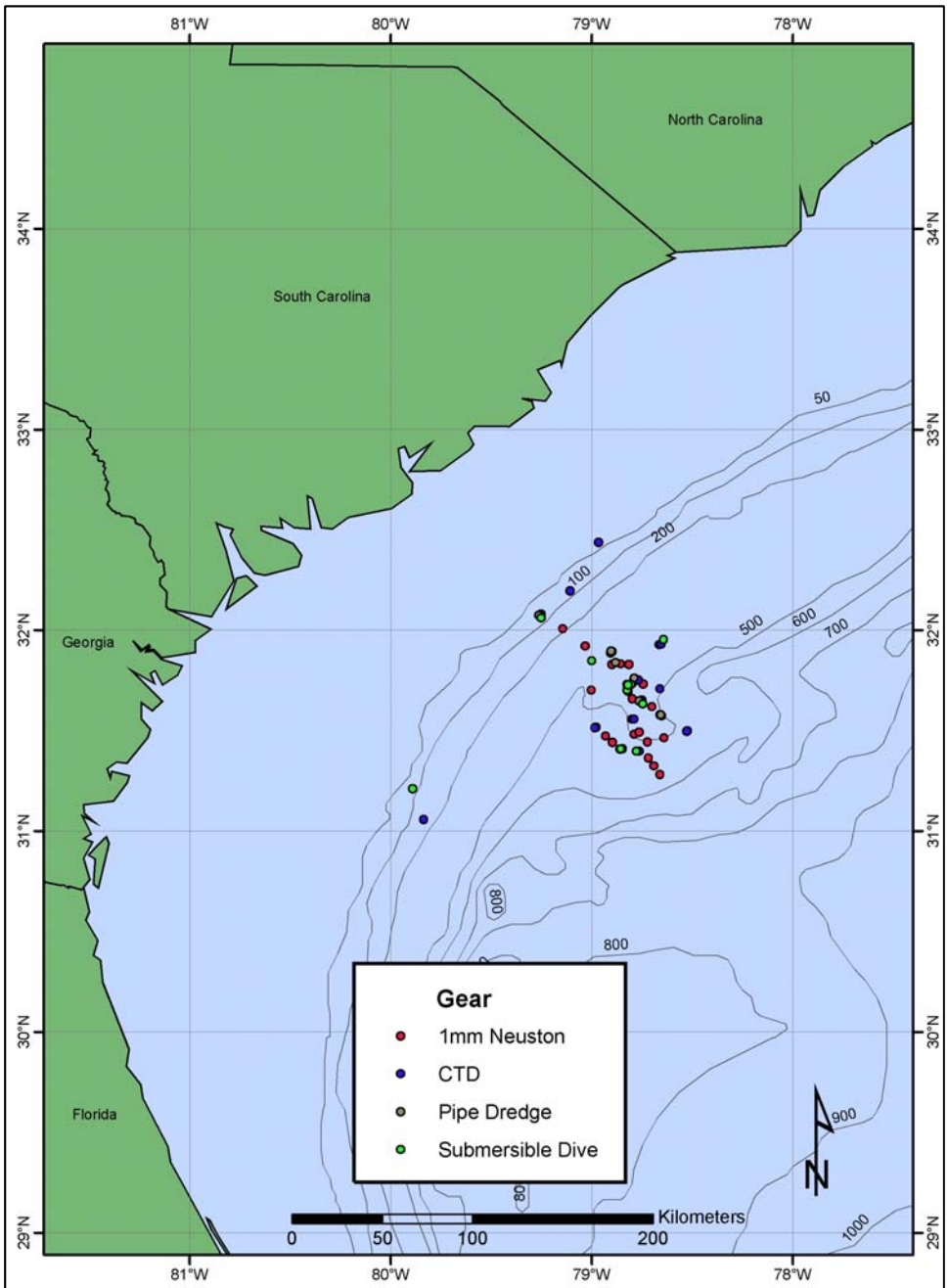


Figure 4. Sampling locations, by gear type, during the 2004 OE ETTA Expedition.

data were collected using a Raytheon DSF-6000N echosounder with a 12 kHz frequency transducer, or an ODOM Hydrographic Systems Echotrac DF3200 MKII echosounder with a 24 kHz transducer. In 2002 and 2003, multibeam sonar data were collected using a Simrad EM-1002 shallow- to mid-water multibeam echosounder. A Sea-Bird SEACAT SBE-19 CTD (conductivity, temperature, depth probe) was used to determine temperature and salinity profiles. Sound velocity profiles were used to calculate sound velocity corrections for depth measurements. A TSS DMS-05 dynamic motion sensor or POS/MV heave, roll, pitch and motion sensor collected heave, pitch and roll (HPS) applied to raw soundings data for correction during HPS processing. Tidal time and ratio correctors were received from NOAA/HSD and applied during post-processing to 6 min tidal values based on the Charleston tide gauge. Positioning information was collected using a Trimble DSM212L GPS Receiver with integrated DGPS VHF receiver. Differential corrections were received from the Ft. Macon NC, Charleston SC or Miami FL radiobeacons. Antenna positions were corrected for offset and layback and referenced to the position of echosounder transducers depending upon which was in use at the time. Accuracy requirements were met as specified in the NOAA Hydrographic Manual and Field Procedures Manual (FPM). The Horizontal Dilution of Precision (HDOP) and Estimated Position Error (EPE) as specified in the FPM were monitored during on-line data collection. If the positioning degraded beyond the acceptable limits while on-line, the data were either rejected or smoothed, depending on the extent of the affected data. Coastal Oceanographics HYPACK software was used for data acquisition. Processing of sounding data was accomplished using NOAA HPS (Hydrographic Processing System included in HYDROSOFT 9.4), Mapinfo 4 (Mapinfo 4.9 in 2000), and the HPS-MI MapBasic application.

Habitat and faunal documentation included sonar surveys conducted between submersible dives and at night, using a Knudsen 3.5/12KHZ echosounder aboard the R/V *Seward Johnson*. During dives, written notes and videotaped transects used for fish and invertebrate surveys (details below) were also used to characterize the habitat. For purposes of habitat and faunal characterization, the video camera was oriented at a 45 degree angle to the bottom and the submersible transected as close to the bottom as possible. This kept the camera about two meters above the bottom. The camera was kept zoomed out to obtain a panoramic view. Descriptions of habitats from videotape included qualitative descriptions of habitat type (rock, sand), extent of vertical relief, and qualitative descriptions of attached biota.

Sediments and rocks were occasionally collected during dives using the submersible's scoop or claw, attached to the manipulator arm. These samples were used to describe the physical characteristics of the bottom. Rock samples were collected for future petrographic (rock chemistry, texture, origin) characterization. Rock samples will eventually be examined in thin section for composition and texture. Characterization of rocks will also include the fossil coral assemblages to determine age and sources of rocks. Additional future characterization of sediments will include a qualitative description of planktonic and benthic foraminifera. Funding was not available for rock and sediment characterizations, but this will be completed in the future.

During all dives and sampling, we continuously monitored sea surface temperature, salinity and fluorometry. CTD casts were done at each station to describe hydrography (Table 1), and a CTD was mounted aboard the *JSL2*.

Fish Observations

On each submersible dive, timed (4-min) transects at slow speed were conducted along the bottom to be used in describing habitats and fish and invertebrate assemblages. A position fix was obtained at the beginning and end of each transect to estimate transect distance, and we attempted to go in a straight line each time. We determined mean transect length from previous OE expeditions using the same submersible system (Sedberry, Cooksey, Crowe et al. 2004). Briefly, we plotted a subset of 20 of the 4-min video transects that had very clearly identified start and end points in ArcView GIS, to get an estimate of average transect length, assuming that the submersible went in a relatively straight line during the four minutes. This resulted in an average distance of 76.7 m ($\pm$ 6.97 m) per 4-min transect. This indicated a submersible speed over ground of 17 - 21 m/min (mean = 19.175 m/min). Horizontal area viewed during transects was estimated for each transect, using lasers mounted 25 cm apart on the video camera. For the purposes of fish counting, estimates used for average transect width were more conservative (3-4 m, depending on visibility) than those used for sessile invertebrate counts (which used 7 m; see additional discussion below), because fishes were often highly mobile and therefore more difficult to identify and count than were sessile invertebrates. Because many fishes ranged up in the water column, we estimated area viewed on each transect in cubic meters, to include the water column above the bottom that was visible on the video tapes (3-4 m, depending on vertical visibility).

Transects were recorded on digital videotape (mini-DV) and analyzed for fish assemblages and assemblages of sessile epifauna (see below). Fishes on transects were identified to the lowest possible taxon, and densities on each transect calculated, based on field of view of the video camera and length of each transect. Continuous depth, temperature and salinity measurements were made along submersible transects. At the end of each transect, current measurements were also made.

Benthic Fauna Characterization

Benthic samples were also collected from submersible. Samples were collected with a scoop (0.03 m^2) attached to the submersible manipulator arm. Samples from hard substrates were collected with the submersible suction device. Samples were collected from sand and rocks and from exposed upper and undercut lower edges of rock outcrops. The purpose of this sampling was to compare invertebrate faunas from various rock surfaces exposed at various angles to the current and shelter. Those samples (Table 2; 22 scoop samples and 54 suctions samples) were transferred to the University of South Carolina for analysis, and will be reported on in the future. All benthic samples were preserved in 10% buffered formalin and stained with Rose Bengal.

In addition to describing infaunal assemblages of macroinvertebrates, we collected sponges to examine macroinvertebrate faunas that live in and on sponges (Table 2). Twelve sponge specimens were collected during the 2003 cruise at depths ranging from 45-570 m. Sponges were collected using a grab scoop attached to a moveable arm on the *JSL2*. Upon collection, each sponge was immediately emptied into a large Plexiglas container on a rotating conveyer belt on the submersible. A coordinating lid was closed over each container immediately after collection to avoid the loss of associated fauna into the water column. Once aboard the R/V *Seward Johnson*, most sponge specimens were digitally photographed to record

color and external characteristics, and then fixed in a 10% formalin-seawater solution. The remaining water in the collection container was passed through a 0.5mm sieve to ensure capture of any additional faunal associates, which were then preserved with the sponge specimen.

One of the sponge specimens collected was randomly selected for an initial analysis of associated fauna. The specimen, *Chondrilla* sp., was collected from a submersible dive at Razorback, a shelf-edge site off Georgia. In the laboratory, sponges were transferred to 70% ethanol. Estimated sponge volume was measured by water displacement after draining the canals (error ± 5%, Crowe and Thomas 2002). The sponge was subsequently dissected to remove any remaining commensal organisms or other faunal associates that did not evacuate the sponge during initial fixation in the formalin-seawater solution. Associated fauna were identified to major taxonomic group and enumerated. The host sponge was identified using photographs and spicule preparations. Microscopic photographs of sponge internal structure and spicules were taken using a Nikon CoolPix 990 with microscope attachment mounted to a Nikon SMZ 800 dissecting microscope or Nikon Eclipse E400 compound microscope.

Four carrion traps (Fig. 5) were deployed (*JSL2* Dive 3415) and recovered (*JSL2* Dives 3416-3417). Carrion traps consisted of 19-l (5-gal.) plastic buckets that were half-filled with oyster (*Crassostrea virginica*) clusters collected alive and frozen. These were designed to collect deep-sea organisms that are often attracted to "food falls", consisting of dead organisms and other carrion that rain down to the deep sea from overlying productive waters. The traps were successfully deployed and recovered. The catches have not yet been analyzed, but have been archived at the Southeast Regional Taxonomic Center (SERTC) at the Marine Resources Research Institute (MRRI) in Charleston for future study.

Video Transects for Sessile Megafauna

Video transects for assessment of sessile megafauna coincided with those used for habitat descriptions and fish counts. Multiple video transects of the seafloor and associated epibenthic invertebrates were collected during fourteen dives of the *JSL2* during the current expedition. Video transects from twelve dives on the *JSL2* (Jul - Aug 2002) completed at seven locations off northern Florida and South Carolina, and three additional dives (Jul 1985) conducted off South Carolina (using the *JSL1*) were also analyzed for comparative purposes with the current study (Sedberry, Cooksey, Crowe et al. 2004; Griffin 2005; Schobernd, in prep) (Fig. 6).

Transects were four minutes in length, with submersible speed and distance off the bottom varying based on current conditions, bottom topography, and other variables. The start and end coordinates of a subset of transects (n = 20) collected over ten dives in 2002 were plotted in ArcView 3.1 (ESRI 1998) to determine average transect length (4 min transect = 76.7 m +/- 7.0 m). The average transect length calculated in 2002 was used to analyze data from 4-min transects conducted in 2003. Average transect width (7 m) was estimated from 2003 videotapes, based on the distance between two lasers mounted parallel to the video camera's light ring on the *JSL2* that were spaced 25 cm apart. The estimate of transect width used here is more conservative than the measurement of 10 m used by Parker and Ross (1986) and ~9.1 m used by Wenner *et al.* (1992) using the same submersible.

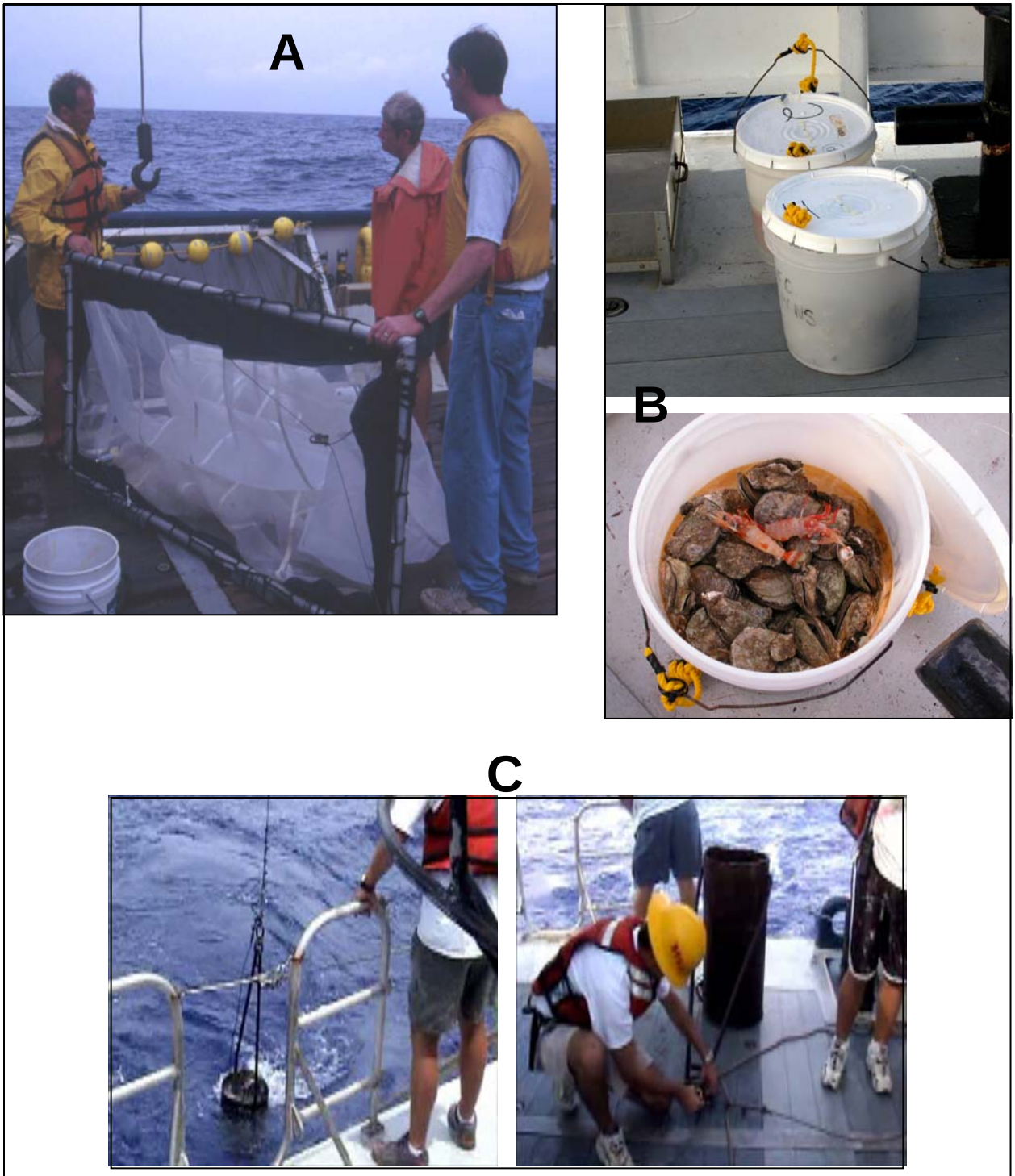


Figure 5. Neuston net (A), carrion traps (B) and pipe dredge (C) used to collect surface plankton, bottom invertebrates and invertebrate and sediment samples, respectively.

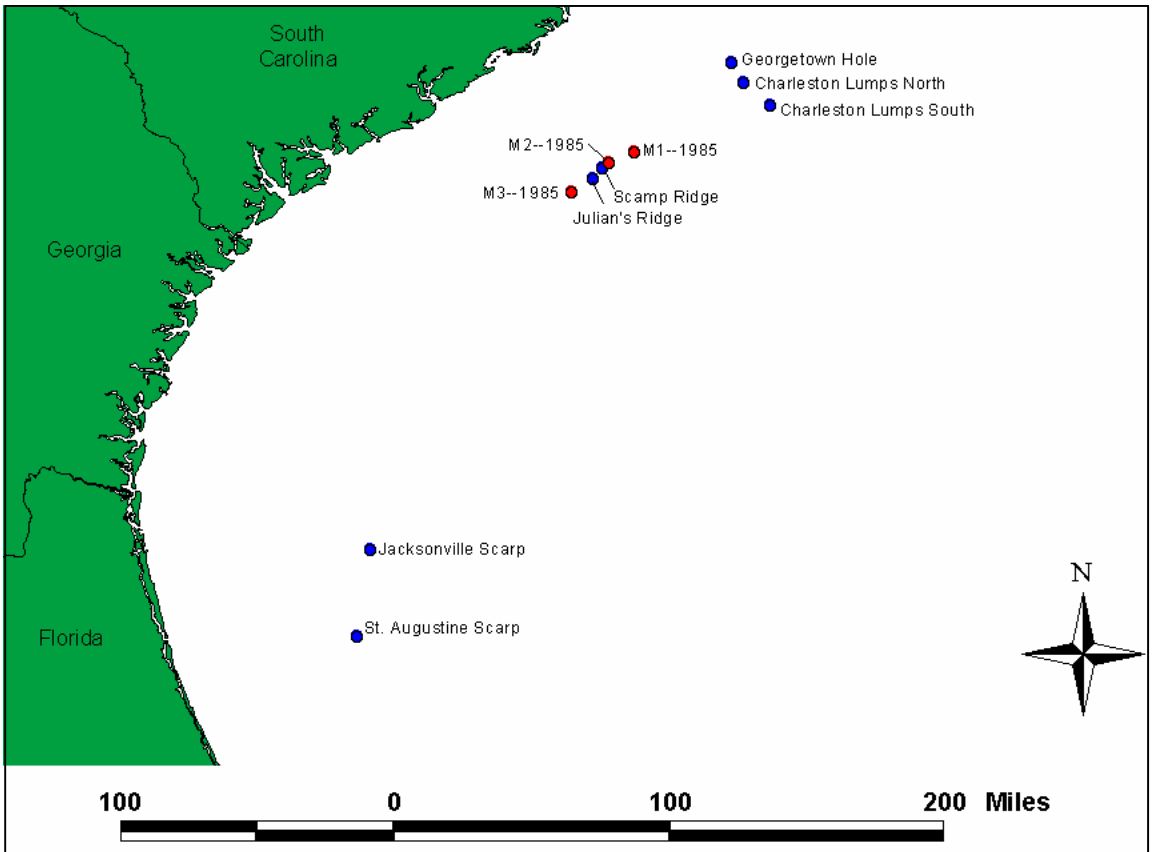


Figure 6. Location of video transects collected via submersible in 2002 (blue dots) and 1985 (red dots).

Video transects were initially reviewed to determine the dominant epibenthic invertebrates. Two taxa, large sponges and the antipatharian coral provisionally identified as *Stichopathes* sp. were selected for further analyses. Five randomly selected two-minute segments of video transects from each dive were reviewed using ATI Multimedia Center 8.1 (ATI 2001). Abundance estimates (number of individuals/m^2) were recorded for *Stichopathes* sp. and large sponges. *Stichopathes* sp. abundances were rank transformed and sponge abundances were ln (x+1) transformed, where necessary, for statistical tests. Differences in abundance among 2003 dives and between 1985, 2002, and 2003 dives were tested using one-way ANOVA followed by post-hoc comparisons with the Tukey test or Dunn's test. SigmaStat 3.1 was used for all statistical tests (SPSS 2004).

Additional Shipboard Sampling

Additional shipboard sampling included neuston sampling, pipe dredge sampling, and bottom mapping with the ship's sonar (previously described). We sampled the surface waters with a 1 x 2 m neuston frame equipped with a 947µ nitex net (Fig. 5). Neuston nets were towed with the frame half submerged for 10 min, at a vessel speed of 6.5 km/h (3.5 knots), adjusted to

keep the net with the lower half submerged. The net was equipped with a flowmeter to measure the volume of water filtered. Samples were preserved in 95% ethyl alcohol (full strength ethanol), which was replaced after 24 h. A CTD cast was done at each station.

We conducted neuston tows throughout the study area (Fig. 4) to collect larvae of economically valuable fishes and crustaceans and other species, to examine the role of the Charleston Bump in the early life history of marine organisms. Time and funding constraints have prevented us from analyzing these samples, but they have been archived at SERTC for future analysis.

Eight bottom samples were obtained with a pipe dredge (Fig. 4-5, Table 1). The dredge was 35 cm (internal diameter) x 76 cm long and weighed approximately 87 kg. The pipe dredge was lowered to the bottom and recovered a few moments after bottom contact was detected by movement of the tow wire. Organisms were removed from the pipe dredge and preserved in 95% ethyl alcohol for later taxonomic identification, aging and DNA analysis. These samples have been archived at SERTC or transferred to an appropriate expert for later analysis.

Project Management

This project was paired by OE with a very similar project proposed by investigators from the University of South Carolina, and funded by OE to conduct very similar sampling on the same cruise. This made management and flow of samples problematic, and all benthic samples collected by the submersible (exclusive of carrion trap samples and selected specimens of macrofauna) were transferred to USC for management and analysis.

This Project NA03OAR4600097 was managed by the Principal Investigator, George R. Sedberry. He was to serve as Chief Scientist on the cruise, but was recovering from surgery when the cruise occurred. The job of Chief Scientist was ably performed by Charles A. Barans.

John C. McGovern was initially a Co-Principal Investigator and helped with project planning. He resigned from SCDNR before the project started, and his new position with NOAA did not allow him to participate further on the project. Co-Principal Investigator Pamela Cox Jutte (formerly of SCDNR) was responsible for analysis of invertebrate samples that were returned to SCDNR (sponge fauna), and for analysis of large sessile fauna recorded on videotapes. She was assisted by Stacie E. Crowe (SCDNR) and Graduate Research Assistant Cara L. Fiore (College of Charleston).

Cooperating Investigator C. Fred T. Andrus [formerly of Savannah River Ecology Laboratory (SREL), University of Georgia; currently with University of Alabama] was responsible for sampling corals at sea and conducting isotope and microconstituent analysis of corals. He was assisted by Cooperating Investigator Christopher T. Romanek (SREL). Cooperating Investigator Scott C. France (formerly of the College of Charleston) will investigate the population genetics of deep corals and other deep-sea organisms preserved and returned to him for future analysis at the University of Louisiana, where he is currently employed. Cooperating Investigator Antony S. Harold (College of Charleston) assisted with fish identifications and cataloguing of specimens into the collections at SERTC and Grice Marine Laboratory (College of Charleston). Cooperating Investigator Leslie R. Sautter (College of Charleston) assisted at sea and provided descriptions of geological features and has archived sediment and rock samples for future detailed analysis. She also provided extensive photographic and video documentation of sampling and organisms, and constructed numerous

educational web sites and presentations from materials obtained during the Expedition. Cooperating Investigator Elizabeth L. Wenner (SCDNR) assisted at sea and was responsible for pipe dredge and carrion trap construction, deployment and sample processing. She was assisted by Susan T. DeVictor, who also took amazing photographs of specimens. Many of the photographs were used for educational materials developed during and after the cruise, and will appear in future publications.

Educator-at-Sea Connie Leverett (Charleston County School District) assisted at sea and developed web logs and presentations based on scientific results, personal experience on the cruise and interviews of cruise participants.

We acknowledge with grateful thanks the other members of the Scientific Party aboard the R/V *Seward Johnson*. They were Susan Thornton DeVictor (SCDNR), Frank Helies (University of South Carolina, USC), Dara Hooker (USC), Connie Leverett, Josh Loefer (SCDNR), John McDonough (NOAA-OE), Jerry McLelland (University of Southern Mississippi), Jeremy Potter (NOAA-OE), Stephen Stancyk (USC), Denise Stickland (USC), Rich Styles (USC), Betty Wenner (SCDNR), Phil Weinbach (SCDNR), and David Wyanski. We also thank Ralph Van Hoek (Captain, R/V *Seward Johnson*) and Craig Caddington (Chief Sub Pilot) and their crews for facilitating a successful cruise.

Dara Hooker, Josh Loefer, Jessica Stephens (SCDNR) Richard Styles and Phil Weinbach assisted with data management and analysis. John McDonough and Jeremy Potter NOAA provided valuable assistance in cruise logistics and data management. Dan Russ (SCDNR) helped with cruise logistics. Rich Styles provided the summary of hydrographic observations made during the cruise.

Letters of acknowledgement (LOAs) and permits that allowed us to sample fishes, corals and live rock were provided by the NOAA Fisheries Southeast Regional Office and NOAA Office of Sustainable Fisheries (Permit HMS-SRP-03-02). The research described herein complied with all laws of the United States. Support was provided by grants (including NA16RP2697, NA03OAR4600097 and NA0ROAR4600055) from the NOAA Office of Ocean Exploration. Additional support was provided by Grants NA03NMF4720321 and NA17FF2874 from the NMFS Special Programs Office, and MARMAP Grant 52WCNF6006013. NOAA Marine and Aviation Operations provided ship time for bathymetry mapping, and the crews of the NOAA Ships *Whiting* and *Thomas Jefferson* (previously named the *Littlehales*) collected and processed the bathymetry data.

The Principal Investigator, George Sedberry, extends special thanks to Charlie Barans for serving as Chief Scientist on the cruise.

FINDINGS

Habitat Characterization

Reconnaissance of rugged bottom topography on the Charleston Bump using submersibles in 1989, 1990 and 2001, and sonar surveys in 2000-2003, revealed a diversity of bottom types, from flat hard bottom to rugged relief and near-vertical scarps (e.g. Fig. 2; see also Sedberry et al. 2001; Popenoe and Manheim 2001; Sedberry, Pashuk, Loefer et al. 2004). Submersible observations during the present study revealed a variety of bottom formations.

Two dives were conducted at shelf-edge sites that were not the focus of this study and will be described only briefly. These two shelf-edge sites were very patchy in extent of hard bottom, low in relief and contained extensive sediments. Generally, the shelf-edge reefs were atypical patchy habitat, and did not contain the diversity or abundance of biota normally found on shelf-edge reefs (Sedberry, Cooksey, Crowe et al. 2004). The habitats seen at the two shelf-edge dive sites in 2003 were often buried in large amounts of sediment, or comprised low relief rocky features. Three reef morphologies were observed: bioeroded rock (flat rock pitted with small depressions containing patches of sediment); boulders with sand (large rocks that were irregular in shape, with large accumulations of sand throughout) and sand (five out of the 15 transects were conducted on sand). The predominant feature of these sites was the reduced amount of rock relief, and the high amount of soft sediment, relative to shelf-edge reefs we observed in 2002 (Sedberry, Cooksey, Crowe et al. 2004).

The Tattler Town site consisted mainly of sand with scattered rocks. Transects at this dive location usually covered flat coarse sand with sparsely-distributed rocks. Relief of the rocks was approximately 15 cm or less. There was no well-defined reef at this location. Large boulders with sand were found at Razorback where transects crossed many large buried boulders interspersed with patches of sand. The tops of some boulders were partially covered in sand in low depressions that occurred on top of the rocks. The reef at Razorback was not well defined, but appeared to be a flat hard bottom area with very low relief rubble and rocky pavement. Rocks appeared pitted and eroded, presumably from encrusting and boring invertebrate organisms. One transect at each of these two shelf-edge sites did not cross over any visible rock, but remained over coarse shelly sediment for the entire transect.

Dives and sonar surveys on the Charleston Bump indicated rugged bottom topography ranging from few to over 100 m in relief (Fig. 3, 7). Surveys concentrated on the wreckfish grounds (near dive sites 3405-3406) and adjacent shoaling bottom topography. From the southern end of the survey area (about 31°15'N; near Dive Site 3415, Fig. 3), the bottom sloped upward toward the north from depths of about 570 m. North of this area, from about 31°20' to 31°25' N is a series of ridges with depths shoaling to 510 m on top of the ridges and 550 m in the valleys between ridges (Dive Sites 3415-3417, Fig. 3). These ridges were important wreckfish and red bream habitat (see below). To the north of the ridges, the bottom was relatively smooth and sloped gradually upward to rough bottom at the top of a system of scarps, at about 430 m depth, in the middle of the survey area. Northward of this shoal, the bottom droped precipitously at a series of scarps ("Wreckfish Scarp"), dropping down to depths greater than 580 m at the bottom of scour depressions to the north of the scarp. Northward of the scarps, which were important wreckfish habitats, the bottom is very rough, and shoals up to depths of 350 m at the northwest corner of the survey area on the upper continental slope. Catches of wreckfish on

fishery research cruises indicate that they are associated with the series of ridges at 31°20' to 31°25 N, and are particularly abundant around the scarps (Popenoe and Manheim 2001; Sedberry et al. 2001; Sedberry unpublished data).

We attempted two submersible dives (Dive 3405-3406) on the north-facing "Wreckfish Scarp" (north of Dive 3406, Fig. 3 and Site 2, Fig. 7). Because of the strong currents and extremely rugged bottom topography, we missed the target and had only limited maneuverability of the sub on the bottom. Nevertheless, the dives gave us the opportunity to look at low to moderate relief habitat, including wreckfish habitat on rocky bottom north of the main scarp (Site 2, Fig.7) and on rocky ridges to the south (Dives 3414-3417, Fig. 3; Site 1, Fig.7). The deep area between the main scarp on the Bump (Dives 3405, 3406, 3409, 3418, Fig 3; Site 2, Fig. 7) and the upper continental slope to the north was nearly continuous hard bottom, composed of manganese-phosphorite pavements. The southern edge of this relatively flat area contained some high-relief bottom and wreckfish habitat, and we completed a successful dive

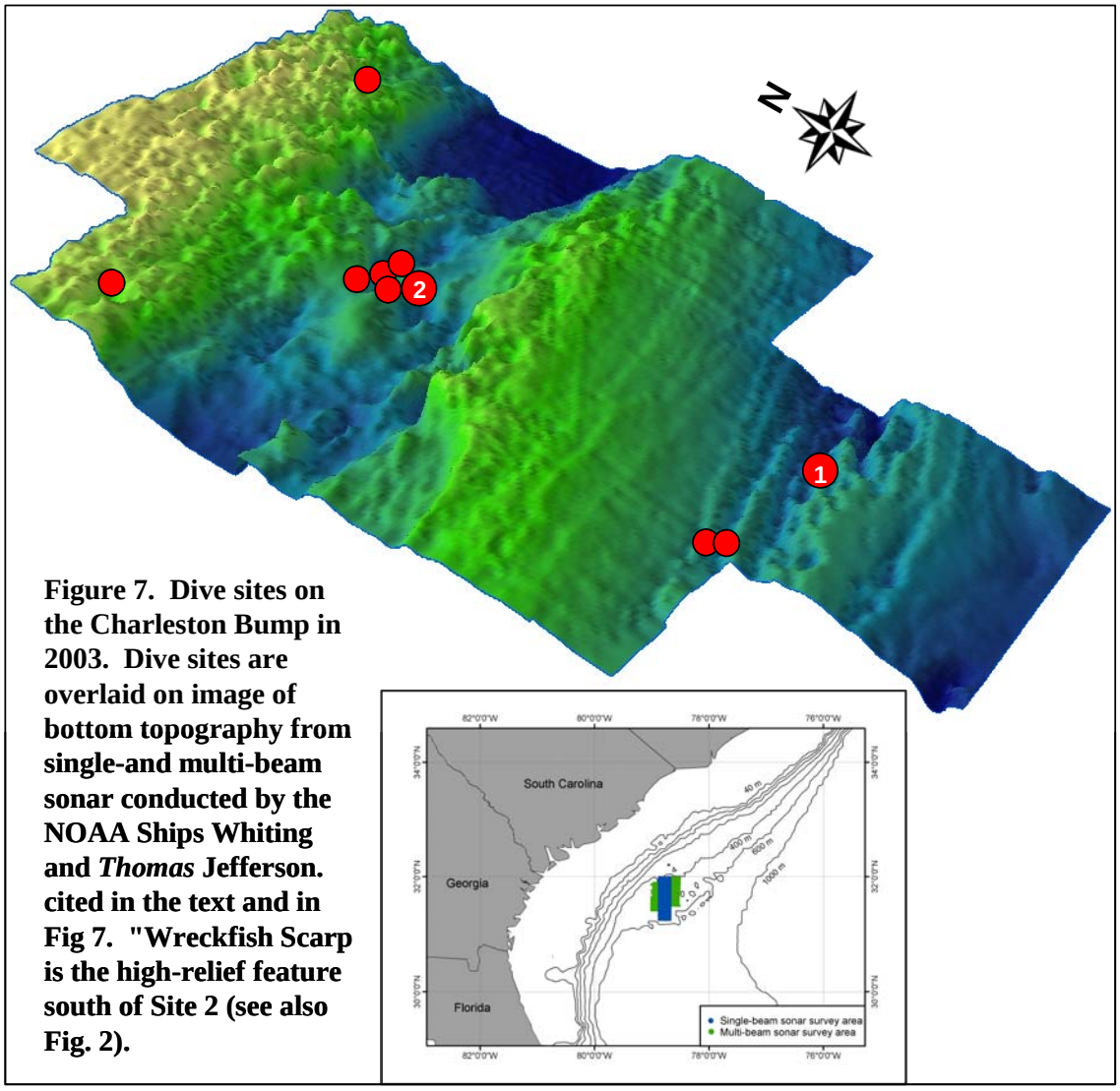


Figure 7. Dive sites on the Charleston Bump in 2003. Dive sites are overlaid on image of bottom topography from single-and multi-beam sonar conducted by the NOAA Ships Whiting and *Thomas* Jefferson. cited in the text and in Fig 7. "Wreckfish Scarp is the high-relief feature south of Site 2 (see also Fig. 2).

near the smaller scarps that had wreckfish. We observed wreckfish closely associated with high-relief rocky bottom, and none were observed over flat hard bottom. In flat areas, moras and grenadiers (Macrouridae) were found (Table 4). Individual moras and grenadiers were often associated with small corals (*Lophelia*) that grew in evenly-spaced clumps on the hard pavement. Pink frogmouths and redeye gapers were also found in this habitat. Skates were occasionally observed. We observed red bream on the south of the Wreckfish Scarp on the southern series of ridges (Dives 3414-3417, Fig. 3; Site 1, Fig. 7). They, like wreckfish, were associated with high-relief rocky bottom and overhangs (Fig. 8).

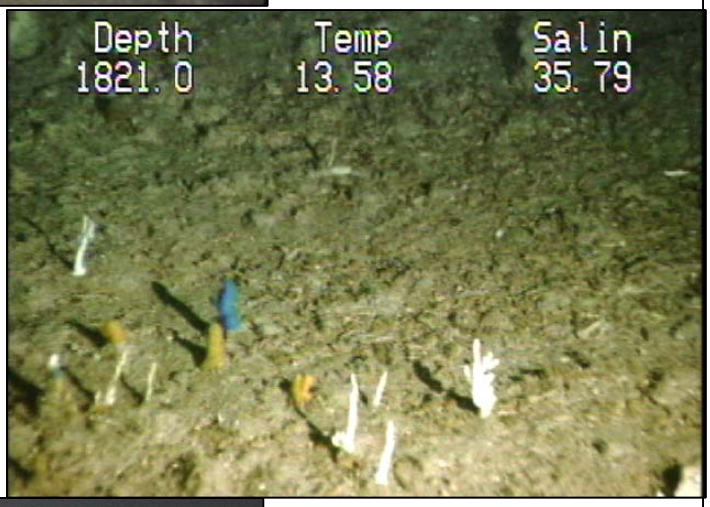
Rock samples obtained on the Charleston Bump during the 2003 Expedition have been subjected to preliminary qualitative analysis (Fig. 9). Preliminary examination indicates that there are at least three distinct rock types forming the sea floor in the Charleston Bump area. These include manganese-phosphorite pavement and nodules, foraminiferan limestone and calcareous mudstone (Fig. 9). The latter two types were found in an interbedded sequence north of the Wreckfish Scarp (Dives 3405, 3406, 3408, 3409, 3418; near Site 2, Fig. 7). This area had "stairstep" relief of about 20 m. The mudstone exhibited greater erosion *in situ* and was very chalky to the touch. The foraminiferan limestone was more resistant to the erosive forces of the strong bottom currents and produced overhangs and steeper-faced slopes where exposed. The result was a terraced, step-like sequence of alternating calcareous mudstones (the eroded terraces) and foraminiferan limestones (the “stairs” at "Neptune's Staircase"). These rocks indicated the cyclical fluctuations over time of the alternating strength of the Gulf Stream, with the mudstone deposition only being possible in low-energy flow regimes. Sessile benthic organisms clearly preferred the foraminiferan limestone as their anchoring substrate and were found in abundance in places where limestone occurred. In some places, the rocks formed nearly vertical cliffs, with alternating layers of the two carbonate rocks. Between these steep areas were narrow terraces, creating a stairway to depths well below 500 m. Overhanging ledges occurred at some intervals, and corals, anemones, and sponges grew on the protected underside of these overhangs. The invertebrate organisms that inhabit these strata preferentially selected the coarser foraminifera limestone as their substrate. Few, if any, organisms were observed attached to the mudstone, perhaps because of its low resistance to erosion, making it a tenuous substrate upon which to attach.

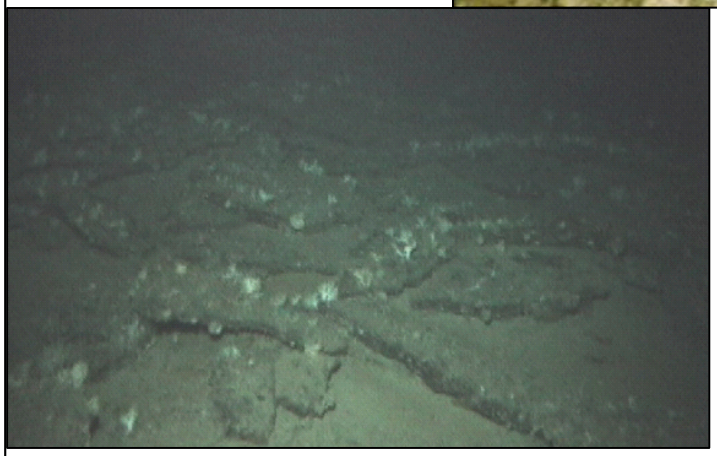
Throughout the Neptune's Staircase dive site, phosphorite was found intermittently as nodules or small individual rocks, but we never encountered a phosphorite rock layer. The origin of these rocks remains unknown.

On our second dive at Neptune's Staircase we encountered several large wreckfish, conger eels and some spectacular rock overhangs, but found no rock layers other than the two types of carbonate. At 554 m, near the base of the staircase, we collected a single rock that contained two distinct layers of manganese-phosphorite, with foraminifera limestone sandwiched between them.

A wreckfish and a red bream shelter beneath a carbonate outcrop festooned with sessile invertebrates. The substrate beneath the outcrop is also hard bottom, but is not encrusted with sessile invertebrates, perhaps because it is of softer material and/or is constantly eroded. These outcrops were common on the southern ridge sites (Site 1, Fig. 6). on the Charleston Bump.

An area of flat hard bottom that is commonly found near Site 2 (Fig. 6). Such areas were swept by swift currents that may restrict recruitment of sessile invertebrates to small colonies such as the corals seen here.

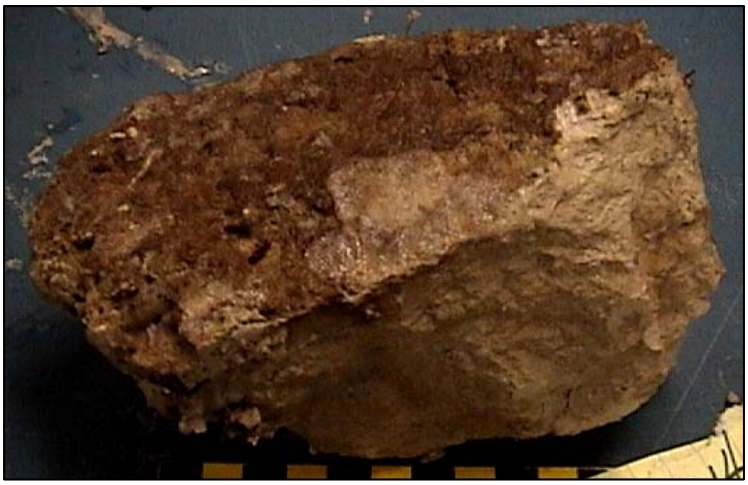




Hard carbonate slabs outcropping from softer carbonate hard bottom on the Charleston Bump (Site 1, Fig. 6).

Figure 8. Habitats and species observed on the Charleston Bump during OE submersible dives in 2003. Depths in feet and temperatures in Celsius. Site numbers refer to numbered sites on Fig. 6.

Manganese-Phosphorite rocks precipitated from seawater



Calcareous mudstone: lithified calcareous phytoplankton

Figure 9. Rock types found on the Charleston Bump during OE submersible dives in 2003.

On the southern ridges area (Dives 3414, 3416; site west of Site 1 in Fig. 7 and Fig. 8) we observed what appeared to be large slabs of the foraminiferan limestone with high-density populations of corals and other invertebrates. Some of these slabs provided large overhanging sheltered habitats. We encountered a school of red bream (75 cm TL) and a wreckfish (100 cm TL) living under one long slab (Fig. 8). No rocks of these large slabs were collected, unfortunately, as they were all too large for the submersible to retrieve. Their blocky nature, particularly on the edges, indicated that they were foraminiferan limestone, rather than manganese-phosphorite. Nearby, however, an excellent example of manganese-phosphorite pavement was collected. It consisted of numerous nodules ranging in diameter from 3 - 6 cm cemented together by manganese-phosphate. Several encrusting bryozoa were living on it, along with several other sessile invertebrates that were different from those seen on the large slabs discussed above.

Manganese-phosphorite was found on most Charleston Bump dives, as broken pavement or scattered rubble, some of which was nodular in form. Generally though, we encountered less than expected. Near Site 2 (Fig. 7), several loose pieces were observed and collected, but an intact pavement layer was never observed. One rock, however, was collected that included a pavement layer on top of a limestone layer. There was also a small piece of manganese-phosphate at the rock's base. This rock is evidence that nearby there was probably an interbedded manganese-phosphorite and limestone sequence.

The manganese-phosphorite rocks appeared to have a different group of organisms inhabiting their surface, and densities were lower than on the limestone, although this has not yet been quantified. Only a few solitary anemones, sponges, ascidians and stony corals were encountered on collected rock specimens.

Sediment samples were also collected on all dives. These samples are all very low in volume, as there was not a lot of sediment available for sampling. These samples will be eventually processed for grain size, organic carbon content and the presence of fossil and recent shelled invertebrates.

During the 2003 Expedition, an acoustic Doppler current profiler (ADCP) made continuous water-column current measurements. Although the data have not been analyzed, we have made some qualitative observations that support hydrographic measurements previously made in the area (Sedberry, Pashuk, Loefer et al. 2004). Full water column current speed and direction acquired from a low (78K Hz) and high (150K Hz) frequency acoustic Doppler current profiler (ADCP) indicated strong along axis currents (> 1 m/s) throughout the water column in the center of the Gulf Stream. This was confirmed by concurrent measurements with the current meter mounted on the submersible that indicated swift currents approaching 1 m/s at the bottom over some dive sites. Measurements at the shelf break indicated a possible subsurface jet traveling opposite to the Gulf Stream.

In addition to ADCP profiles, 16 CTD rosette casts showed a well-defined mixed layer on the bottom that extended 30 km laterally across the swiftest portion of the Gulf Stream (Fig. 10). Bottom temperatures were around 10°C and the mixed layer depth was approximately 100 m thick in the central part of the Gulf Stream. Isotherms tilted upwards towards the shelf edge in agreement with our earlier observations of upwelling at the shelf edge in this region. Salinity varied less than 2 psu between the surface and bottom and subsurface isohalines also tilted upwards towards the edge of the continental margin. The salinity maximum (36.6 psu) occurred

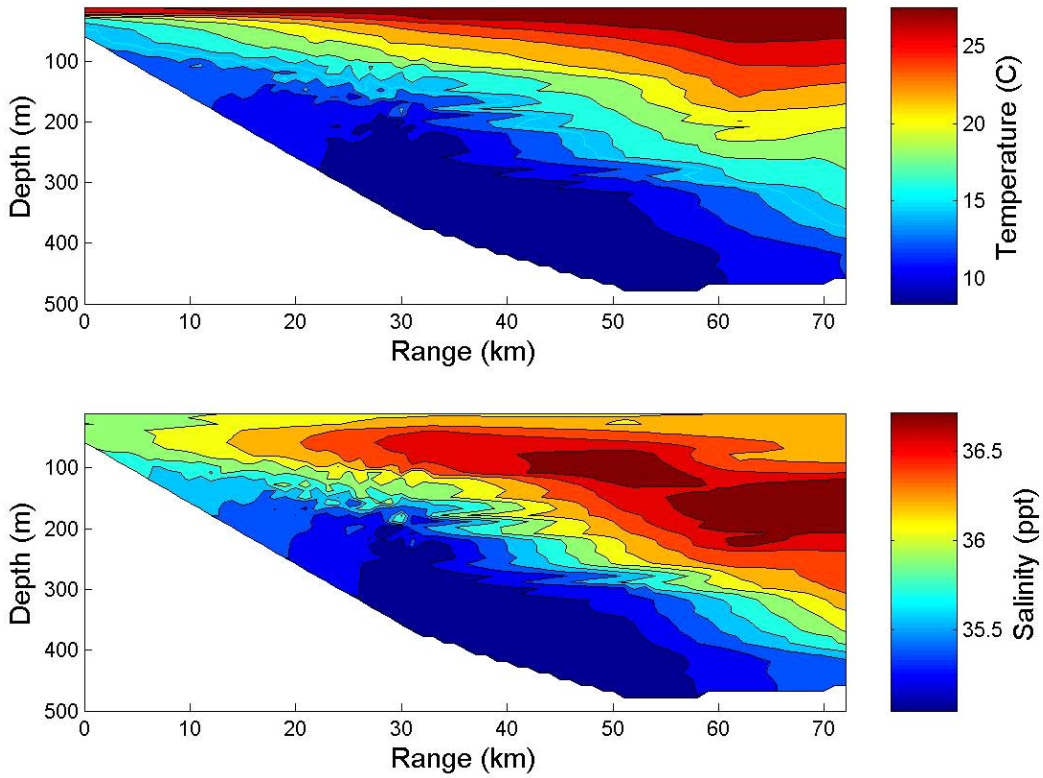


Figure 10. Salinity and temperature cross-section from the shelf edge into the middle of the Gulf Stream from CTD casts during 2003 OE cruise.

at about 150 m depth and a minimum of 35.2 psu was seen in the bottom mixed layer.

Fish Observations

A total of 68 4-min transects was analyzed. This encompassed 4.36 ha of habitat (Table 3). The dominant fish species overall was the tattler, *Serranus phoebe* (Serranidae), which was found only at the shallowest sites sampled, on the shelf-edge reef (Table 4). Other dominant species found on the shelf-edge sites (Tattler Town and Razorback) included tomtate (*Haemulon aurolineatum*, Haemulidae) and unidentified wrasses (Labridae). Tomtate is a shelf species, and was a dominant species at all shelf-edge sites but was absent from the deeper sites on the Charleston Bump and Blake Plateau. Tattler are found mainly on deep shelf-edge reefs. Bigeyes (*Prisigenys alta*), bank butterflyfish (*Chaetodon sedentarius*, Chaetodontidae) and cubbyu (*Equetus umbrosus*, Sciaenidae) were also abundant at shelf-edge reef sites.

Species observed at shelf-edge reefs were not observed in habitats on the Charleston Bump, and vice versa. Rocky habitats on the Charleston Bump were dominated by blackfin codling (*Laemonema melanurum*, Moridae), saddled grenadier (*Caeolrinchus caelorincus*, Macrouridae), red bream (*Beryx decadactylus*, Berycidae), blackbelly rosefish (*Helicolenus dactylopterus*, Scorpaenidae) and shortnose greeneye (*Chlorophthalmus agassizi*, Chlorophthalmidae). Other common fishes of the Charleston Bump were the Cuban dogfish

(*Squalus cubensis*, Squalidae), chain dogfish (*Scyliorhinus retifer*, Scyliorhinidae), lightnose skate (*Breviraja colesi*, Rajidae), pink frogmouth (*Chaunax pictus*, Chaunacidae) and wreckfish (*Polyprion americanus*, Polyprionidae).

Table 3. Number of transects and mean values of length, area volume, depth, temperature and salinity measured along transects at each dive site.

Site	Number	Length (m)	Area (m^2)	Volume (m^3)	Depth (m)	Salinity (psu)	T (°C)
B-Cubed	7	98.51	617.04	3,754.15	552	35.78	13.54
Fathom Ridge	10	148.47	990.70	5,906.40	412	35.17	9.47
Neptune's Staircase	7	56.94	181.60	525.40	550	35.26	9.97
Razorback	7	61.29	337.84	1,493.92	48	35.76	15.43
Sherwood Valley	7	259.21	1,879.30	9,866.34	385	35.37	11.03
Ski Jump	11	91.71	448.74	1,812.39	505	35.07	8.51
Slab Garden	8	67.91	269.54	877.86	543	35.83	14.08
Tattler Town	8	104.95	361.61	919.49	77	35.87	13.72
Velvet Steps	3	117.80	854.05	4,483.76	553		

Fish assemblages at shelf-edge reefs were much more diverse than those of the Charleston Bump (Table 4). Overall, at least 34 species representing 24 families were observed. Only ten species in ten families were observed at the Charleston Bump sites. The Serranidae (sea basses) was the most diverse family among all sites, represented by three species. Chaetodontids (butterflyfishes), bigeyes (Priacanthidae) porgies (Sparidae) were represented by two species each. Identification of wrasses (Labridae) was difficult, but at least two species were observed. Fish diversity was rather low at all sites. Deep reefs and less complex reefs generally have lower fish diversity than shallower reefs or reefs with greater habitat complexity, and the shallowest reefs we observed during this Expedition had generally low relief and less complex habitat than we have observed on previous studies (Sedberry, Cooksey, Crowe et al. 2004).

Economically valuable fishes observed included blackbelly rosefish, wreckfish and red bream observed on the Charleston Bump, and vermilion snapper, red porgy, knobbed porgy, scamp, snowy grouper and greater amberjack at shelf-edge reefs.

Table 4. Fishes observed at each dive site during preliminary analysis of submersible transects, expressed as number per cubic meter of water transected. Species are ranked by overall density, from highest to lowest.

						Dive Sites				
Species (common name)	Total	B-Cubed	Fathom Ridge	Neptune's Staircase	Razorback	Sherwood Valley	Ski Jump	Slab Garden	Tattler Town	Velvet Steps
Serranus phoebe (tattler)	0.08701	-	-	-	0.00036	-	-	-	0.01060	-
Laemonema melanurum (blackfin codling)	0.04603	0.00154	0.00207	0.00114	-	0.00021	0.00066	0.00085	-	0.00026
Labridae (wrasses)	0.03912	-	-	-	0.00054	-	-	-	0.00448	-
Haemulon aurolineatum (tomtate)	0.03374	-	-	-	0.00562	-	-	-	-	-
Pristigenys alta (short bigeye)	0.02539	-	-	-	0.00165	-	-	-	0.00193	-
Unknown	0.02058	0.00010	0.00044	-	0.00072	0.00029	0.00021	-	0.00097	-
Caelorinchus caelorhincus (saddled grenadier)	0.01537	-	0.00057	0.00103	-	0.00004	0.00076	-	-	-
Beryx decadactylus (red bream)	0.01424	-	-	-	-	-	-	0.00356	-	-
Chaetodon sedentarius (reef butterflyfish)	0.01060	-	-	-	0.00025	-	-	-	0.00114	-
Helicolenus dactylopterus (blackbelly rosefish)	0.00991	-	0.00078	-	-	0.00015	0.00014	-	-	-
Equetus umbrosus (cubbyu)	0.00914	-	-	-	0.00152	-	-	-	-	-
Chromis enchrysura (yellowtail reeffish)	0.00829	-	-	-	-	-	-	-	0.00104	-
Seriola dumerili (greater amberjack)	0.00677	-	-	-	0.00113	-	-	-	-	-
Pagrus pagrus (red porgy)	0.00632	-	-	-	-	-	-	-	0.00079	-
Bodianus pulchellus (spotfin hogfish)	0.00588	-	-	-	0.00098	-	-	-	-	-
Chlorophthalmus agassizi (shortnose greeneye)	0.00498	0.00055	0.00011	-	-	-	-	-	-	-
Holacanthus ciliaris bermudensis (blue angelfish)	0.00480	-	-	-	0.00067	-	-	-	0.00010	-
Priacanthus arenatus (bigeye)	0.00479	-	-	-	0.00067	-	-	-	0.00010	-
Squalus cubensis (Cuban dogfish)	0.00418	-	0.00024	-	-	0.00021	0.00005	-	-	-
Canthigaster rostrata (sharpnose puffer)	0.00400	-	-	-	-	-	-	-	0.00050	-
Sparidae	0.00391	-	-	-	0.00065	-	-	-	-	-
Myripristis jacobus (blackbar soldierfish)	0.00292	-	-	-	0.00049	-	-	-	-	-
Mycteroperca phenax (scamp)	0.00158	-	-	-	-	-	-	-	0.00020	-
Calamus nodosus (knobbed porgy)	0.00142	-	-	-	0.00024	-	-	-	-	-
Holocentrus adscensionis (squirrelfish)	0.00142	-	-	-	0.00024	-	-	-	-	-
Chaetodon sp.(butterflyfishes)	0.00095	-	-	-	-	-	-	-	0.00012	-
Synodus sp. (lizardfishes)	0.00095	-	-	-	-	-	-	-	0.00012	-
Epinephelus niveatus (snowy grouper)	0.00079	-	-	-	-	-	-	-	0.00010	-
Prognathodes aya (bank butterflyfish)	0.00079	-	-	-	-	-	-	-	0.00010	-
Scyliorhinus retifer (chain dogfish)	0.00045	0.00006	-	-	-	-	-	-	-	-

Table 4. Continued.

Species (common name)	Total	B-Cubed	Fathom Ridge	Neptune's Staircase	Razorback	Sherwood Valley	Ski Jump	Slab Garden	Tattler Town	Velvet Steps
					Dive Sites					
Breviraja colesi (lightnose skate)	0.00040	-	0.00004	-	-	-	-	-	-	-
Rhomboplites aurorubens (vermilion snapper)	0.00035	-	-	-	0.00006	-	-	-	-	-
Chaunax pictus (pink frogmouth)	0.00032	-	-	-	-	-	-	0.00008	-	-
Polyprion americanus (wreckfish)	0.00016	-	0.00002	-	-	-	-	-	-	-

Shelf-edge reefs (Tattler Town, Razorback) observed in 2003 had a much lower abundance and diversity of fishes, compared to shelf-edge reefs observed by us in 2002 (Sedberry, Cooksey, Crowe et al. 2004). Lower abundance and diversity of fishes at the 2003 sites resulted from fewer transects done at these locations when compared to other shelf-edge sites during 2002. Eight transects were conducted at Tattler Town, and seven at Razorback; whereas 2002 shelf-edge sites had an average of 21.6 transects. More importantly, the habitats seen at the two 2003 shelf-edge dive sites were often buried in large amounts of sediment, and included only low-relief rocky features. The bioeroded rock and boulders observed at the two sites were often patchily distributed and low in relief, with large expanses of open sandy bottom. Five out of the 15 transects were conducted on sand habitat, which contains few fishes relative to high-relief hard bottom (Wenner 1983). Habitats seen during 2002 shelf-edge dives had much more relief, a greater diversity of habitats and less sediment cover when compared to 2003 sites (Sedberry, Cooksey, Crowe et al. 2004). Low fish abundances and species diversity seen at Tattler Town and Razorback were the result of both a small sample size and the dominance of low relief/sandy habitat types.

One of our objectives was to observe feeding behavior on fishes on the Charleston Bump, to determine if wreckfish, red bream and other large predators could be observed feeding on vertically migrating mesopelagic fishes and invertebrates, as has been documented for some predatory fishes of the continental slope (Sedberry and Musick 1978; Weaver and Sedberry 2001). We did not observe any feeding behavior, but the submersible lights may have prevented such observations. Without the lights, phosphorescent glows from numerous mesopelagic species could be observed, but with the lights on, the organisms responsible could not be seen and predators like red bream and wreckfish appeared to move slowly away from the sub. Resolution of food chain dynamics on the Charleston Bump will need additional study, and such work is currently planned with additional funding obtained from NOAA Fisheries.

Benthic Fauna Characterization

Visual Observations of Sessile Invertebrates

Analysis of videotapes for sessile epifauna was restricted to selected antipatharian corals (*Stichopathes* sp.) and sponges. *Stichopathes* sp. was chosen because it is readily observable and its abundance has been documented on previous OE expeditions in the region.

The only record of *Stichopathes* sp. on the 2003 Ocean Exploration cruise was observed at Razorback, the 47-m deep shelf-edge site off Georgia. Razorback was one of two shelf edge dives conducted on the 2003 cruise. There were no *Stichopathes* sp. observed at the second shelf edge site (Tattler Town), a 61-m deep site off northern South Carolina. However, OE exploration of shelf-edge reefs off the southeastern United States in 2002 (Sedberry, Cooksey, Crowe et al. 2004) and during the present Expedition revealed two different reef systems. Shelf-edge reef systems off Florida and Georgia appear to be low-relief formations in tranquil areas, while those in northern South Carolina are near documented upwelling areas (Sedberry, Pashuk Loefer et al. 2004) which may not be a suitable habitat for antipatharian corals. During the 2002 Ocean Exploration cruise, *Stichopathes* sp. observations were limited to the shallower, shelf-edge dives (46-58 m), and no *Stichopathes* sp. were observed at the deeper, upper slope Charleston Lump sites (183-215 m) in 2002 (Fig. 6). Over all shelf-edge dives in 2002, *Stichopathes* sp. abundances were approximately 0.12 per m^2 ($\pm$ 0.02), with highest densities

observed at the St. Augustine Scarp site off northern Florida (ranging from 0.10 to 0.74 individuals/m^2). No significant differences in the abundances of *Stichopathes* sp. were observed among the 2002 dives ($p > 0.05$). Abundances of *Stichopathes* sp. on the 1985 dives were similar to those observed on the 2002 Ocean Exploration cruise, with the exception of site M3 (Fig. 6), which had significantly fewer *Stichopathes* sp. than the one of the St. Augustine dive sites ($p < 0.05$). Abundances of *Stichopathes* sp. recorded in 2003 were not compared to previous years because only two specimens of the coral were observed at one site. A majority of the dives completed in 2003 were at the Charleston Bump feature off South Carolina, an area where *Stichopathes* sp. is not typically observed.

Stichopathes sp. has been previously documented in shelf edge habitats in the South Atlantic Bight. Television transects collected as part of the South Atlantic OCS Area Living Marine Resources Study off North Carolina, South Carolina, and Georgia documented the presence of corkscrew-shaped antipatharian corals at outer-shelf sites (46-100m) (DUML 1982; SCWMRD 1982). A single representative specimen obtained at one site was taxonomically identified as *Stichopathes* sp. by F.M. Bayer at the Smithsonian Institution (SCWMRD 1982). These corals were observed occasionally at outer-shelf sites and were absent at inner- and middle-shelf stations (18-33 m) using towed underwater television. In general, greater abundances were found off North Carolina than at stations sampled off South Carolina and Georgia (SCWMRD 1982). In North Carolina waters, *Stichopathes* sp. were estimated to occur at a frequency of approximately seven percent along transects. Off South Carolina and Georgia, *Stichopathes* sp. had an average frequency of occurrence along transects of less than one percent (0.63%).

Estimates of *Stichopathes* sp. abundance from the 2002 study (0.12 per $m^2 \pm 0.02$) were similar to previous reports for this species off South Carolina and Georgia, while densities in shelf-edge habitats off North Carolina were higher than those documented by the Ocean Exploration 2002 and 2003 cruises. Photographic quadrats (3 m^2) used in the South Atlantic OCS Area Living Marine Resources Study to characterize bottom fauna estimated *Stichopathes* sp. abundances at 0.02 per m^2 ($\pm$ 0.13) on the outer-shelf of South Carolina and Georgia based on the analysis of 108 quadrats. Off North Carolina, *Stichopathes* sp. densities were estimated at 1.1 per $m^2 \pm 0.3$ at outer-shelf sites, and occurred in 15% of the 71 photographic quadrats analyzed (SCWMRD 1982).

Collections made in the South Atlantic Bight as part of a survey of four oil and gas lease blocks in the Georgia Embayment (Continental Shelf Associates, Inc. 1979) found a spiral sea whip to be abundant in an area studied off South Carolina that had depths ranging from 44 to 78 m. Specimens were not collected, but the coral was tentatively identified as *Cirrhipathes* sp. based on photographs. The morphology of the coral, which was found primarily associated with ridges and scarps, is very similar to the coral observed during the 2002 and 2003 Ocean Exploration cruises and may be the same organism (Fig. 11). Another antipatharian coral, *Antipathes rhipidion*, was also found in Continental Shelf Associates (1979) dredge collections.

Taxonomic identification of sponges is complex and typically requires examination of spicules for confirmation; in addition, several of the deep-water sponge specimens in the South Atlantic Bight may constitute species new to science (Pomponi, personal communication). Therefore, in the current study, all large sponges were quantified as a single metric. Several morphotypes were included in estimates of sponge abundances, such as vase sponges, “cake”

sponges, and "cantaloupe" sponges, but estimates did not include encrusting varieties. Detailed taxonomic identification was completed on a subset of the sponges collected during OE submersible dives from 2002-2004 as part of an analysis of faunal associates. These species included *Geodia* sp., *Ircinia campana*, *Chondrilla* sp., *Erylus* sp., *Aplysina archeri,* and members of the families Halichondriidae and Geodiidae; more details on these specimens are presented below.

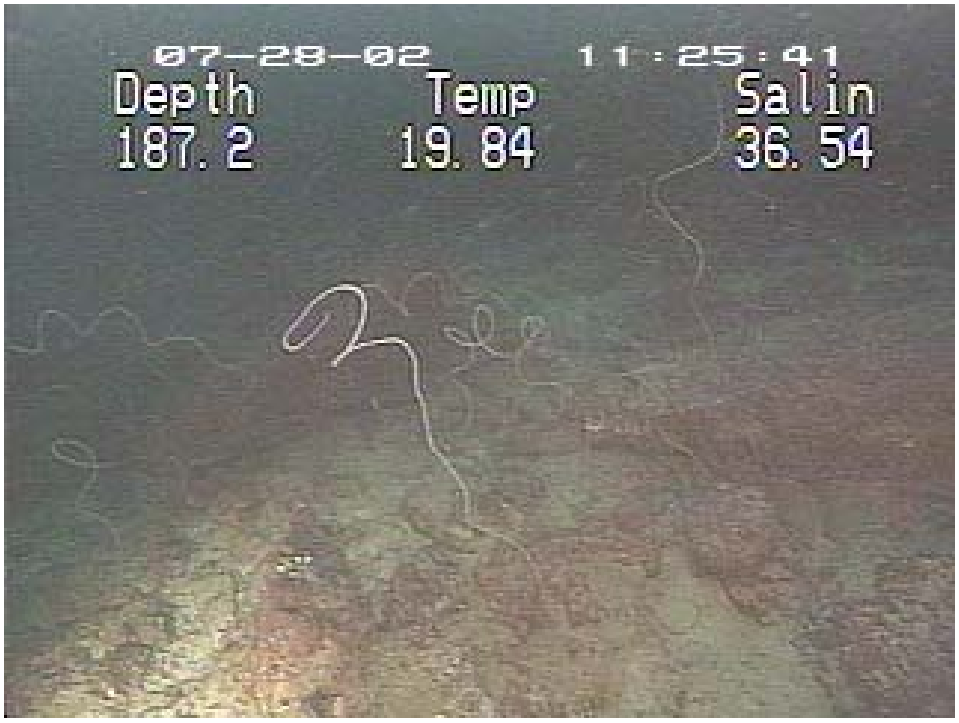
Overall sponge abundance in the current study ranged from zero to 0.373 individuals per m^2 (zero to 100 individuals per two minute transect), with an average of approximately 0.05 per m^2 ($\pm$ 0.01). The highest density of sponges was observed during the first Slab Gardens dive, and included vase sponges and "cake" sponges (Fig. 12).

Substantial variability occurred within the study sites surveyed in 2003, but not between them. When shelf-edge and Charleston Bump sites were considered separately, there was no significant difference in the abundance of large sponges. Within the group of shelf-edge sites, the Tattler Town site had a significantly greater density of large sponges than Razorback ($p = 0.021$). However, there was no significant difference in the abundance of large sponges between shelf edge sites surveyed in 2002 and 2003. Within the Charleston Bump dive sites, Slab Gardens 1 had significantly higher abundances of large sponges than both B-Cubed sites, both Velvet Steps sites, both Neptune's Staircase sites, Slab Gardens 2, and Ski Jump site ($p < 0.05$); Sherwood Valley had significantly higher large sponge abundances than both B-Cubed sites, both Velvet Steps sites, Ski Jump, Slab Gardens 2, and Neptune's Staircase 2 ($p < 0.001$). Neptune's Staircase, a 550m site on the Charleston Bump, had significantly higher abundances of large sponges than Velvet Steps 1 and B-Cubed 1 ($p < 0.040$), while Fathom Ridge (411m) had significantly higher abundances than both Velvet Steps sites and both B-Cubed sites ($p < 0.001$). Slab Gardens 2 (550m), had significantly higher abundances of large sponges than the deepest site, Velvet Steps 1 (564m) ($p< 0.017$).

Estimates of large sponge densities generated from the current study (0.05 per $m^2 \pm 0.010$) and the 2002 study (0.04 per $m^2 \pm 0.007$) are similar to values reported for *Ircinia campana* at outer-shelf sites off South Carolina based on photographic quadrats (n = 108, mean density = $0.04/m^2 \pm 0.03$) (SCWMRD 1982, Wenner et al. 1983). *Geodia gibberosa* was also observed at outer-shelf sites in South Carolina and Georgia waters, but density estimates were not available (SCWMRD 1982). *Ircinia campana* and *Geodia gibberosa* were also reported on the outer-shelf of North Carolina based on television transects, dredges, and trawls (DUML 1982).

Several of the sponge species that were taxonomically identified as part of the 2002 and 2003 studies have been reported in collections made in the South Atlantic Bight during a survey of four oil and gas lease blocks (Continental Shelf Associates, Inc. 1979). *Geodia* sp. and *Ircinia campana* were found in several dredge collections, while *Chondrilla* sp. and *Erylus* sp. were collected in one to two dredge samples. *Aplysina archeri* was not documented during the Continental Shelf Associates survey, although it is possible that this species was among the unidentified porifera that were collected.

A.



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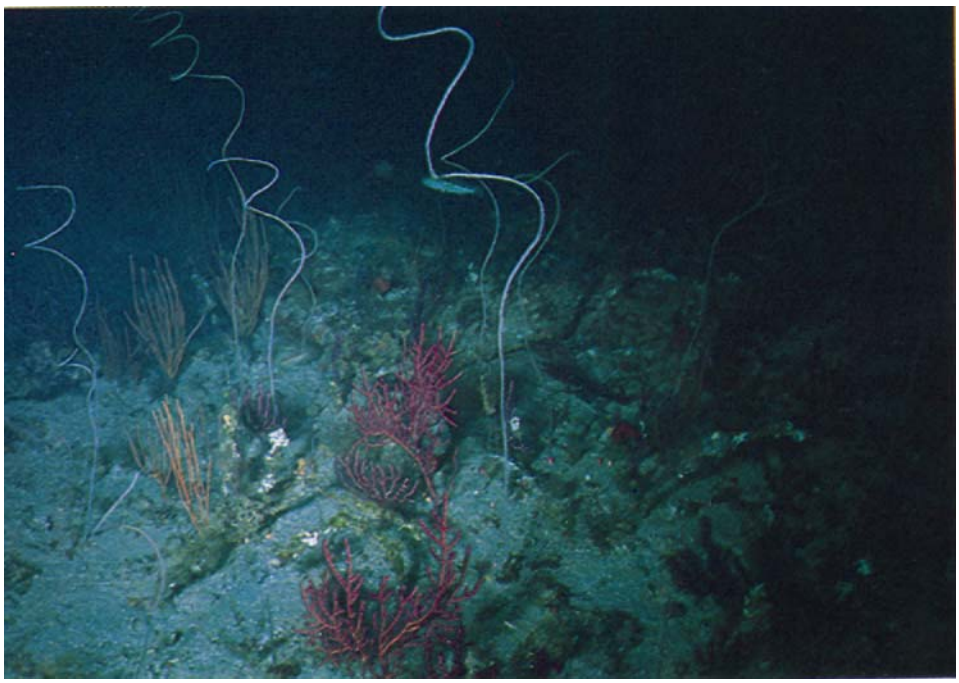

Figure 11. A. Antipatharian coral provisionally identified as *Stichopathes* sp. from the 2002 Ocean Exploration cruise. Date, time, depth (ft), temperature (°C), and salinity (psu) are shown on the screen. B. Antipatharian coral identified based on photographs as *Cirrhipathes* sp. from a survey off Charleston SC (depth = ~53 m) in 1978 (Continental Shelf Associates 1979).

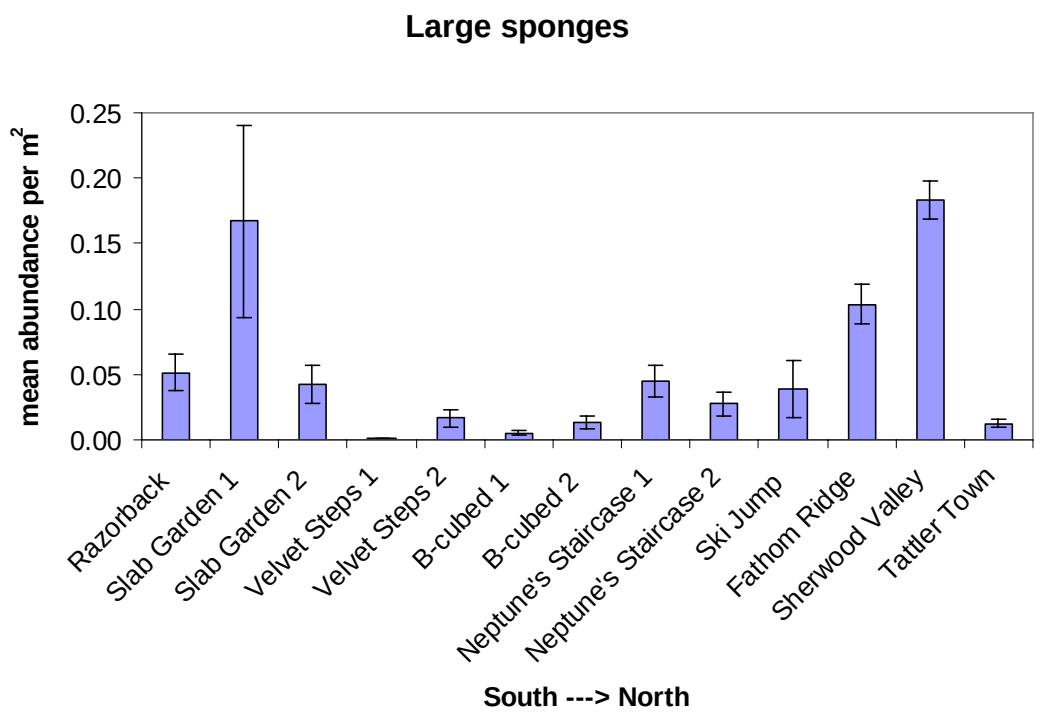

Figure 12. Abundance per m^2 of large sponges observed during 2003 submersible dives. Standard error bars are shown.

Sponge Symbionts

Eleven sponge specimens collected from Ocean Exploration submersible dives in 2002-2004 were analyzed in order to determine the number and composition of associated fauna. A total of 9,834 organisms representing ten taxa were supported by the host sponges (Table 5). High densities of faunal associates on large macroinvertebrates such as sponges indicated that these organisms are being used either as a source of food or a refuge from predation (Wendt et al. 1985). Polychaetes and amphipods accounted for the greatest number of faunal associates, contributing 93% and 5%, respectively, to the total number of taxa collected from all host sponges. All other taxa contributed less than 2% to the total number of organisms.

The host sponge specimen, *Chondrilla* sp., collected during the present Expedition in 2003, supported a total of 163 organisms representing six taxonomic groups (Table 5). Amphipods, polychaetes, and decapods accounted for the greatest number of faunal associates, contributing 38%, 23% and 23%, respectively, to the total number of taxa collected from *Chondrilla* sp. Isopods (13%) were also important constituents of the associated fauna, while all other taxa contributed less than 4% to the total number of organisms (Fig. 13). *Chondrilla* sp. examined from 2002 and 2004 cruises were also dominated by amphipods, contributing 51% and 45%, respectively, to the total number of taxa (Fig. 13, Table 5). Two amphipod species, *Leucothoe* sp. and *Erichthonius brasiliensis*, and a snapping shrimp, *Synalpheus townsendi*, were

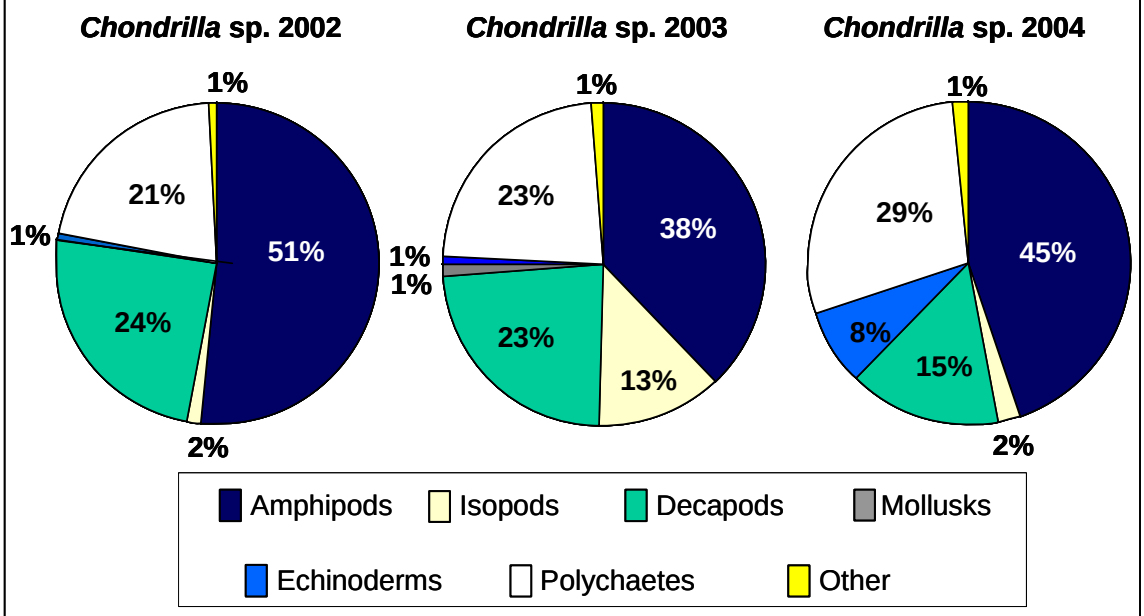

Figure 13. Percent of the total faunal associates representing general taxonomic groups found in the sponge *Chondrilla* sp., collected during OE submersible dives in 2002, 2003 and 2004.

the most abundant taxa found in association with all three specimens of *Chondrilla* sp. *Leucothoe* sp. and *S. townsendi* have both been previously reported as commensal organisms (Crowe and Thomas 2002, Williams 1984), while *E. brasiliensis* is a common tube-dwelling species (Bousfield 1973), which is most likely constructing its domicile on the outside of the sponge. Duffy (1992) found that the commensal snapping shrimps of the genus *Synalpheus* occurred more commonly in hosts that exhibited a diversity of canal widths, while Villamizer and Laughlin (1991) suggested that sponges offering a system of channels and meanders that could provide a complex domicile may support a greater number of individuals and diversity of taxa. The internal architecture of *Chondrilla* sp. is characterized by numerous meandering canals and cavities which may provide a suitable habitat for commensal organisms (Fig. 14).

The number and composition of faunal associates varied within and between sponge species. Faunal associates on *Erylus* sp. were heavily dominated by annelids (96%), while fauna associated with all three specimens of *Chondrilla* sp. were primarily composed of arthropods (average of 71%), including amphipods, decapods, and isopods. Annelids and arthropods were abundant on *A. archeri*, while Geodiidae was dominated by ophiuroids. The specimens of *Ircinia campana* collected in 2002 and 2004 differed in faunal associates between those two time periods. Although they were both collected at the same site, St. Augustine Scarp, FL, and at similar depths, the 2002 specimen was dominated by arthropods (59%), while the 2004 specimen contained the highest number of annelids recorded (8,365) which constituted 99.7% of all associated fauna in that specimen. The 2002 and 2004 *I. campana* specimens had substantially

different volumes, 275ml and 655ml, respectively, which could have played an important role in the number and composition of their associated fauna. Interestingly, the largest sponge specimens analyzed, both *Geodia* sp., had the fewest faunal associates (Table 5). This species is characterized by oxea and oxyaster spicules (among others) and relatively small internal canals, which may result in an inhospitable habitat for faunal associates (Fig. 15).

In an initial taxonomic review of faunal associates from the eleven host sponges, several commensal organisms (i.e. relationships where one species benefits from association, while the other is neither harmed nor benefited) have been noted. The overwhelming numerical dominance by polychaetes is likely attributed to the occurrence of a single commensal species, *Syllis spongicola*. Other commensal organisms that have been identified include the snapping shrimps, *Synalpheus* sp., and the amphipods *Colomastix* sp., and *Leucothoe* sp. Further analyses are necessary to determine identifications to the species level, which would lead to more detailed analyses involving the faunal associates in general. While rarely studied in marine ecosystems, commensal associations are important in determining and evaluating evolutionary changes and maintaining ecosystem balance.

While no studies to date have investigated faunal associates of deep-water sponges, Wendt *et al.* (1985) completed an analysis of macrofauna associated with three sponges (*Haliclona oculata*, *Ircinia campana*, and *Cliona celata*) from nearshore waters off Georgia (~ 20 m depth). A similar number of host sponges were analyzed (n = 9), and faunal associates from 19 general taxonomic categories were identified. As in the current study, the syllid polychaete *Syllis spongicola* was dominant. In a comparison of faunal associates on *Ircinia campana*, the only sponge species analyzed in both studies, Wendt *et al.* (1985) found the syllid *Syllis spongicola* contributed more than 98% of the total abundance of faunal associates on *I. campana* (n = 3), followed by the gastropod *Parviturboides interruptus*, (1.01%), which is similar to the 2004 *I. campana* specimen that housed an identical percentage of polychaetes (99%) while the remainder of the faunal associates consisted mainly of amphipods. In contrast, faunal associates on the 2002 specimen of *I. campana* analyzed were dominated by amphipods (59% of total abundance), while annelids (including *Syllis spongicola*) contributed to only 34% of the total abundance. Future studies exploring trends in deep-water and nearshore sponge faunal associates would benefit from increased sample sizes and more detailed taxonomic identification of faunal associates.

Table 5. Associated fauna of the eleven host sponges collected during Ocean Exploration Expeditions in the South Atlantic Bight, 2002-2004. One specimen (*) has been analyzed from the current (2003) Expedition. Additional sponges collected in 2002 and 2004 are included for comparison.

	2002 Sponge Hosts				
	Erylus sp.	***A. archeri***	***Chondrilla* sp.**	***I. campana***	***Geodia* sp.**
Associated Fauna	**Number of Individuals of Each Symbiont Taxon**				
Annelida	515	76	25	33	4
Arthropoda	20	101	92	57	11
(Amphipoda)	14	6	61	44	3
(Cirripedia)	0	72	0	0	0
(Copepoda)	0	0	0	1	0
(Decapoda)	0	19	29	7	3
(Isopoda)	0	3	2	0	3
(Tanaidacea)	6	1	0	5	2
Echinodermata	2	0	2	6	1
Mollusca	1	0	0	1	0
Other	0	1	0	0	0
Total	538	177	119	97	16

Table 5. Continued.

	2003-2004 Sponge Hosts					
	Chondrilla* sp.	***I. campana***	**Halichondriidae**	***Geodia* sp.**	***Chondrilla* sp.**	**Geodiidae**
Associated Fauna	**Number of Individuals of Each Symbiont Taxon**					
Annelida	38	8365	9	0	53	27
Arthropoda	121	15	1	0	115	13
(Amphipoda)	62	11	0	0	83	2
(Cirripedia)	0	0	0	0	0	0
(Copepoda)	0	0	0	0	0	0
(Decapoda)	38	2	0	0	28	1
(Isopoda)	21	2	1	0	4	10
(Tanaidacea)	0	0	0	0	0	0
Echinodermata	2	1	4	3	14	83
Mollusca	2	2	0	0	0	2
Other	0	0	9	1	3	4
Total	163	8383	23	4	185	129

* 2003 specimen; all other specimens were collected in 2002 or 2004, but are used here for comparative purposes

A.

B.

Figure 14. *Chondrilla* sp. specimen collected during the 2003 Ocean Exploration cruise which was dissected for analysis of faunal associates. A) Entire *Chondrilla* sp. collected from the shelf-edge reef at Razorback; and B) view of internal canals of *Chondrilla* sp.

A.

B.

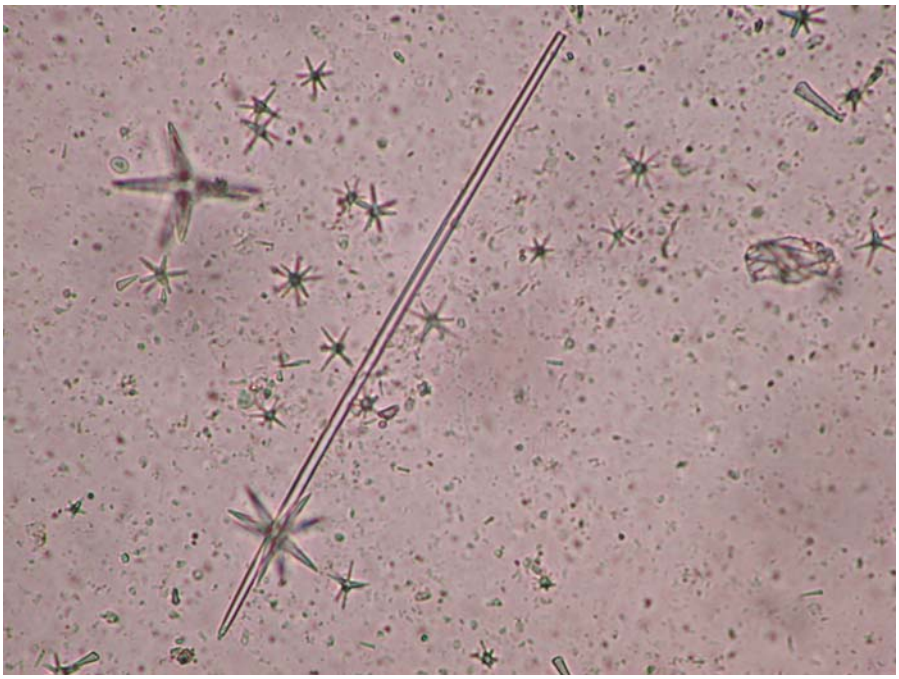

Figure 15. A. View of *Geodia* sp. internal canal structure (6.3x magnification). B. Long, slightly curved oxea spicule and star-shaped oxyaster spicules from *Geodia* sp. (40x magnification).

Coral Microconstituent and DNA Samples

Multiple species of deepwater scleractinian coral were present on the manganese-phosphorite pavements and rocks that we sampled during the 2003 OE Expedition. All are ahermatypic, existing beneath the photic zone. Although thickets of corals such as *Lophelia* were present, they were neither as extensive as noted elsewhere on the southeastern North American coast, nor were they the most abundant type. Smaller encrusting taxa were far more abundant. The growth habits of these species vary from small solitary corals, to short robust branching colonies, to more delicate branching colonies.

The distribution of these corals was not uniform on all hard substrate, with some areas displaying dense growth and offering critical habitat for larger commercially important finfish species such as wreckfish. Other areas had only sparse encrustation. The distribution of fossil corals in the same region suggests that this pattern has persisted. The aging and growth studies that we have begun will eventually give insight into the causes of these distributions.

Preliminary results from the chemical analysis of corals by ontogenetic microsampling of the skeletal aragonite revealed stable carbon and oxygen isotope and Sr:Ca profiles that often oscillated in tandem with visible growth bands apparent in cross section. Otherwise sinusoidal geochemical profiles were interrupted by zones of more abrupt variation, suggesting periods of growth diminishment or cessation. This observed elemental and isotopic cyclicity may enable future coral growth rate analysis and therefore facilitate future development of these corals as paleoclimate proxies. Most of the coral colonies seemed to grow slowly (< 1mm/year) and episodically (sometimes it appeared regular and seasonal and at other times it did not).

Abundant fossil corals were also present in this location and many were collected adjacent to the living analogue specimens described here. The isotopic and elemental data contained in these fossils may represent a valuable paleoclimate archive. The Charleston Bump is an area of significant relief (~300 m rise from the Blake Plateau), consisting principally of limestone and extensive manganese-phosphorite pavement. It is situated so as to deflect the Gulf Stream, causing large-scale eddies and upwelling, such as the biologically productive Charleston Gyre. Therefore, unlike many other deepwater coral habitats, the Charleston Bump is comparatively dynamic with respect to temperature, current flow, and other climate-related variables. As such, coral climate proxies from this region may be sensitive indicators of past Gulf Stream variation.

Although solitary corals likely offer the best opportunity to discern past climate change through geochemical analysis, growth analysis in this project has focused on the more ecologically consequential colonial branching corals at this stage. Widely variable growth rates along different axes of extension may create differing isotopic and elemental distributions. For example, growth is greater perpendicular to the direction of principle current flow than along other axes. Further, most polyps are situated on the upstream side of the colony. These patterns complicates environmental interpretation of geochemical profiles, however, general trends in these profiles may indicate seasonal variation in growth. Generally sinusoidal oscillations were present in profiles of stable carbon isotopes ($\delta^{13}C$; Fig. 16) and Sr:Ca ratios (Fig. 16), and are less evident in oxygen isotope profiles ($\delta^{18}O$; Fig 16). In the figure (Fig. 16), the presence of growth
zones in the coenosteum are indicated by vertical lines. Dashed lines indicate poorly resolved zones.

In addition to the above analyses, we have analyzed corals for 10 additional elements.

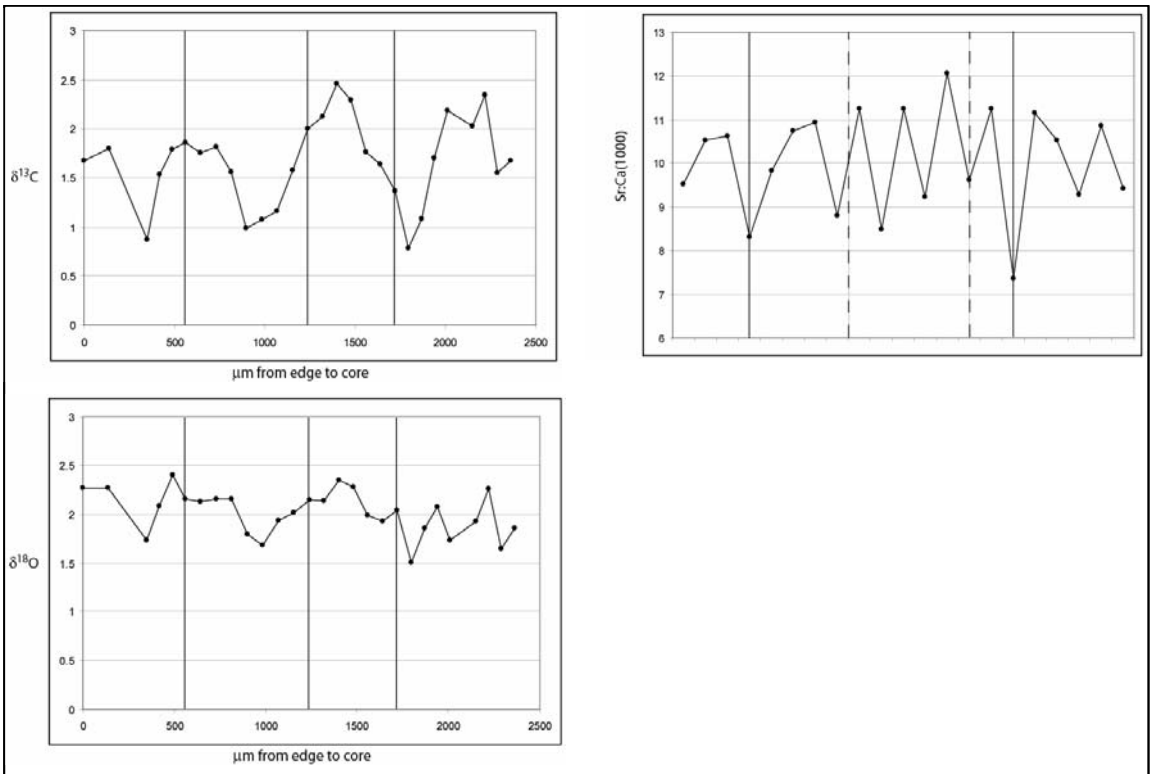

Figure 16. Oscillations in stable carbon isotopes (upper left), Sr:Ca ratios (upper right) and oxygen isotope (lower left) profiles in corals from the Charleston Bump.

Dr. Andrus has measured the increments on thin sections of several corals, which have been analyzed for aragonite and calcite content via Raman Spectroscopy. Twelve samples for have been sent off for radiocarbon analysis though Dr. Patrick Harris at SCDNR. Investigators have begun a collaboration toward studying the fossil corals from the Charleston Bump, to determine past populations changes relative to modern.

Fourteen samples of living corals were collected by submersible or pipe dredge for DNA analysis. Samples included a voucher specimen for identification and cataloging, and a tissue sample for DNA analysis. These samples were forwarded to Dr. Scott C. France, University of Louisiana, and will be processed in the future.

Neuston Samples

An additional 27 collections were made with a surface neuston net during the 2003 Ocean Exploration Cruise (Table 1, Fig. 4). Because of a lack of funding, neuston samples have not been sorted. We are looking for additional sources of funding to sort and identify the larval fishes and decapods from these collections.

EVALUATION

In spite of some weather and technical difficulties, most field tasks were accomplished, and we made some very valuable observations and collections. We still have many objectives to achieve. As noted above in several places, funding was not available to completely analyze the samples and videotapes collected. However, as also noted above, samples have been archived and are in the laboratories of cooperating investigators who have expertise in the particular area of each sample. We are seeking sources of funding for continued analysis of samples and hope to achieve all the project objectives in the future.

A problem with completing the objectives of the project is the analysis of benthic suction and scoop samples, to examine the distribution of benthic invertebrates in relation to bottom features such as amount of exposure and surface orientation. Two separate projects were funded by OE to conduct this analysis, and the samples ended up in the laboratory of the other group of investigators. It is hoped that these samples will be analyzed in the future, but funding remains a problem.

Dissemination of Project Results

An important goal of the NOAA Ocean Exploration program is to advance knowledge of living and nonliving ocean resources in poorly understood ocean regions and to promote public awareness of the achievements of OE projects. Communicating scientific information gained as part of the proposed study to the non-scientist, the amateur scientist, or the general populace was a high priority to the investigators on this project. Educational products we produced have been incorporated into the Ocean Exploration 2003 Charleston Bump web site (http://www.oceanexplorer.noaa.gov/explorations/03bump/welcome.html), with additional detailed educational materials and activities from the Expedition and post-mission work incorporated into the Project Oceanica website (http://oceanica.cofc.edu/CharlestonBump2003/home.htm). The Oceanica web site also provides links for web-based science summaries, image galleries, and databanks. Web-based educational and informational projects that were developed include the following:

1) Science Summaries:

http://oceanica.cofc.edu/CharlestonBump2003/ScienceSummaries.htm - Web-based short synopses of journal articles, reports, and presentations produced by the investigators on this project. These summaries are figure- and photo-rich, with explanatory text written for the amateur scientist.

2) Photo Documentaries:

http://oceanica.cofc.edu/CharlestonBump2003/Photodoc.htm - Digital images (photos, video clips, figures, graphics, illustrations, etc.) of sampling, habitats and organisms collected have been archived in slide shows with brief text descriptions. Users have access to these items from either the web or (by request) on a CD-ROM, where higher resolution/better quality images can be stored and accessed. Several research narratives have been generated by project personnel and Oceanica staff, and are available online at this site for use in classrooms or for students to access from a personal computer. PowerPoint versions of these presentations with downloadable narrative text will are available by request on CD-ROM.

3) Photo Galleries:
http://oceanica.cofc.edu/CharlestonBump2003/PhotoGallery/photogallerybump03.htm - Digital images of shipboard operations and personnel are archived here to give viewers a feel for shipboard life. Users have access to these items from either the web or (by request) from a CD-ROM, where higher resolution/better quality images can be stored and accessed.
4) Sample Repository:
http://oceanica.cofc.edu/samplematerial/samples.htm - Oceanica has established a sample repository and protocol for geological material collected during recent exploration and research cruises. These samples are intended primarily for educational use by K-12 and post-secondary educators and students. Geological material collected during this study has been carefully catalogued, described and stored at the University of Charleston, and subsamples can be made available on request. The sample inventory has been documented and made accessible via the Project Oceanica home page. Biological materials have been deposited in the collections of the Southeast Regional Taxonomic Center (invertebrates) or the Grice Marine Laboratory collections (fishes) and are available for educational use and taxonomic study. The Sample Repository web site gives additional information on sampling and identification of samples.
5) Charleston Bump Glossary - Oceanica has developed an on-line glossary for unusual terminology and jargon associated with the Charleston Bump mission.

During the course of this project, there has been much interest by the general public (especially fishermen) and other NOAA research and management agencies. To disseminate the findings to a more non-technical audience, we have done a large number of press releases that resulted in the following newspaper articles:
22 July 2003: *Workshop to spotlight exploration of ocean*. *News and Courier* (Charleston SC).
1 August 2003: *Voyage to the Bump*, by Lynne Langley. *News and Courier* (Charleston SC).
14 August 2003: *A bumpy voyage ends,* by Lynne Langley. *News and Courier* (Charleston SC)
25 August 2003: *The promise of deep-sea discovery,* Editorial. *News and Courier* (Charleston SC).
31 August 2003 *Group studies ocean odditiy,* by Robert Pavey. *Augusta Chronicle* (Augusta GA).

Presentations:

Project personnel have made a number of presentations to a wide variety of audiences, ranging from scientists and resource managers to educators and students, to the general public. The following presentations included materials based on the 2003 OE Expedition to the Charleston Bump:

Andrus, C.F.T., C.S. Romanek and G.R. Sedberry. 2004. Geochemical cyclicity in colonial deepwater corals from the Charleston Bump, Blake Plateau. Geological Society of American Annual Meeting.

Fiore, C.L. and P.C. Jutte. 2005. Characterization of macrofaunal assemblages associated with sponges of the southeastern United States. Benthic Ecology Meetings, Williamsburg VA.

Griffin, S. and G.R. Sedberry. 2005. Reef morphology and invertebrate distribution at continental shelf edge reefs off the U.S. southeast Atlantic coast. South Carolina Marine Educators Association Annual Meeting, Pawleys Island SC.

Leverett, C. 2004. Taxonomy of the Charleston Bump. South Carolina Marine Educators Association Annual Meeting, Palm Key SC.

Leverett, C. and E.L Wenner. 2003. Mission to the Charleston bump. Murray-LaSaine Elementary School, Charleston SC.

Loefer, J.K. and G.R. Sedberry. 2004. Satellite telemetry tagging of large pelagic fishes off the southeastern United States. South Carolina Chapter, American Fisheries Society Annual Meeting.

Meister, H.S. 2004. The diverse biological communities of the Charleston Bump. James Island Charter High School senior marine biology class. Charleston, SC.

Meister, H.S. and G.R. Sedberry. 2005. *Sargassum* communities of the southeastern US coast. South Carolina Chapter American Fisheries Society Annual Meeting, Clemson, SC.

Meister, H.S. and G.R. Sedberry. 2004. *Sargassum* communities of the western North Atlantic. National Oceanographic and Atmospheric Administration's Ocean Explorer Professional Development Workshop. SC Aquarium, Charleston, SC.

Negreiros-Fransozo, M.L., D.M. Knott, E.L. Wenner and S.T. DeVictor. 2004. A preliminary report on the crustacean zooplankton from the Charleston Bump, a unique physiographic feature of the Atlantic coast of the southeastern USA. The Crustacean Society Annual Meeting, Florianópolis, Brazil.

Ralph, C. and G.R. Sedberry. 2004. Fish assemblages of deep reef habitats off the southeastern U.S: implications for management. South Carolina Marine Educators Association Annual Meeting, Palm Key SC (poster).

Sautter, L.R. 2003. Focus on the Charleston Bump: looking at macro, meso, and micro scales to discover new habitats. NOAA Office of Ocean Exploration Charleston Bump Expedition Professional Development Institute, Charleston SC.

Sautter, L.R. 2003. Live rocks of the southeastern shelf edge: an exploration of hardbottom microcosms. National Marine Educators Association Annual Meeting, Wilmington NC.

Sautter, L.R. 2004. Exploring the seafloor of the southeast U.S. continental margin: submersible dive observations from the continental shelf edge, Charleston Bump, and Blake Plateau. NOAA Ocean Exploration Workshop, South Carolina Aquarium, Charleston SC.

Sautter, L.R. and R. McEvers. 2004. How to have fun with marine sediment. South Carolina Marine Educators Association Annual Meeting, Palm Key SC.

Schobernd, Z. and G.R. Sedberry. 2004. Species assemblages, distribution and abundance of serranids in the South Atlantic Bight, 1973-2003. South Carolina Marine Educators Association Annual Meeting, Palm Key SC (poster).

Sedberry, G.R. 2003. Reef fish identification. Reef Environmental Education Foundation and South Carolina Aquarium, Charleston SC.

Sedberry, G.R. 2003. Wreckfish around the world: Lessons learned in fishing, conservation and population genetics. National Marine Educators Association Annual Meeting, Wilmington NC.

Sedberry, G.R. 2003. Mounds, depressions, scarps and caves: Exploration of habitat and species diversity on the Charleston Bump and Blake Plateau. NOAA Office of Ocean Exploration, Charleston Bump Expedition Professional Development Institute, Charleston SC.

Sedberry, G.R. 2003. Research and technology to manage SC offshore fisheries. East Cooper Outboard Motor Club, Sullivans Island SC (also presented to Wando High School Marine Science Club, Mt. Pleasant SC).

Sedberry, G.R. 2003. Discovery, exploration and description of deep reef-fish habitats and assemblages. Graduate Seminar in Marine Biology, College of Charleston.

Sedberry, G.R. 2004. Invertebrate slide show. South Carolina Marine Educator Association, Palm Key SC (also presented at Harbor View Elementary School, 2005).

Sedberry, G.R. 2004. Fish and fish habitats of the South Atlantic Bight. Seminar, College of Charleston.

Sedberry, G.R. 2004. A summary of past, present and future research efforts on the Charleston Bump (EFH-HAPC). South Atlantic Fishery Management Council, Joint Coral and Habitat Advisory Panel meeting, Charleston SC.

Sedberry, G.R. 2004. Learning ocean science through ocean exploration: demersal fishes and fish habitats of the South Atlantic Bight. NOAA Ocean Exploration Workshop, South Carolina Aquarium, Charleston.

Sedberry, G.R. 2004. Offshore fisheries monitoring and assessment: overview of MRD programs. Marine Advisory Committee, SCDNR, December 2004.

Sedberry, G.R. 2005. The role of the Charleston Bump in the life history of southeastern marine fishes. Lunz Chapter, Sierra Club, Charleston SC.

Sedberry, G.R. 2005. Fish and fish habitats of the South Atlantic Bight. College of Charleston. February, 2005.

Sedberry, G.R., H.S. Meister, D.M. Wyanski, J.K. Loefer, S.W. Ross and K.J. Sulak. 2004. Further evidence for the invasion of *Pterois volitans* (Teleostei: Scorpaenidae) along the Atlantic coast of the United States. South Carolina Marine Educators Association Annual Meeting, Palm Key SC (poster).

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Fiore, C.L. In prep. Characterization of macrofaunal assemblages associated with sponges of the southeastern United States. M.S. Thesis, College of Charleston.

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SUMMARY AND CONCLUSIONS

Habitats observed during sonar surveys and submersible dives ranged from very rugged, nearly vertical scarps of more than 100 m in height with undercut ledges and caves, to smaller ridges and staircase-like terraces, to low-relief hard pavements and scattered pockets of sand. Steep scarps made up the ridge-and-trough bottom topography of the Charleston Bump, but those features were difficult to observe from submersible, because of the swift Gulf Stream currents. Dense low growth of sponges, corals and other sessile invertebrates occurred in sheltered habitats, but hard bottom overlain by strong currents had only sparse invertebrate growth.

Species composition and abundance of fishes analyzed from videotape transects indicated a low diversity and abundance of fishes on the Charleston Bump. In terms of biomass, wreckfish and red bream (two commercial fishery species) dominated the fish assemblage. Abundance and diversity of fishes observed on the shallower shelf-edge sites were also low compared to previous submersible observations. This low abundance and diversity at the shelf-edge sites we observed is probably related to the low habitat quality relative to that preferred by abundant and diverse shelf-edge reef fishes of the region. Shelf-edge fish assemblages were dominated numerically by small seabasses, wrasses, grunts and bigeyes. The fish fauna of the Charleston Bump was dominated numerically by blackfin codling, saddled grenadier, red bream and blackbelly rosefish.

Video surveys from the 2003 Ocean Exploration cruise suggested that large sponges are dominant constituents of deep-water hard bottom communities in the South Atlantic Bight. Average abundances were estimated at approximately 0.05 per m^2 ($\pm$ 0.01), and included various sponge morphotypes such as vase sponges, “cake” sponges, and “cantaloupe” sponges.

One sponge from the 2003 collection, *Chondrilla* sp., was identified taxonomically, and dissected to remove faunal associates. A total of 163 organisms representing six taxonomic groups were identified. These faunal associates included several known commensal organisms. Comparisons of faunal associates on *Chondrilla* sp. from 2002, 2003 and 2004 Ocean Exploration cruises found similarities in dominant taxa, which could be attributed to the internal morphology of that sponge species. This represents the first study ever conducted on faunal associates of deep-water sponges.

Living colonial branching corals from the Charleston Bump contained stable carbon and oxygen isotope and Sr:Ca profiles that often oscillated in tandem with visible growth bands

apparent in cross section. Otherwise sinusoidal geochemical profiles were interrupted by zones of abrupt variation, suggesting periods of growth diminishment or cessation. This observed elemental and isotopic cyclicity may enable coral growth rate analysis and therefore facilitate future development of these corals as paleoclimate proxies. Preliminary data analysis suggests vertical extension rates of at least 1mm/y in some of these corals. This growth rate permits sub-annual isotopic and elemental sampling resolution. Abundant fossil corals were also collected on the Charleston Bump, at sites where living corals were collected. The isotopic and elemental data contained in these fossils may represent valuable paleoclimate archives. Coral climate proxies in fossil corals from this region may be sensitive indicators of past Gulf Stream variation.

While essential fish habitat (EFH) includes "those waters and substrate necessary to fish for spawning, feeding or growth to maturity", much of the evaluation of EFH (and concentration of management efforts to date) has been with freshwater, estuarine, coral reef, seagrass and coastal habitats. Consideration of deepwater EFH has been limited to deepwater coral (e.g. *Lophelia prolifera, Oculina*) banks occurring primarily in the Straits of Florida. In spite of the concentration on shallow habitats, the South Atlantic Fishery Management Council (SAFMC 1998) considered the Charleston Gyre as "an essential nursery habitat for some offshore fish species with pelagic stages, such as reef fishes", because of increased productivity that is important to ichthyoplankton. In addition to its effect on oceanography and subsequent production of larval fishes, the Charleston Bump bottom features are important sheltering, feeding and spawning grounds for wreckfish, red bream and barrelfish. Because the Charleston Bump Complex is important in the life history of several current and potential fishery species, it should be considered Essential Fish Habitat.

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