Characterization of Deep Reef Habitat off the Southeastern U.S., with Particular Emphasis on Discovery, Exploration and Description of Reef Fish Spawning Sites

Final Report

by

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ABSTRACT

Populations of economically valuable reef fishes have been in decline for at least two decades in the South Atlantic Bight (SAB) from Cape Hatteras to Cape Canaveral, and south through the Florida Keys. Such declines of top-level predators have an effect down through the food chain to benthic invertebrate communities, and there is evidence for ecosystem overfishing on reefs off the southeastern U.S. Atlantic coast. As a result of this overfishing and the inability of traditional methods to reverse this trend, the South Atlantic Fishery Management Council (SAFMC) has proposed a series of Marine Protected Areas (MPAs) that could include no-take marine reserves. The SAFMC has recently gone through an MPA designation process that included obtaining input from user groups, interested parties, and the general public, along with some review of existing biological and habitat data. Of prime concern is protecting those habitats and locations that are essential to completing the life cycles of overfished species. This SAFMC process highlighted some significant gaps in knowledge of the characteristics of deep reef habitats, spawning locations for fishes, and oceanographic processes that affect recruitment to and from such locations. Knowledge of such habitats and processes will enable placement of MPA networks to maximize resource spawning and protection and surplus spillover into adjacent fished areas. This project included a multi-disciplinary study to describe faunas and features of deep reef habitats and spawning sites, including sites being considered for MPA designation. Baseline geological descriptions and detailed studies of demersal fishes, benthic infauna and selected epifaunal groups were conducted. The objective was to assess the distribution and composition of soft and hard substrates and their associated invertebrate and fish faunas at shelf-edge and upper-slope reefs. We used an existing database on capture locations of reef fishes in spawning condition to direct submersible and shipboard sampling of spawning locations. Visual observations from submersible were used to describe habitats and fish assemblages found in spawning locations. Courtship and other reproductive behavior was observed in scamp (*Mycteroperca phenax*), hogfish (*Lachnolaimus maximus*), gray triggerfish (*Balistes capriscus*), speckled hind (*Epinephelus drummondhayi*) and red snapper (*Lutjanus campechanus*). Spawning habitats and benthic assemblages (including potential prey fields) were described. Generally, the shelf-edge reef (50-60 m depth) off Florida consisted of a narrow steep scarp of considerable (10 m) nearly-vertical relief and faulted blocks of hard substrate. Progressively northward, the shelf-edge reef was interspersed with coarse to fine sediments and appeared partially buried and broader in inshore-offshore extent, sometimes consisting of a double-ridge system. Offshore of the shelf-edge reef, upper slope reefs consisted of rocky pinnacles, rubble areas and deep sediments. Fish and coral faunas changed with increasing latitude and depth. Larval groupers were not found in plankton collections, but additional identifications are needed to determine if shelf-edge waters support larvae of snappers and other reef fishes. High zooplankton biomass and abundance of larvae were associated with a known upwelling zone on the slope and shelf edge. The data obtained during this exploration will be included in descriptions of proposed MPA sites. Data collected will maximize the effectiveness of management measures such as no-take reserves that are perceived to be an extreme burden on fishermen. By strategic placement of MPAs in networks based on biological and oceanographic data, it is hoped that the maximum positive effect can be achieved with the minimum impact on fishermen.

INTRODUCTION

The consumption of fishes by humans has increased dramatically in the last several decades, because of increases in human population, per-capita consumption of seafood, and advances in fishing technology (Hardin 1968; Holdren and Ehrlich 1974; Ehrlich 1994; Brown 1997; Dayton et al. 1995). Reef fishes such as those of the warm-temperate hard-bottom reefs in the South Atlantic Bight (SAB, Cape Hatteras NC to Cape Canaveral FL) appear to be particularly at risk, and many species are severely overfished or in danger of being so (SAMFC 1993; Vaughan et al. 1995; Harris and McGovern 1997; Zhao and McGovern 1997; Zhao et al. 1997; McGovern et al. 1998a,b; Sadovy and Eklund 1999; Schirripa and Legault 1999; Coleman et al. 2000; Musick et al. 2000; Wyanski et al. 2000; Burgos 2001; Harris et al. 2001). Goliath grouper (*Epinephelus itajara*) and Nassau grouper (*E. striatus*) have been so heavily overfished in the southeastern U.S. that they are candidates for the Endangered Species List (Sadovy and Eklund 1999). Warsaw grouper (*E. nigritus*) and speckled hind (*E. drummondhayi*), formerly common groupers of the SAB, may soon follow (Coleman et al. 2000). The fishery for red porgy (*Pagrus pagrus*) in the U.S. Atlantic was closed in 1999 because of extremely low spawning potential. The economic value of this reef species complex makes protecting the sustainability of the fishery a critical consideration for this region. Commercial reef fish landings in the SAB from 1980-1996 were roughly 147 million pounds with an exvessel value near $186 million (http://www.st.nmfs.gov/st1/commercial/landings/annual_landings.html).

In addition to reduced populations of top-level predators, community structure changes have been observed in reef fish communities, as predator-prey relationships are disrupted by overfishing (Sedberry et al. 1999). There is evidence that this is occurring in the SAB, as relative abundance of fishery species declines while less economically-desired species increase in abundance (McGovern et al. 1998a). Because fishery and non-fishery species may feed very differently (e.g. Sedberry 1985; Sedberry 1988), such fishing-induced changes probably affect benthic prey communities.

Many economically important reef fish species share a suite of life history and behavioral characteristics that make them particularly susceptible to overexploitation. These characteristics include long life, large adult size, late maturity, protogyny, and spawning in aggregations and/or at sites that are predictable in time and space (PDT 1990; Coleman et al. 2000; Musick et al. 2000; Sala et al. 2001). Predictable spawning aggregations are particularly well-documented in tropical reef fishes, and the negative impacts of fishing these aggregations are well-known (Craig 1969; Carter et al. 1994; Domeier and Colin 1997; Sala et al. 2001). Although some studies have presented evidence for spawning aggregations of gag, *Mycteroperca microlepis* (Serranidae) on temperate reefs of the Gulf of Mexico (Coleman et al. 1996), it is uncertain if such aggregations represent a major regional spawning ground, as has been documented for some tropical groupers (Carter et al. 1994), and what the effects might be of fishing such aggregations if they do represent the major reproductive output for a large region. There are few data available on spawning locations, times and behavior of reef fishes of the SAB, but there is some circumstantial evidence for aggregations of some species, including gag and greater amberjack (*Seriola dumerili*). Circumstantial evidence includes long-distance migration of these species (Fig. 1). These migrations sometimes coincide with the spawning season, and are thought to be movements toward pre-spawning aggregations or movements to actual spawning sites (Van Sant et al. 1994; McGovern et al. in prep.). However, migration patterns and behavioral or other reproductive impetus for movements is not well understood, and some mature female gag do not migrate to spawning sites in the Gulf of Mexico (Coleman et al. 1996).

Additional circumstantial evidence for spawning aggregations of gag in the SAB includes concentrations of fish in spawning condition at specific depths such as deep shelf edge reefs (Fig. 2). Such concentrations might represent spawning aggregations, or they might represent ontogenetic movements of larger, and therefore sexually mature, fish into deeper water, as has been shown for other fishes (Macpherson and Duarte 1991). As in the Gulf of Mexico, there has historically been more concentrated fishing effort along those deeper (45-90 m) reefs during gag spawning seasons (Coleman et al. 1996; McGovern et al. 1998b). If these are spawning aggregations that are being targeted, such fishing can have deleterious effects (Carter et al. 1994; Coleman et al. 1996).

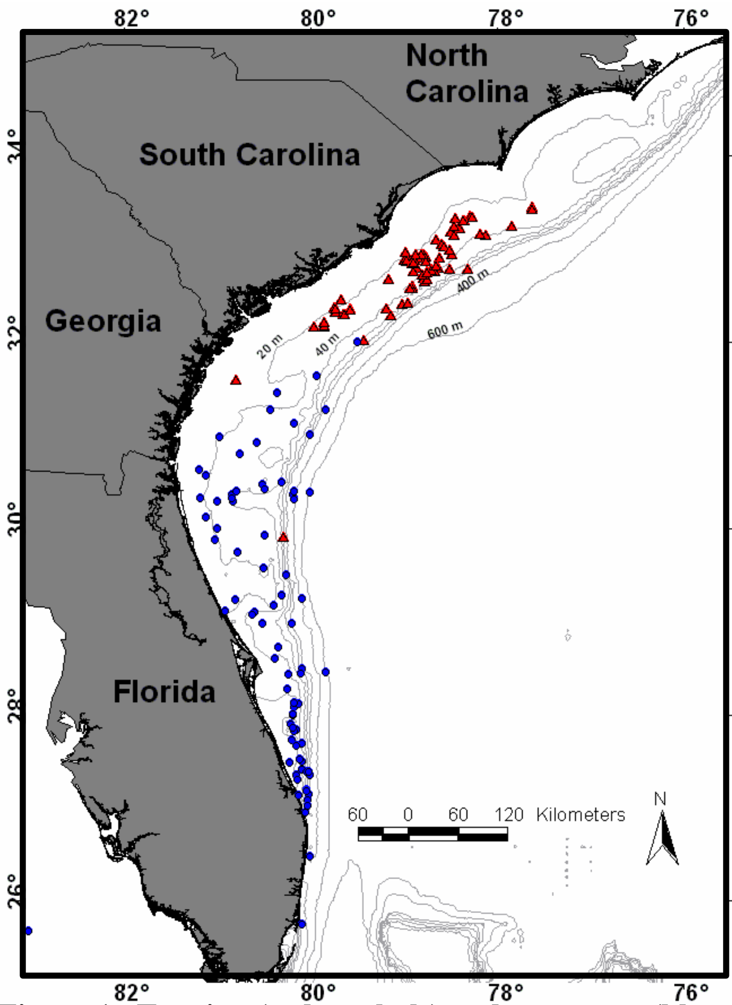


Figure 1. Tagging (red symbols) and recapture (blue symbols) locations for gag in the South Atlantic Bight. Tagging studies indicate a southward and offshore migration during the spawning season.

Spawning aggregations in reef fishes are believed to correspond spatially and temporally with hydrographic features that insure greatest survival of early life history stages. For this reason, many species utilize the same locations for spawning, even at different times of the year (Carter et al. 1994; Carter and Perrine 1994; Domeier and Colin 1997; Sala 2001). These hydrographic features are often associated with prominent bottom features that influence circulation near (and downstream from) the spawning banks (Carter et al. 1994; Sedberry et al. 2001; Govoni and Hare 2001). Many reef fishes with pelagic eggs and larvae spawn in the vicinity of gyres near the shelf edge (Johannes 1978). Such topographically-produced gyres (i.e. the Tortugas Gyre off Florida) are implicated in removal of pelagic eggs from the spawning site, thus reducing predation, while retaining fish eggs and larvae for the ultimate return of larvae to the shelf at later developmental stages that can avoid some predation (Lee et al. 1992; Limouzy-Paris et al. 1997; Lee and Williams 1999). Such gyres may carry eggs and larvae away from

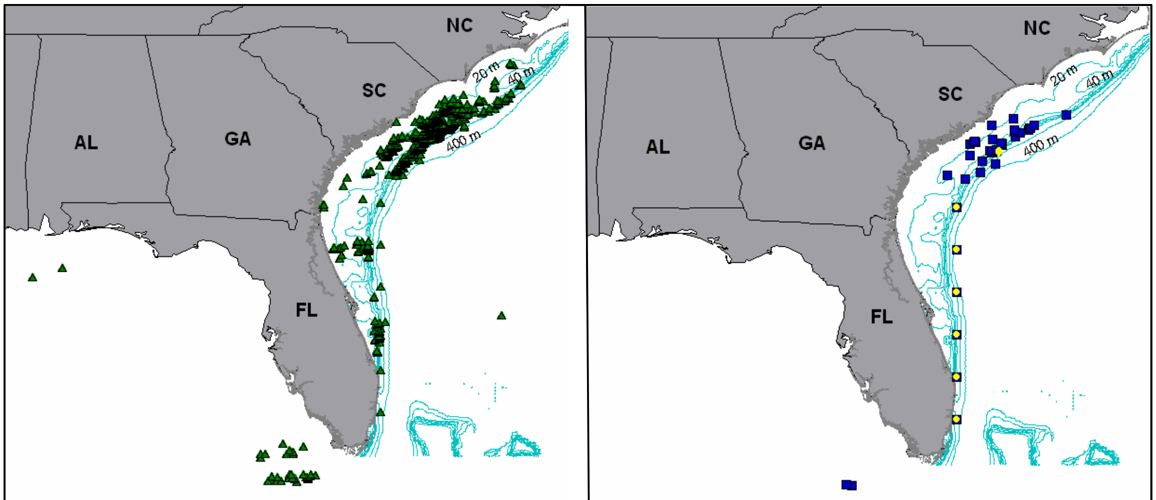


Figure 2. Locations where the MARMAP program has collected gag throughout the year (left) and during the spawning season (right). Yellow circles indicate the capture of female gag in spawning condition (determined histologically).

predators on the reef, or toward ideal post-larval settlement habitat, or toward areas of high larval fish food production (Carter et al. 1994; Domeier and Colin 1997).

Along the continental shelf edge of the SAB, there are areas of gyres and upwelling that are associated with high nutrients and plankton productivity (Atkinson and Targett 1983; Paffenhöfer et al. 1984; Mathews and Pashuk 1986; Sedberry et al. 2004). Small occasional frontal eddies and meanders that propagate northward along the western edge of the Gulf Stream provide small-scale upwellings of nutrients along the shelf break in the SAB (Lee et al. 1981; Lee et al. 1985; Miller 1994). Such intermittent upwellings might coincide with reef fish spawning locations. In addition to these intermittent upwellings, there are two areas in the SAB where upwelling of nutrient-rich deep water is more permanent. One such upwelling is located just to the north of Cape Canaveral and is caused by diverging isobaths (Paffenhöfer et al. 1984). The other much larger and stronger upwelling occurs mainly between 32°N and 33°N (Atkinson 1985; Mathews and Pashuk 1986) and results from a deflection of the Gulf Stream offshore by the topographic irregularity known as the Charleston Bump (Bane et al. 2001). Off of South Carolina and North Carolina, the large meander set up by the Charleston Bump forms the Charleston Gyre, an eddy with upwelled water at its core, and which moves shoreward across the edge of the shelf. The strength and duration of Gulf Stream meanders caused by the Charleston Bump influence the degree and location of upwelling of nutrients and the cross-shelf transport of warm Gulf Stream (Charleston Gyre) waters (Bane et al. 2001; Sedberry et al. 2001).

The presence of high nutrients at the shelf edge, and a mechanism to transport larvae from shelf-edge spawning to estuarine nursery habitats influences recruitment success in gag (Sedberry et al. 2001). Recruitment in gag and some other fishes is correlated with the location, strength and persistence of the Charleston Gyre (Powles 1978; Sedberry et al. 2001; Govoni and Hare 2001). It is likely that spawning of gag, snappers and other reef fishes off the Carolinas is timed and located to take maximum advantage of the hydrographic conditions created by the Charleston Bump complex from 32°N and 33°30'N (Powles 1978; Sedberry et al. 2001; Govoni and Hare 2001). Other intermittent upwelling sites along the shelf edge of the SAB, and the more permanent upwelling north of Cape Canaveral might also be important spawning grounds.

Populations of economically valuable reef fishes have been in decline for at least two decades in the SAB. Such declines of top-level predators have an effect down through the food chain (Sedberry et al. 1999), and there is evidence for ecosystem overfishing on SAB reefs (McGovern et al. 1998a). As a result of this overfishing and the inability of traditional methods to reverse this trend, the South Atlantic Fishery Management Council (SAFMC) has proposed a series of Marine Protected Areas (MPAs) that could include no-take marine reserves. The SAFMC has recently gone through an exercise in locating potential MPAs that included obtaining input from user groups, interested parties, and the general public, along with some review of existing biological and habitat data. Of prime concern is protecting those habitats and locations that are essential to completing the life cycles of overfished species. This SAFMC process highlighted some significant gaps in knowledge of habitat and faunal characteristics of spawning locations and other deep reef sites. These gaps include knowledge of community structure of benthic food webs; oceanographic processes that affect recruitment to and from deep reefs; and placement of MPA networks to maximize resource protection and production of surplus fish biomass that might spill over into adjacent fished areas. Additional study of reef fish spawning sites in relation to bottom habitats and faunas, and the relationship of bottom features to hydrographic features and proposed MPA sites, are needed. Oceanographic conditions, circulation patterns, chlorophyll-a concentrations, and locations of upwelling need to be determined in relation to spawning locations and areas of juvenile recruitment. These data are needed to maximize the effectiveness of severe management measures such as no-take reserves that are perceived to be an extreme burden on fishermen. By strategic placement of MPAs in networks based on biological and oceanographic data, it is hoped that the maximum positive effect can be achieved with the minimum impact on fishermen. It is imperative to collect such biological and oceanographic data, particularly data on spawning locations and recruitment pathways.

The 2001 Ocean Exploration "Islands in the Stream Expedition" included submersible observations on SAB shelf-edge reefs off Savannah, Georgia. These observations indicated a low-relief hard bottom area that might be a nursery ground for snowy grouper (*Epinephelus niveatus*), scamp (*Mycteroperca phenax*), greater amberjack and other economically valuable reef fishes (Sedberry, pers. obs). These reefs were quite different in morphology than the shelf-edge reefs previously observed off of South Carolina (Barans and Henry 1984; Sedberry and Cuellar 1993; Sedberry et al. 2002), and pointed out the diversity of deep reef types in the SAB, and the need for additional exploration of these important habitats and description of reef morphology in relation to distribution of associated organisms, including fishes.

This report describes the results of a study aimed at submersible exploration and description of deep reef sites in the SAB. This study is complementary of larger interdisciplinary research and fishery monitoring efforts aimed at a better understanding of the ecology of reef habitats in offshore waters along the outer shelf and slope of the southeastern U.S. that are believed to serve as recruitment sites for commercially important species of fishes. The invertebrate infauna found in sediments adjacent to reefs are important components of these ecosystems, playing a vital role in energy flow to higher trophic levels including fishes and invertebrates associated with the reefs and foraging in the surrounding sediments. In addition to describing reef habitats and associated invertebrates and fishes, this study was also aimed at describing benthic macroinfauna collected from sediments in the vicinity of reef habitat at each several shelf-edge and upper-slope locations.

We proposed research to use traditional fisheries and oceanographic sampling, as well as newer marine technologies, to describe deep reefs and other potential spawning sites and to locate spawning sites of reef fishes in the SAB. This research was designed to complement several other National Oceanic and Atmospheric Administration (NOAA) programs.

Study Goals and Objectives

The goal of this project was to discover and explore spawning locations of reef fishes in the SAB, and to describe the oceanographic features, spawning habitats, and associated faunas, so that protective management can be applied to allow sustained fisheries for exploited species that utilize these spawning locations. The following objectives were addressed toward completing this goal:

1. To locate spawning grounds of deep reef fishes in the SAB by sampling locations of capture of reef fishes with hydrated oocytes (HOs) and postovulatory follicles (POFs), which indicate imminent or recent spawning.
2. To confirm spawning by observing reef fishes during diurnal and crepuscular spawning periods using submersible.
3. To describe fish assemblages associated with these deep reefs.
4. To describe benthic habitats, reef structure, substrates and sediments of spawning locations.
5. Do describe oceanographic features near, upstream and downstream from spawning locations.
6. To describe megafaunal invertebrate assemblages from video transects.
7. To describe infaunal invertebrate assemblages from sediment sampling. This objective included characterizing benthic infaunal communities inhabiting the sandy areas surrounding reefs; and examining assemblages for among-reef differences, within-reef variability, and variation related to other environmental factors (e.g., depth, latitude, temperature, salinity, sediment granulometry, sediment organic-carbon content).
8. To collect early life history stages to confirm spawning and to detect transport patterns of larvae in relation to oceanographic features.
9. To map (GIS) spawning habitats and bottom features, including substrates, mega-epifaunal assemblages, infaunal assemblages, fish assemblages, and distribution of early life history stages of fishes using submersible observations and collections.
10. To compare spawning sites to other deep reef habitats.
11. Develop educational materials for broad and narrowly-defined audiences, based on results obtained.

We hypothesized that deep reef fishes of the SAB spawn at shelf-edge (45-300 m) reefs in locations that ensure that eggs and larvae are removed from reef predators by prevailing currents, yet which retain larvae in the vicinity of settlement habitats. Such locations possess specific bottom and oceanographic features that enhance survival of early life history stages, and by characterizing and mapping these features, we hope to discover those characteristics that define spawning grounds. We hope to discover additional spawning grounds by looking for areas that possess such features. We further hypothesize that deep reef fishes of the SAB spawn at reefs that are in close proximity to shelf-edge upwelling that occurs as a result of disturbance of Gulf Stream flow by bottom features. Such bottom features include slope and Blake Plateau

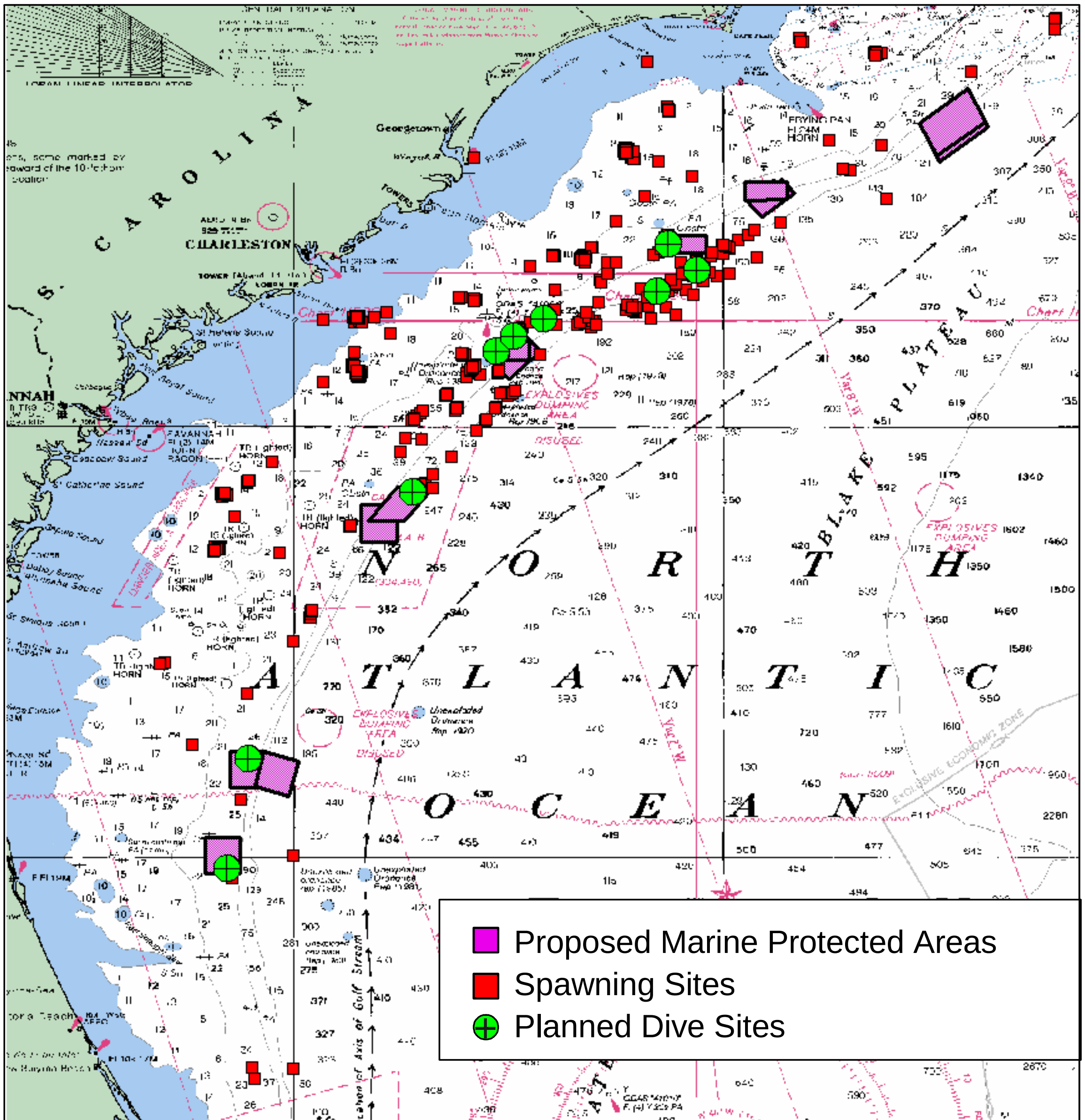


Figure 3. Locations of proposed sampling (dive) sites in relation to proposed MPA sites and spawning locations for bank sea bass, black sea bass, blueline tilefish, gag, gray triggerfish, greater amberjack, knobbed porgy, red grouper, red porgy, red snapper, rock hind, scamp, snowy grouper, speckled hind, tilefish, vermilion snapper, warsaw grouper and white grunt. Locations of proposed MPAs and spawning of reef fishes were used to select potential sampling sites.

features like the Charleston Lumps and the Charleston Bump. The upwelling they induce provides nutrients to early life history stages of fishes, and provides cross-shelf currents that carry juveniles to shallow nursery areas from deep spawning grounds. Upwelling in the vicinity of shelf-edge spawning sites supports greater density and biomass of benthic infauna and epifauna than do other shelf-edge reef sites, which in turn support populations of fishes with high energy requirements, such as those with developing gonads. We will further investigate variations in reef morphology and substrate composition that affect benthic species composition of invertebrate and fish assemblages.

METHODS

Site Selection

Preliminary analysis of spawning locations for some reef species indicated that the shelf-edge/upper slope reef is an important spawning ground for many reef fishes of the SAB. Reconnaissance of shelf edge reef using submersibles in 1985 and during the 2001 Islands in the Stream Expedition revealed a diversity of reef types, some of which might be more important than others as spawning or nursery grounds for reef fishes. Exploration of shelf-edge reefs off Savannah during the 2001 Islands in the Stream Expedition indicated a low-relief formation that was quite different from the shelf-edge ridge system observed by us off South Carolina in 1985. Shelf-edge reefs off northern South Carolina are near documented upwelling areas (Sedberry et al. 2004), whereas those off northern Georgia are in more tranquil areas where sedimentation occurs, and these oceanographic features may account for differences in bottom features. Towed underwater television observations in 1980 and 1981 indicated a different reef morphology off northern Florida, with steeper scarps and less sedimentation (SCWMRD 1982). We proposed additional submersible dives to further explore, describe and map shelf edge reefs off northern Florida, Georgia and South Carolina.

We conducted submersible observations and conventional oceanographic sampling in two suspected reef-fish spawning habitats (Fig. 3):

1. Shelf-edge reefs (50-90 m), consisting of moderate relief (1-5 m) outcrops and ridges along the first break in the continental shelf.
2. Upper slope reefs (175-250 m), consisting of rocky mounds and pinnacles on the upper continental slope.

In addition to picking sites based on known depth and bottom characteristics, we picked the two habitats because they are important fishing grounds and there are different fish assemblages found in each habitat (Sedberry and Van Dolah 1983; Weaver and Sedberry 2001). In addition, the SAFMC has proposed MPAs that would protect deepwater grouper species found in these two habitats, and we chose sites that could be potential MPAs. We also analyzed a large historical database to look for locations where fish diversity is high, indicating complex habitats, and where fish in spawning condition have been captured. The SCDNR has been conducting fishery-independent surveys of the South Atlantic Bight since 1973 (Fig. 4), under the Marine Resources Monitoring, Assessment and Prediction (MARMAP) program. Sampling has included removal sampling and towed underwater television cameras for mapping habitat. We used the historical MARMAP database to pick sites where reef fish habitat or occurrence of reef fish species has been mapped.

The MARMAP program has also been studying the life history of reef fishes since 1978, and has constructed a database of spawning locations, based on histological examination of gonads of important fishery species. As part of the fishery surveys (Fig. 4), gonads were dissected from specimens of fishery species and preserved in formalin, transferred to alcohol, infiltrated with paraffin, sectioned, stained and examined under a microscope to determine sex and maturity. Sections were examined for the presence of hydrated oocytes (HOs) that are indicative of imminent (within 12 h) spawning; and the presence of post-ovulatory follicles (POFs), indicative of recent (within the previous 24 h) spawning. Histological sections were examined under a compound microscope at 40-400 x magnification to determine sex and reproductive state. Reproductive state was assessed using histological criteria described for tilefish by Harris et al. (2001). Specimens with developing, ripe, spent, or resting gonads were considered sexually mature. Females that possessed migratory-nucleus stage oocytes, HOs or POFs less than 48 h old were considered to be in spawning condition. Over the course of the MARMAP project, we have found many reef fishes in spawning condition in July and August in both of the habitats we proposed to sample with submersible (Fig. 3). Some of these sites coincided with areas being considered in 2002 as MPAs by the SAFMC. Because protection of spawning locations is a primary consideration in MPA design, we wanted to confirm spawning in these locations and to describe and characterize them so that additional spawning sites can be located. We also wanted to conduct visual surveys of fishes to determine if any dive sites contained contain the target habitats (reef) and species (reef fishes) that are of concern in management.

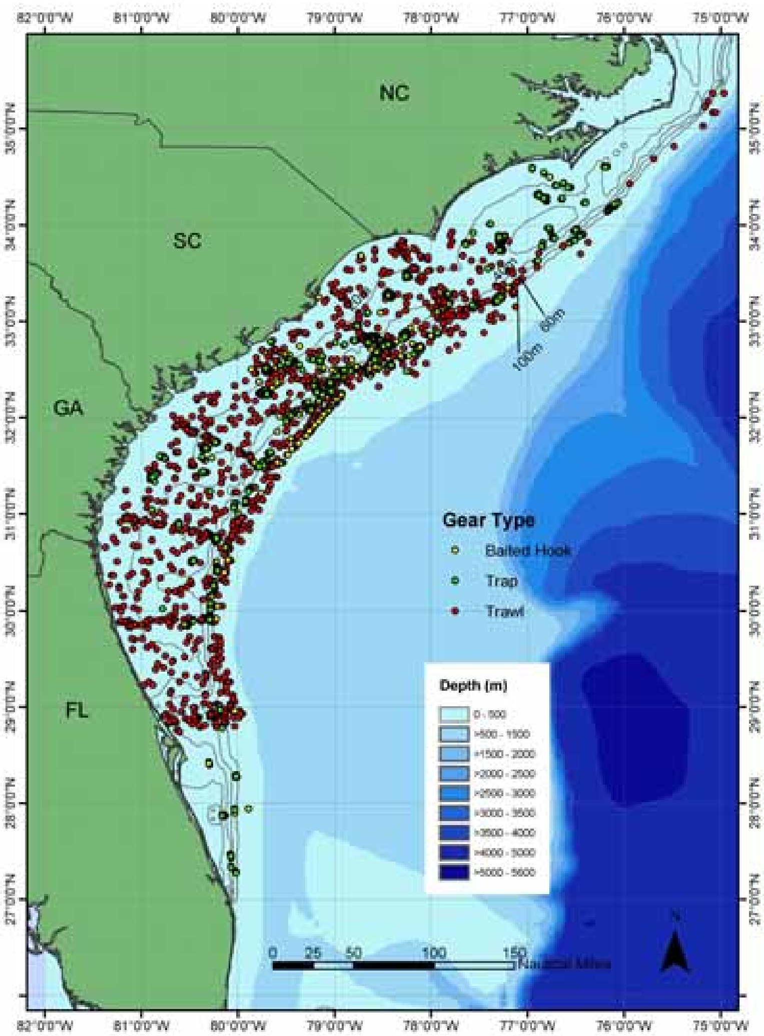


Figure 4. Sites of MARMAP collections, 1973-2001, by gear type (baited hook, baited trap, trawl net).

Based on our analysis of spawning location and seasonality, we concentrated our sampling efforts and locations on reef fishes that spawn in summer (Table 1). To pick sampling sites, we also included information from species that spawn during other seasons (Fig. 3), since many species appear to use the same spawning locations. In addition, many reef species have protracted spawning seasons and spawn at shelf-edge and upper slope reefs of the SAB during all seasons, and our sample sites were chosen to concentrate on those species and areas (Table 1; Fig. 3).

Table 1. Spawning times of economically valuable reef fishes of the SAB, as determined by MARMAP sampling.

Species	Spawning season	Spawning time
Tilefish (*L. chamaeleonticeps*)	Mar – late Jul	?
Blueline tilefish (*C. microps*)	Feb – Oct	Dusk (?) - night
Greater amberjack (*S. dumerili*)	Apr – Jun	?
Gray triggerfish (*B. capriscus*)	Apr – Aug	?
Knobbed porgy (*C. nodosus*)	Mar - Jul	?
Vermilion snapper (*R. aurorubens*)	Apr – late Sep	?
Red snapper (*L. campechanus*)	May - Oct	?
White grunt (*H. plumieri*)	Mar – Sep	?
Tomtate (*H. aurolineatum*)	Apr - May	?
Sand perch (*D. formosum*)	Mar – Sep (G. of Mexico)	?
Rock hind (*E. adscensionis*)	Jan – Jun	?
Graysby (*C. cruentata*)	Aug – Sep (Curacao)	?
Speckled hind (*E. drummondhayi*)	Jul - Sep	?
Yellowedge grouper (*E. flavolimbatus*)	Apr – Sep	?
Coney (*C. fulva*)	May – Aug off Bermuda	Dusk
Red grouper (*E. morio*)	Feb – Jun	?
Warsaw grouper (*E. nigritus*)	?	?
Snowy grouper (*E. niveatus*)	Apr – Sep	?
Black grouper (*M. bonaci*)	Jan – Dec (Gulf FL)	?
Yellowmouth grouper (*M. interstitials*)	Jan – Dec (Gulf FL)	?
Scamp (*M. phenax*)	Feb – Jul	Afternoon – night

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 2, Fig. 5). We used the submersible *Johnson Sea-Link2* (*JSL2*) to conduct visual reconnaissance of different types of shelf-edge reefs from St. Augustine FL to northern South Carolina. We initially proposed two sites off Florida, one off Georgia and six off South Carolina (Fig. 3), with two submersible dives at each site. Because of weather and mechanical problems, we were able to sample only seven of these sites (Fig. 5), and at some we did not complete both dives (Tables 2, 3).

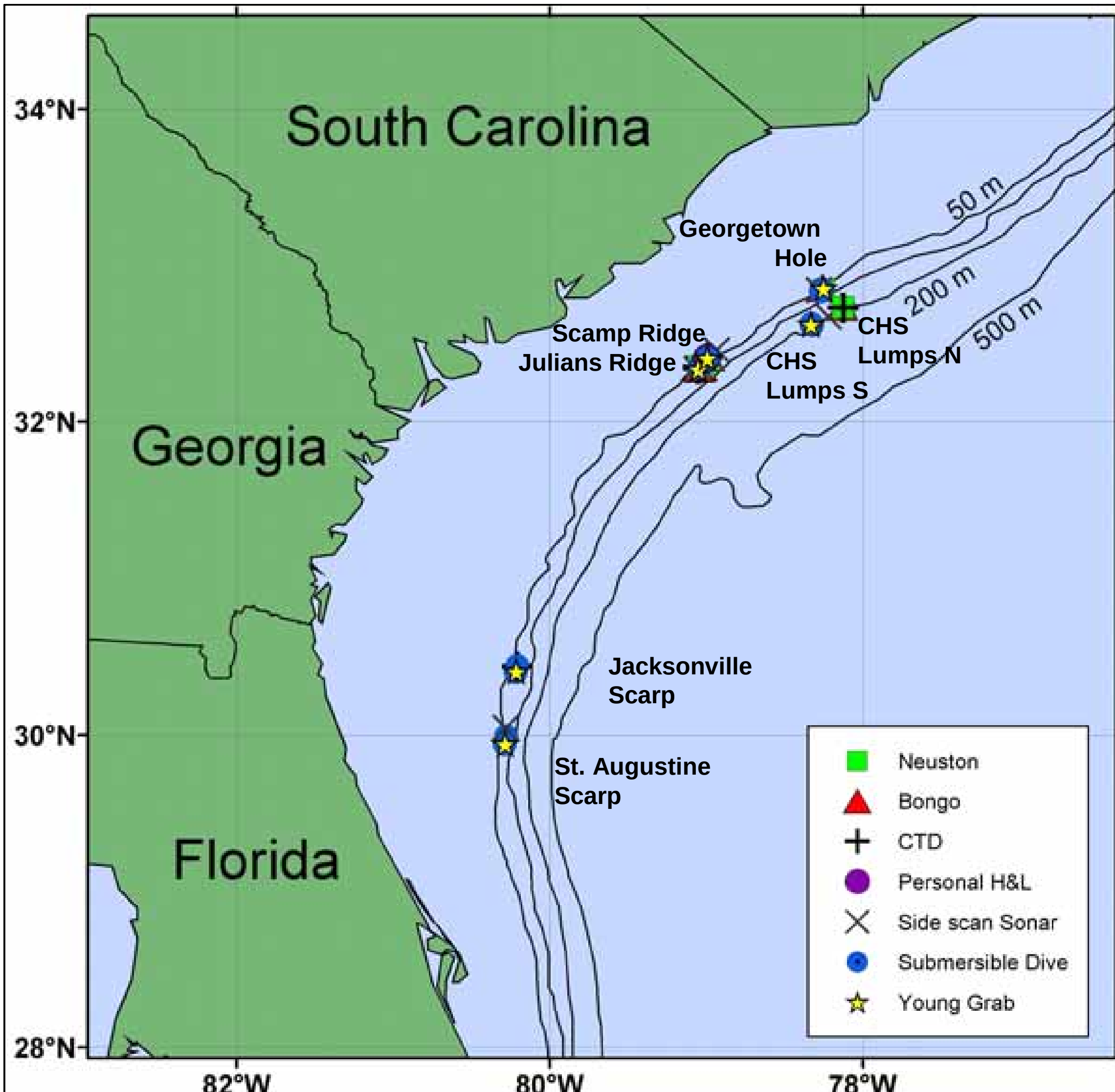


Figure 5. Actual sampling locations and gear deployed on shelf edge and upper slope reefs. "Lumps" sites are on the upper slope (~200 m); all others are shelf-edge sites (45-60 m).

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 using a sampling design to look at the effects of habitat and fishes on benthic infauna. Details of sampling from the submersible are given below.

We used side scan sonar transects to further characterize habitats, and we use a Young grab to collect sediments for contaminant analysis. We conducted plankton and neuston tows to catch larval fishes, and caught fishes with hook and line to obtain educational materials. Details of sampling are described below.

Table 2. Collection data for samples collected during the 2002 Ocean Exploration expedition to shelf edge spawning sites.

Location Date	Latitude	Longitude	Depth (m)	Gear
St. Augustine Scarp FL				
28-Jul	29.9914	-80.2768	61	submersible dive
28-Jul	29.9393	-80.2846	60	submersible dive
28-Jul			59	Young grab
29-Jul	30.0420	-80.2812		side scan sonar
Jacksonville Scarp FL				
30-Jul	30.4372	-80.2046	54	CTD
30-Jul	30.4397	-80.2049	85	submersible dive
30-Jul	30.4009	-80.2162	56	submersible dive
30-Jul			57	Young grab
Julians Ridge SC				
31-Jul	32.3350	-79.0350		neuston
31-Jul	32.3451	-79.0431	50	bongo
31-Jul	32.3453	-79.0325	57	bongo
31-Jul	32.3396	-79.0424	57	bongo
31-Jul	32.3400	-79.0483	46	CTD
31-Jul	32.3495	-79.0320	50	CTD
31-Jul	32.3519	-79.0505	50	CTD
31-Jul	32.3400	-79.0450	58	CTD
31-Jul	32.3431	-79.0465		side scan sonar
31-Jul				Young grab
1-Aug	32.3540	-79.0200		neuston
1-Aug	32.3512	-79.0431		neuston
1-Aug	32.3452	-79.0479		bongo
1-Aug	32.3493	-79.0269		bongo
1-Aug	32.3492	-79.0457	50	CTD
1-Aug	32.3484	-79.0304	58	CTD
1-Aug	32.3468	-79.0352	58	CTD
1-Aug	32.3394	-79.0552		side scan sonar
1-Aug	32.3481	-79.0357	61	submersible dive
1-Aug	32.3428	-79.0452	56	submersible dive

Table 2. Continued.

Location Date	Latitude	Longitude	Depth (m)	Gear
Scamp Ridge SC				
2-Aug	32.3931	-78.9789		1mm neuston
2-Aug	32.4087	-78.9772	59	bongo
2-Aug	32.4079	-78.9929	47	CTD
2-Aug	32.4067	-78.9950		Personal H&L
2-Aug	32.4583	-78.9302		side scan sonar
2-Aug	32.4196	-78.9813	61	submersible dive
2-Aug	32.4112	-78.9883	58	submersible dive
2-Aug				Young grab
Charleston Lumps South SC				
3-Aug	32.6277	-78.8238	200	submersible dive
3-Aug	32.6193	-78.3186	205	submersible dive
3-Aug				Young grab
Charleston Lumps North SC				
4-Aug	32.7337	-78.1239	180	neuston
4-Aug	32.7324	-78.1239	185	bongo
4-Aug	32.7305	-78.1155	210	CTD
4-Aug	32.7294	-78.1239	210	CTD
4-Aug	32.7308	-78.1121	191	submersible dive
4-Aug	32.6756	-78.2162		side scan sonar
Georgetown Hole SC				
4-Aug	32.84.8	-78.2767		side scan sonar
4-Aug	32.8505	-78.2551	57	submersible dive
5-Aug	32.8400	-78.2450	93	neuston
5-Aug	32.8567	-78.2583	47	bongo
5-Aug	32.8367	-78.2650		submersible dive
5-Aug				Young grab

Table 3. Collection data for samples and observations collected during each submersible dive. Generally, multiple samples of each type (e.g. sediment) were collected on each dive.

Location Date	Dive Number	Duration (h)	Depth (m)	Number of Collections: Video Tapes	Photos	Xsect	Other Samples
St. Augustine Scarp FL							
28-Jul	JSL2-3289	3:03	60	2	0	5	rock, sediment, sponge
28-Jul	JSL2-3290	3:24	61	3	0	17	rock, sediment, sponge
Jacksonville Scarp FL							
30-Jul	JSL2-3291	2:42	59	3	0	7	rock, sediment, sponge, coral, misc. invertebrates
30-Jul	JSL2-3292	3:08	55	3	15	5	rock, sediment, sponge, coral
Julians Ridge SC							
1-Aug	JSL2-3293	3:12	55	3	30	16	rock, sediment, sponge
1-Aug	JSL2-3294	3:01	59	3	6	14	rock, sediment
Scamp Ridge SC							
2-Aug	JSL2-3295	2:31	54	3	0	15	rock, sediment, sponge
2-Aug	JSL2-3296	2:29	53	2	0	11	rock, sediment
Charleston Lumps South SC							
3-Aug	JSL2-3297	3:17	206	3	50	13	rock, sediment, sponge, anemone
3-Aug	JSL2-3298	3:13	201	3	8	9	sediment
Charleston Lumps North SC							
4-Aug	JSL2-3299	2:18	200	2	0	15	rock, sediment
Georgetown Hole SC							
4-Aug	JSL2-3300	3:02	54	3	0	16	sediment, coral, sponge
5-Aug	JSL2-3301	0:42	49	1	0	0	none

Habitat Characterization

Habitat and faunal documentation included written notes and videotaped transects used for fish and invertebrate surveys (details below). 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. Insert details of camera from proposal and OE docs. Descriptions of habitats from videotape included qualitative descriptions of habitat type (rock, sand), extent of vertical relief, and qualitative descriptions of attached biota.

Sediments at each reef site were collected using the submersible's scoop attached to the manipulator arm. In addition to describing benthic infauna, these samples were used to describe the sediments adjacent to reefs and at varying distances from the reef. Details of sediment sampling are described below (*Benthic Fauna Characterization*).

Sediment composition samples were analyzed for percentages (by weight) of sand, silt, clay, and calcium carbonate content using procedures described by Folk (1980) and Pequegnat et al. (1981). Sand fractions were dry-sieved using a Ro-tap mechanical shaker and fourteen 0.5 phi-interval screens for grain size determinations. Measurements of total organic matter were obtained by burning a portion of each sample at 55 C for 2 h as described by Plumb (1981). The significant differences found among sites with respect to sand content, $CaCO_3$ content, and mean sand grain size were used to explain spatial differences observed in benthic infaunal assemblages because sediment characteristics can influence the structure of benthic communities (Olafsson et al. 1994; Gray 1974; Snelgrove and Butman 1994; Van Dolah et al. 1997).

Rock samples were collected for future petrographic (rock chemistry, texture, origin) characterization. Rock samples will 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 characterization of sediments will include a qualitative description of planktonic and benthic foraminifera. Funding was not available for rock characterizations, but this will be completed in the future.

Between submersible dives and at night side scan sonar transects were used to provide additional visual and acoustic assessment of reef formations and faunas (Table 2). A 100 Khz towed side scan sonar was used to obtain profiles of sites prior to submersible dives. The primary use of the side scan sonar observations was to further direct submersible operation, but preliminary observations of reefs were also summarized. Additional analysis of the side scan sonar data is planned for the future.

During all dives and sampling on the spawning grounds, we continuously monitored sea surface temperature, salinity and fluorometry. CTD casts were done at each station to describe hydrography (Table 2).

Habitat and hydrographic data were incorporated into the GIS database containing historical data on hydrography and fish distribution, to aid in characterization of reef fish spawning sites.

Fish Observations

On each submersible dive, timed (4 min) transects at slow speed were conducted along main reef ledge features (Fig. 6). 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 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 using lasers mounted 25 cm apart on the video camera. Transects were recorded on digital videotape (mini-DV) and analyzed for priority reef fish species, other reef fish assemblages and assemblages of sessile epifauna (see below). Priority reef fishes included economically valuable groups such as snappers and grouper, and fishes exhibiting spawning behaviors (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 be made.

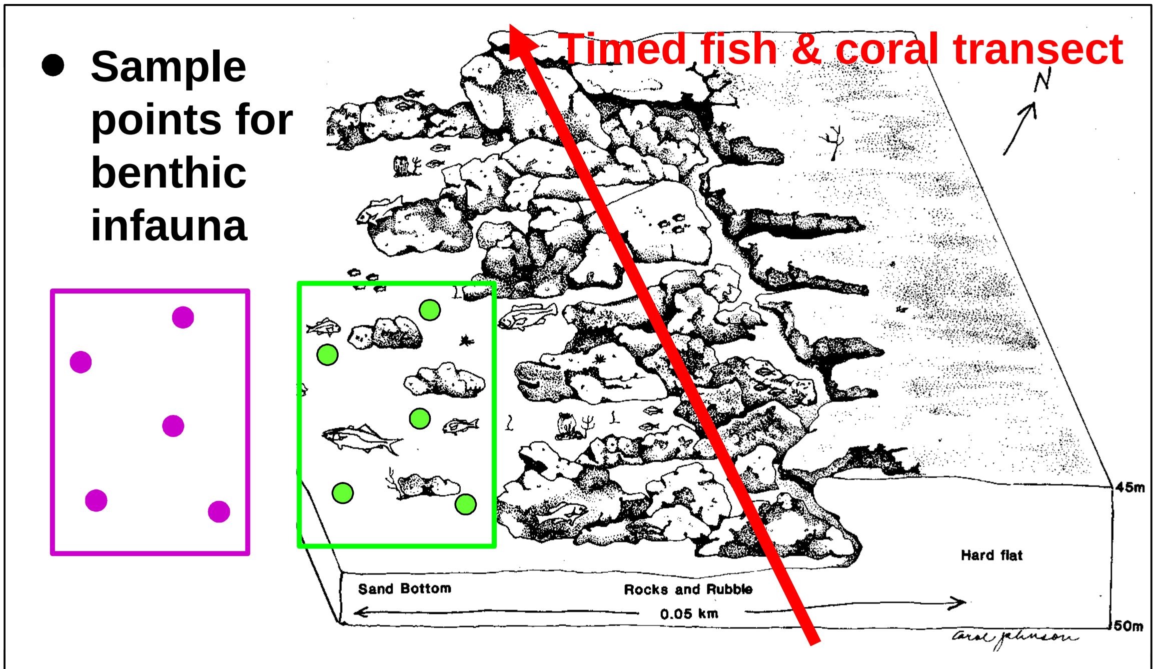


Figure 6. Schematic showing submersible transect moving southward along the shelf-edge reef, and relative location of "nearfield" (green dots) and "farfield" (purple dots) benthic samples.

In addition to recording and analyzing transects, we recorded and observed courtship and other reproductive behavior in fishes whenever it occurred. Reproductive behaviors included exhibition of spawning coloration and other courtship displays, nest guarding, and unusual aggregations of fishes. We also observed individual female fishes with unusually swollen abdomens, indicating ripe ovaries. Because much reef fish spawning occurs at dusk, just after sunset (Carter et al. 1994; Carter and Perrine 1994; Domier and Colin 1997), we were unable to observe actual spawning behavior. However, we collected plankton samples (see below) in an attempt to collect recently-spawned fishes.

Species diversity was calculated for pooled replicate transects at each dive site by H' and its components, evenness and species richness (Margalef 1958; Pielou 1975).

Benthic Fauna Characterization

In an effort to better characterize the shelf edge reef habitats used as fish spawning sites, the benthic infaunal and epifaunal communities at the five study sites were studied in detail. Three general habitats (including potential prey fields) were sampled as part of the characterization effort: (1) benthic macroinfaunal communities in sandy, soft bottom habitats, (2) benthic macroinfaunal organisms in the sandy veneer over hard bottom habitats, and (3) epibenthic sponge/coral assemblages on hard bottom substratum. Several sampling and censusing techniques were used to assess the benthic assemblages.

For infauna, we were particularly interested in comparing sites near the reef and its associated aggregations of fishes, to sites farther from the reef (Fig. 6). To address the effects of reefs and associated fishes on assemblages of benthic infauna, macroinfaunal samples were collected at nearfield stations in close proximity to the reef (i.e., within 5-10 m) at all seven shelf/slope locations (Table 4). Samples were collected with a scoop (0.03 m^2) attached to the submersible manipulator arm. At four of the shelf/slope locations, a second replicate reef site, in a different area of the reef, was sampled to allow for tests of within-reef variability (Table 4). Also, at four of the individual reef sites, additional farfield samples (30-50 m from live bottom) were collected to allow for nearfield-farfield comparisons in relation to reef proximity (Table 4). Two to four replicate samples were collected for macroinfaunal analysis at each of these various stations. An additional sediment sample was collected at each station for analysis of sediment granulometry (% silt-clay vs. coarser fraction) and total organic carbon (TOC) content. As with other submersible observations and collections, water-column variables (salinity, temperature, and depth) were measured at each station with the submersible's onboard instrumentation.

All benthic infaunal samples were sieved at sea through a 0.5-mm sieve. Material remaining on the sieve was preserved in 10% buffered formalin stained with Rose Bengal. In the laboratory, all organisms from each sample were sorted from the remaining sediment and debris, identified to the lowest practical taxonomic level (usually species), and enumerated.

Spatial patterns in the distribution of benthic infauna among shelf/slope locations were examined using normal (Q mode) cluster analysis (Boesch 1977). Group-average sorting (= unweighted pair-group method; Sneath and Sokal 1973) was used as the clustering method and Bray-Curtis similarity (Bray and Curtis 1957) was used as the resemblance measure. The analysis was run on log(x+1) transformed abundances using the PRIMER software package (Clarke and Gorley 2001). Results were expressed as a dendrogram in which samples were ordered into groups of increasingly greater similarity based on resemblances of component-species abundances.

Table 4. Reef sites from which benthic scoop samples were collected. Near and far refers to samples of sediments and infauna collected near the reef and far from it.

Site	Date	Dive No.	Location
St. Augustine Scarp	28-Jul	JSL2-3289	near & far
St. Augustine Scarp	28-Jul	JSL2-3290	near & far
Jacksonville Scarp	30-Jul	JSL2-3291	near
Julians Ridge	1-Aug	JSL2-3293	near
Julians Ridge	1-Aug	JSL2-3294	near & far
Scamp Ridge	2-Aug	JSL2-3295	near
Scamp Ridge	2-Aug	JSL2-3296	near & far
Charleston Lumps South	3-Aug	JSL2-3297	near
Charleston Lumps South	3-Aug	JSL2-3298	near
Charleston Lumps North	4-Aug	JSL2-3299	near
Georgetown Hole	4-Aug	JSL2-3300	near

In addition to the cluster analysis, one-way ANOVA was used to determine significant differences in mean values of benthic response variables among nine different dive site combinations (i.e., St. Augustine Scarp Dives 1 and 2, Jacksonville Scarp Dive 1, Julians Ridge

Dives 1 and 2, Scamp Ridge Dive 1, Scamp Ridge Dive 2, Georgetown Hole, Charleston Lumps North, Charleston Lumps South Dives 1 and 2).

Sediment composition samples were analyzed for percentages (by weight) of sand, silt, clay, and calcium carbonate content. Sand fractions were dry-sieved using a Ro-tap mechanical shaker and fourteen 0.5 phi-interval screens for grain size determinations. Measurements of total organic matter was obtained by burning a portion of each sample at 550 C for 2 h. Any differences found among sites with respect to sand content, $CaCO_3$ content, and mean sand grain were used to explain spatial differences observed in benthic infaunal assemblages.
Like the fish observations, benthic sampling concentrated on spawning sites in or near proposed MPA zones (Fig. 3), to be consistent with NOAA's strategic plans regarding building a better understanding of ecological conditions and potential human impacts in MPAs.

In addition to describing infaunal assemblages of macroinvertebrates, we collected sponges to examine macroinvertebrate faunas that live in and on sponges (Table 5). Twelve sponge specimens were collected during the cruise at depths ranging from 58 - 215 m. Sponges were collected using the scoop attached to the manipulator arm on the *JSL2*. Upon collection, each sponge was immediately emptied into one of the large Plexiglas buckets on the rotating conveyer belt on the submersible work platform. 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 that may have left the sponge while it was in the capture container. These were also preserved with the sponge specimen.

Table 5. Summary of sponge collection data. Volume = sponge volume displacement.

Species	Volume (ml)	Dive Location	Latitude	Longitude	Depth (m)	Temp (C)	Salin (psu)
Ircinia campana	275	St. Augustine Scarp FL	29.9425	-80.2840	58.5	19.86	37
Chondrilla sp.	180	St. Augustine Scarp FL	29.9939	-80.2803	60.7	19.27	37
Erylus sp.	530	Julian's Ridge SC	32.3445	-79.0454	54.9	20.94	37
Geodia sp.	1840	Charleston Lumps SC	32.6198	-78.3178	194.2	13.27	36
Aplysina archeri	220	Georgetown Hole SC	32.8532	-78.2531	50.3	20.88	37

Five of the sponge specimens collected were randomly selected for an initial analysis of their associated fauna (Table 5). Two specimens, *Chondrilla* sp. and *Ircinia campana*, were collected from submersible dives at St. Augustine Scarp, off the coast of Florida (Fig. 7). The other three specimens, *Aplysina archeri*, *Geodia* sp., and *Erylus* sp. were collected from Georgetown Hole, Charleston Lumps South, and Julians Ridge, respectively, off South Carolina (Fig. 8). 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)]. Sponges were 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.

Figure 7. Sponge specimens collected during the 2002 Ocean Exploration cruise that were dissected for analysis of faunal associates. A) *Chondrilla* sp. collected from St. Augustine Scarp FL; and B) *Ircinia campana* collected from St. Augustine Scarp FL..

Associated fauna were identified to major taxonomic group and enumerated. Host sponges were identified using photographs and spicule preparations. Microphotographs of internal structure and spicules were taken using a Nikon CoolPix 990 digital camera with microscope attachment mounted to a Nikon SMZ 800 dissecting microscope or Nikon Eclipse E400 compound microscope. Shirley Pomponi, a sponge taxonomy expert from Harbor Branch Oceanographic Institute, has been contacted to confirm identifications to at least the genus level and provide other taxonomic assistance.

Video Transects for Sessile Megafauna

Videotapes collected during the 12 dives and analyzed for fish assemblages were also analyzed for the occurrence of selected taxa of large sessile invertebrates (Tables 2 and 3; Fig. 5). Video transects from three additional dives (M1, M2, and M3) conducted off the South Carolina coast from July 14th through 17th, 1985 in the submersible *Johnson Sea Link I* were also analyzed for comparative purposes with the current study (Table 6, Fig. 9). Multiple video transects were collected at all sites and generally followed the main reef feature at each site (Fig. 6). Timed transects were 4 min in length. Although we attempted to keep them constant, submersible speed and distance off the bottom varied, depending 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 $\pm$ 7.0 m). Average transect width (7 m) was estimated during the cruise based on the distance between two parallel lasers mounted 25 cm apart on the video camera. 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, but seemed reasonable based on visibility and the rugged bottom topography on our dives, which often obscured views.

Figure 8. Sponge specimens collected during the 2002 Ocean Exploration cruise that were dissected for analysis of faunal associates. A) *Geodia sp*. collected from Charleston Lumps SC; and B) *Aplysina archeri* collected from Georgetown Hole SC.

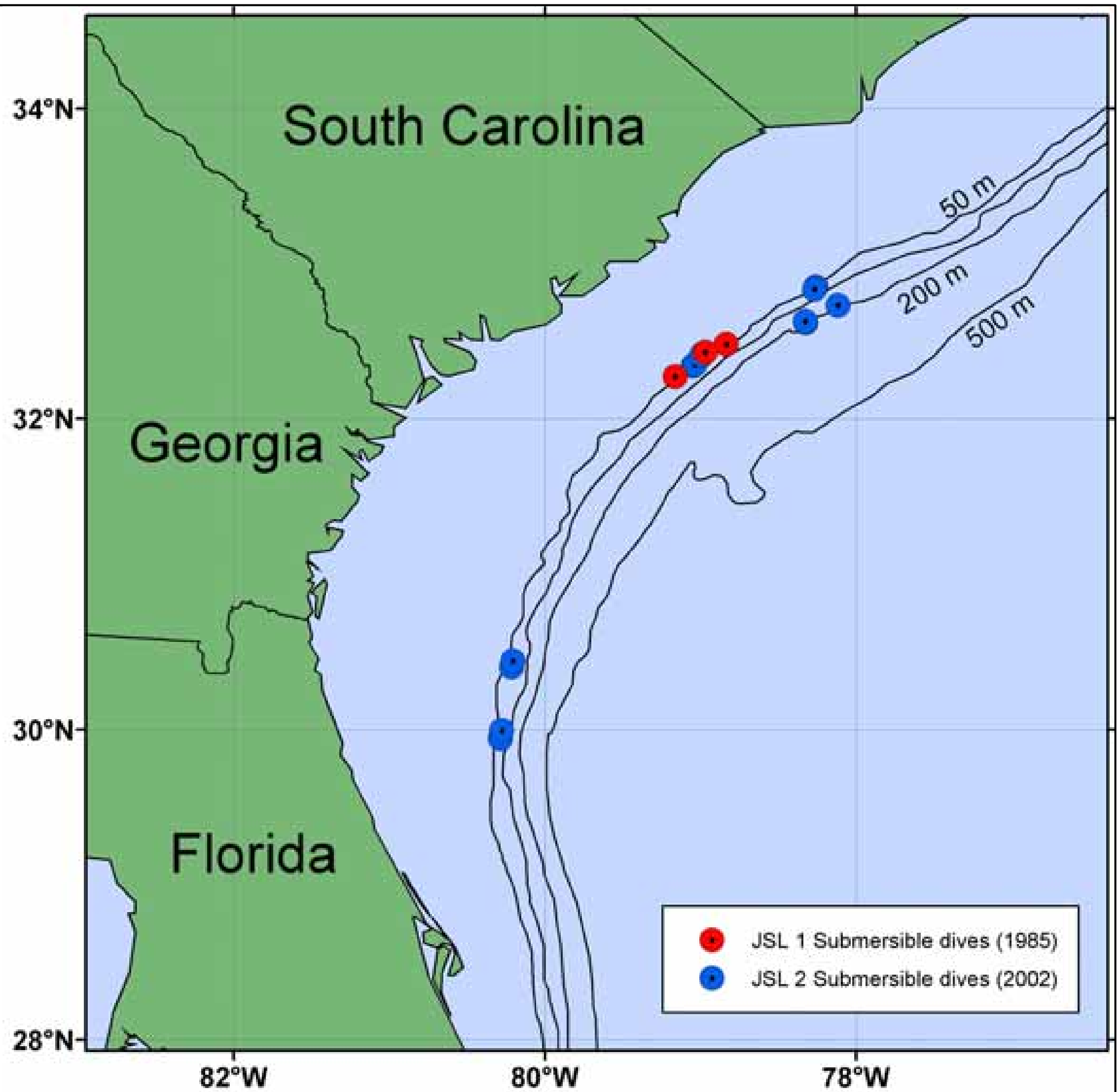


Figure 9. Location of video transects collected via submersible in 2002 (blue dots) and 1985 (red dots).

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 identified as the most abundant taxa and selected for further analyses. Five randomly selected 2-min segments of video transects from each dive were reviewed using ATI Multimedia Center 8.1 (ATI 2001). Abundance estimates (number of individualas/m^2) were recorded for *Stichopathes* sp. and large sponges. Abundances of *Stichopathes* sp. were rank-transformed and sponge abundances were ln (x+1) transformed, where necessary, for statistical tests. Differences in abundance among 2002 dives and between 1985 and 2002 dives were tested using one-way ANOVA followed by post-hoc comparisons with the Tukey test or Dunn's test. SigmaStat 2.03 was used for all statistical tests (SPSS 1997).

Table 6. Sites sampled in 1985 using the *JSL2*.

Site	Latitude	Longitude	Depth (m)
M1-- Porgy Park	32.4820	-78.8308	51
M2-- Scamp Ridge	32.4278	-78.9663	57
M3-- South of Julians Ridge	32.2701	-79.1617	53

Additional Shipboard Sampling

Shipboard sampling included sediment and plankton sampling, and bottom mapping with side scan sonar (previously described).

Sediment Contaminant Sampling

For each of the seven reef sites (Fig. 5), a composite sediment sample for the analysis of chemical contamination was collected. The sediment sample was acquired by deploying a Young grab from the deck of the vessel during non-dive periods. These sediment samples were taken as close as possible to the coordinates where benthic samples were collected during submersible sampling. Approximately 3-5 drops of the Young grab were needed to provide the material required for the composite sample. Sediment contaminant samples were archived for future analysis, pending funding.

Sampling of Early Life History Stages of Fishes

We conducted plankton tows at most sites (Table 2) to look for early larvae of fishes that may have spawned recently. Time and funding constraints have prevented us from identifying all the fish larvae in those samples, but the larvae have been sorted out of the samples, and larvae of some groups removed for further identification.

Plankton sampling at most reef sites consisted of standard continuous double-oblique bongo tows (60 cm frame with 0.947 µm and 505 µm mesh) from the surface to the bottom or to 200 m. Vessel speed was adjusted to maintain a 45° wire angle. Neuston tows (1 x 2 m frame, 0.947 µm mesh net) were for 10 min at the surface at a vessel speed of 6.5 km/h (3.5 knots), adjusted to keep the net with the lower half submerged. All nets were equipped with a flowmeter to measure the volume of water filtered. Six bongo and eight neuston collections were made. Samples were preserved in 95% ethyl alcohol (full strength ethanol), which was replaced after 24 h. A CTD cast was done at each station.

In the laboratory, settled plankton volume was measured to estimate plankton biomass. Fishes and fish eggs were removed from the samples, counted, and priority groups were sorted out and identified to the lowest possible taxon. Priority groups included wreckfish, groupers (Epinephelinae), swordfish, billfishes and marlins (Istiophoridae), and tunas and mackerels (Scombridae).

Pending funding from an additional, source larvae of economically valuable taxa will be identified to the lowest possible taxon. Samples have been archived for future taxonomic analysis and aging of larvae of priority taxa, to pinpoint spawning times and locations.

RESULTS AND DISCUSSION

Habitat Characterization

Preliminary analysis of spawning locations for some reef species indicated that the shelf-edge reef (Barans and Henry 1984; Collins and Sedberry 1991; Sedberry et al. 2002) is an important spawning ground for some reef fishes of the SAB (Burgos 2001; Moore 2001). Reconnaissance of shelf edge reef using submersibles in 1985 and during the 2001 Islands in the Stream Expedition revealed a diversity of reef types, some of which might be more important than others as spawning or nursery grounds for reef fishes (Sedberry et al. 2002; Sedberry pers. obs.). Exploration of shelf-edge reefs off Savannah during the 2001 Islands in the Stream Expedition indicated a low-relief formation that was quite different from the shelf-edge ridge system found off South Carolina (Barans and Henry 1984; Wenner et al. 1983; SCWMRD 1982; Sedberry personal observations). Shelf-edge reefs off northern South Carolina are near documented upwelling areas, whereas those off northern Georgia are in more tranquil areas where sedimentation occurs (Weaver and Sedberry 2001; Wenner and Barans 2001), and these oceanographic features may account for differences in bottom features.

Submersible observations during the present study revealed a variety of reef formations from south (St. Augustine, FL) to north (Charleston, SC), and from the shelf edge (~50 m) to the upper slope (~200m). Observers noted a transition of communities from the southern shelf edge reefs at St. Augustine and Jacksonville Scarps FL to northern shelf edge reefs at Julians and Scamp Ridges, SC. Significantly different habitat (and associated biota--see below) were noted along the upper slope reefs at Charleston Lumps, relative to shelf-edge sites. Shelf-edge reefs off of Florida were a continuous ridge of rock, with a broken or faulted blocky pattern, generally 2-3 m in relief (Fig. 10). The reef became more discontinuous features of rubble and bioeroded rock at sites off South Carolina, where sediments surrounding the reef appeared deeper, as if the reef were more buried by sediments than those to the south (Fig. 11, Fig. 17A). Whereas a distinct ledge and drop-off was present at the shelf-edge reef (most pronounced off Florida), no distinct ridge or scarp features occurred at the slope reefs (Charleston Lumps). The slope reefs consisted of mounds 30-50 m high, with large rock outcrops and extensive fields of small rubble and hard pavements (Fig. 12). Shelf-edge reef sediments were lithogenic (eroded rock) and biogenic (from biological sources) with little-to-no fine grains (Table 7). Slope reef sediments contained more fine sediment and coarse fraction of sand, shell and rock fragments, and small rounded rock nodules. The large rock outcrops at shelf edge sites supported diverse assemblages of sessile epifauna (large sponges, wire corals, bryozoa). They were especially dense off Florida, with decreasing density of larger species at northern sites off South Carolina, where larger invertebrates were replaced by smaller tunicates, encrusting sponges and hydrozoans.

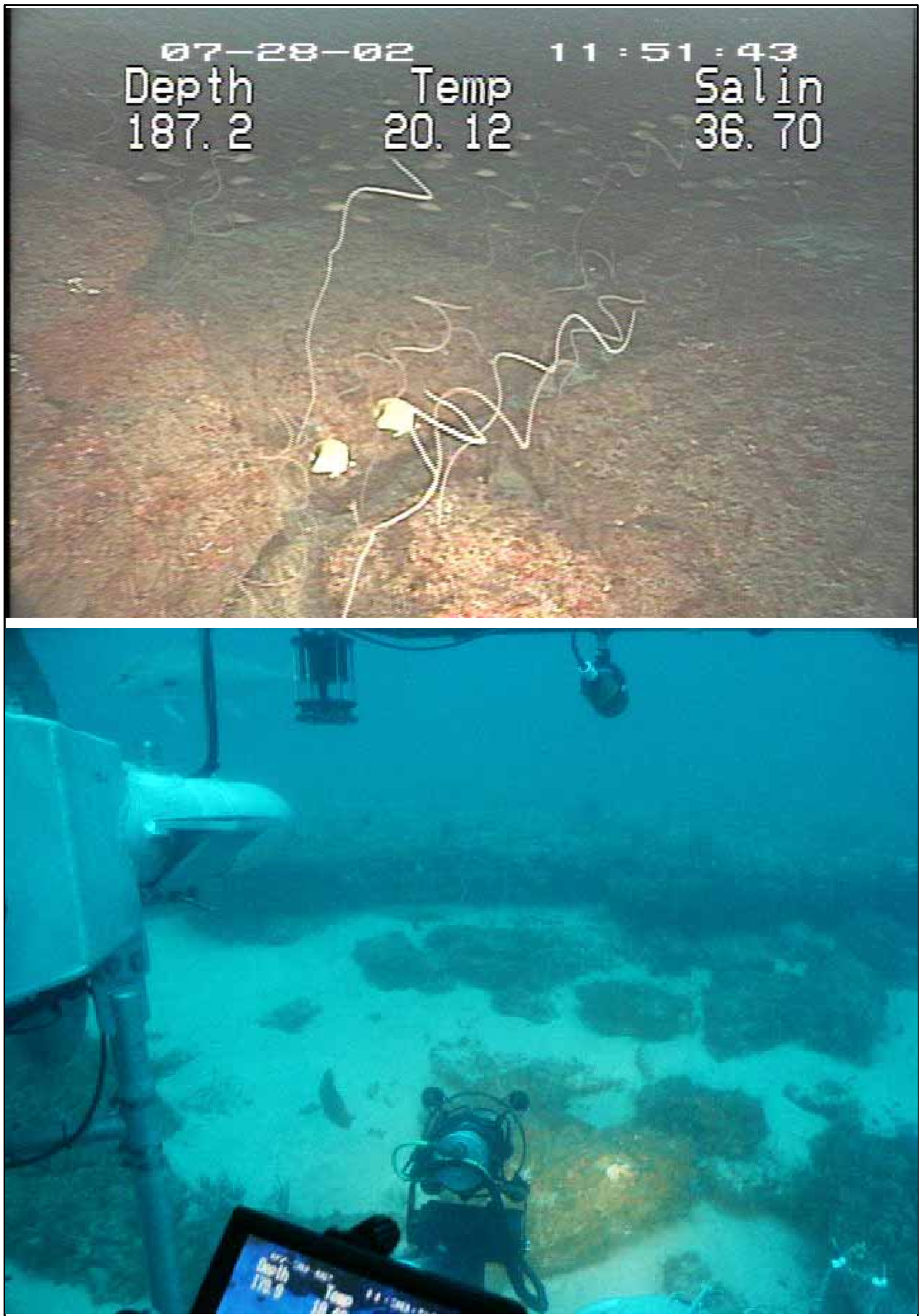


Figure 10. Shelf-edge reef sites off Florida. Depth in ft., temperature in C and salinity in psu.
Top: Large blocks of broken rock on the scarp face at St. Augustine Scarp. View is to the north, with the offshore side of the scarp to the right.
Bottom. Large rocks in the rocky rubble area at the base (offshore side) of the scarp at Jacksonville Scarp. View is to the west, looking at the scarp face from offshore of it.

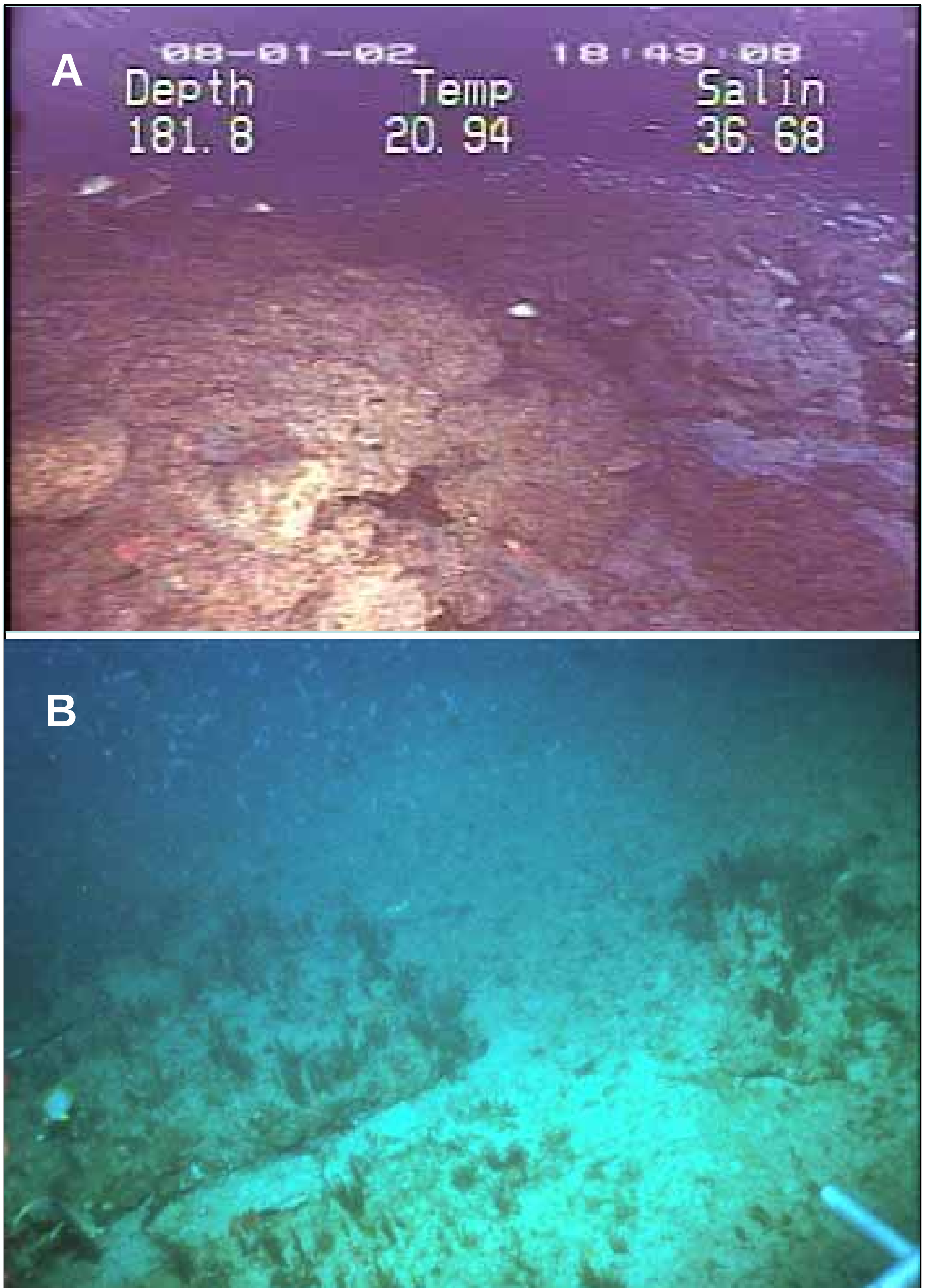


Figure 11. Shelf-edge reef sites off South Carolina. Depth in ft., temperature in C and salinity in psu.
A: Large broken rocks at the shelf break . Deeper sediments were observed offshore (to the right in the image) at South Carolina sites than at Florida sites, and sediments were often seen on inshore and offshore sides of the ridge.
B. Large rocks buried in deeper sediments typical of the South Carolina sites.

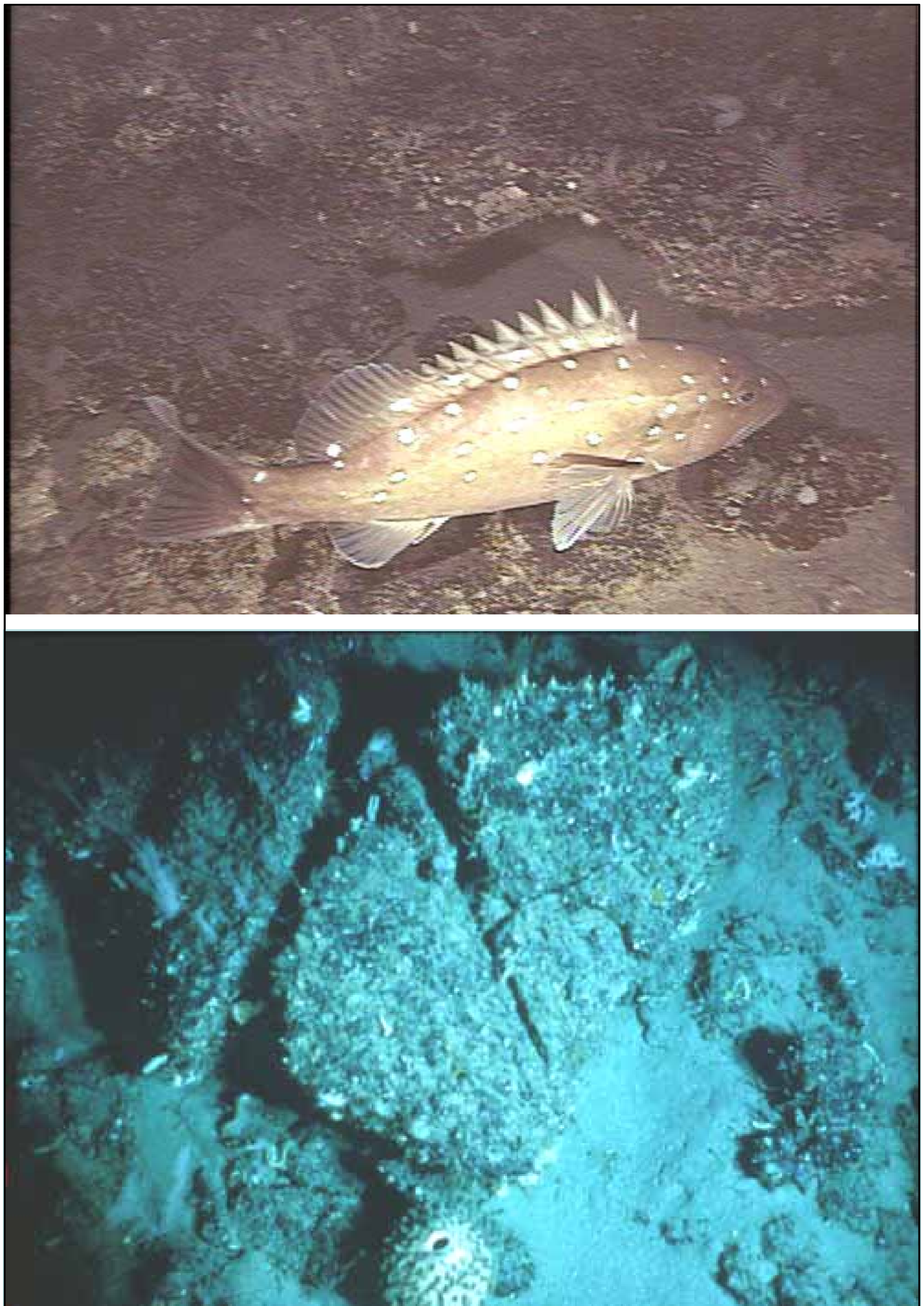
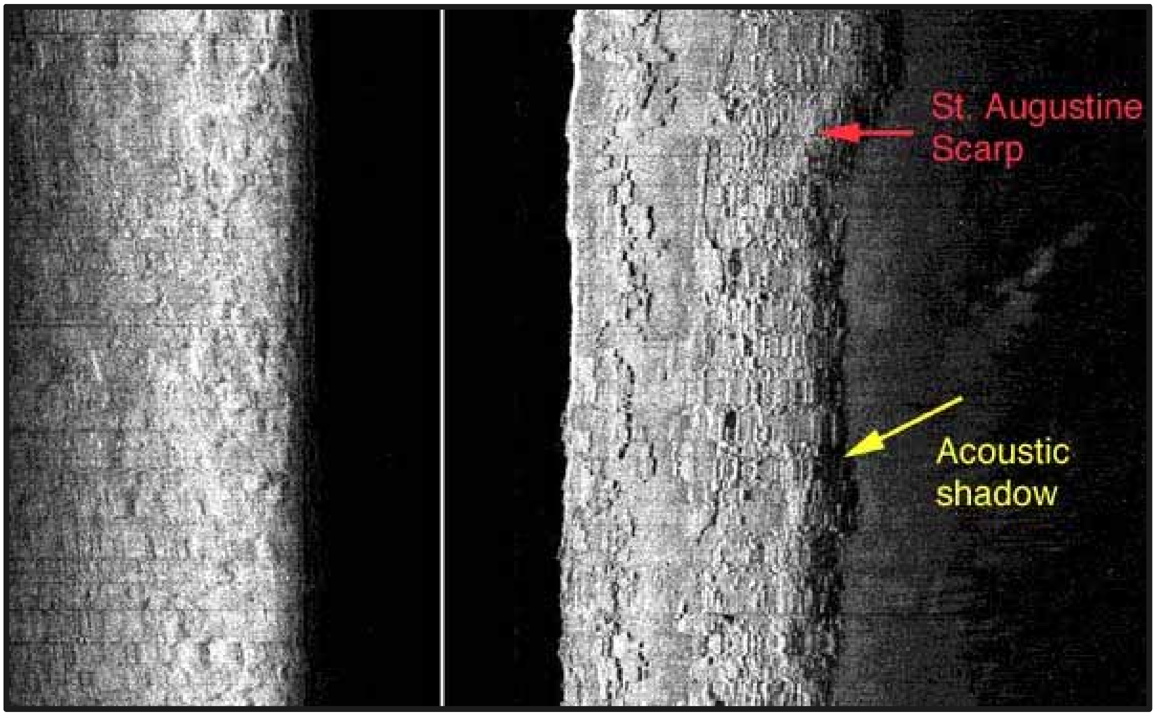


Figure 12. Upper slope reef sites off South Carolina.
Top: Large broken pavement rocks found near the top of pinnacles and mounds. Snowy grouper are associated with this habitat.
Bottom. Large broken rocks surrounded by smaller rocky rubble. Rocky rubble covers much of the slope of the mounds and pinnacles. A *Geodia* sp. sponge is visible at the bottom of the image.

Bottom temperatures and salinity were relatively constant among shelf-edge sites, and upper slope sites were predictably cooler than shelf-edge sites (Table 7). Silt-clay fractions of sediment samples were relatively low, but were higher at southern slope site. TOC was low, but was unusually high at the St. Augustine shelf edge and at the southern slope site. Based on depth, bottom temperatures, proximity to the reef and other abiotic variables (Table 7), sites sampled and analyzed for benthic infauna were grouped into two major categories: shelf-edge sites and upper-slope sites. At shelf-edge sites (St. Augustine Scarp, Jacksonville Scarp, Julians Ridge, Scamp Ridge, and Georgetown Hole), depths ranged from 53.0 to 61.3 m. Temperatures for these sites ranged from 18.46 to 22.06 C. The upper-slope sites (Charleston Lumps North and South) were deeper and cooler, with depths of 199.6 to 206.0 m and temperatures of 12.92 to 13.27 C. Typical oceanic salinities, ranging from 36 to 37 ppt, were observed among all stations regardless of depth zone. TOC and % silt/clay were variable, but without a distinct among-station pattern. Both variables were at relatively low levels, with TOC ranging from 0.5 to 10.9 mg/g (mean of 3.8) at shelf-edge sites and from 3.8 to 9.8 mg/g (mean of 6.9) at upper-slope sites, and with silt/clay content ranging from 1.29 to 7.77 % (mean of 4.21) at shelf-edge sites and from 3.50 to 10.25 % (mean of 7.29) at upper-slope sites (Table 7).

Table 7. Summary of abiotic environmental variables by dive location and proximity to the shelf edge reef (near or far as previously defined). Salinities (not shown) were typical of Gulf Stream waters (36 - 37 psu).

Location	Proximity to Hard Bottom	Depth (m)	Temp (C)	Percent Silt/Clay	TOC (mg/g)
St. Augustine Scarp 1	near	60.4	19.54	5.50	3.8
	far	60.4	19.54	7.77	2.8
St. Augustine Scarp 2	near	61.3	19.27	4.25	10.9
	far	61.3	19.27	3.98	5.1
Jacksonville Scarp 1	near	59.4	18.46	3.52	2.0
Julians Ridge 1	near	54.9	20.94	3.95	6.9
Julians Ridge 2	near	58.8	20.94	1.29	0.5
	far	58.8	20.94	2.61	0.5
Scamp Ridge 1	near	53.6	22.06	4.72	3.6
Scamp Ridge 2	near	53.0	21.12	4.87	2.1
	far	53.0	21.12	3.81	3.3
Charleston Lumps South 1	near	206.0	12.92	8.13	7.2
Charleston Lumps South 2	near	201.2	13.27	10.25	9.8
Charleston Lumps North	near	199.6	13.16	3.50	3.8
Georgetown Hole	near	54.3	20.88	--	--



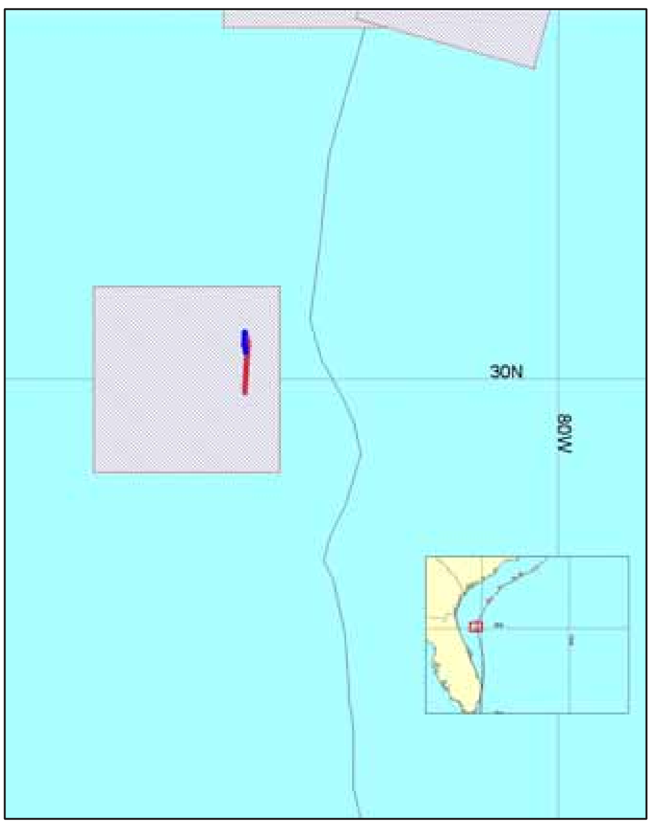


Figure 13. Preliminary results of side scan sonar of the St. Augustine Scarp.

Left: Track of two side scan sonar tows within the proposed MPA site (surrounding box) that encompassed the St. Augustine Scarp.

Above: Image from side scan sonar of the St. Augustine Scarp, showing very sharp drop-off, with nearly vertical relief on the offshore edge (right side in image).

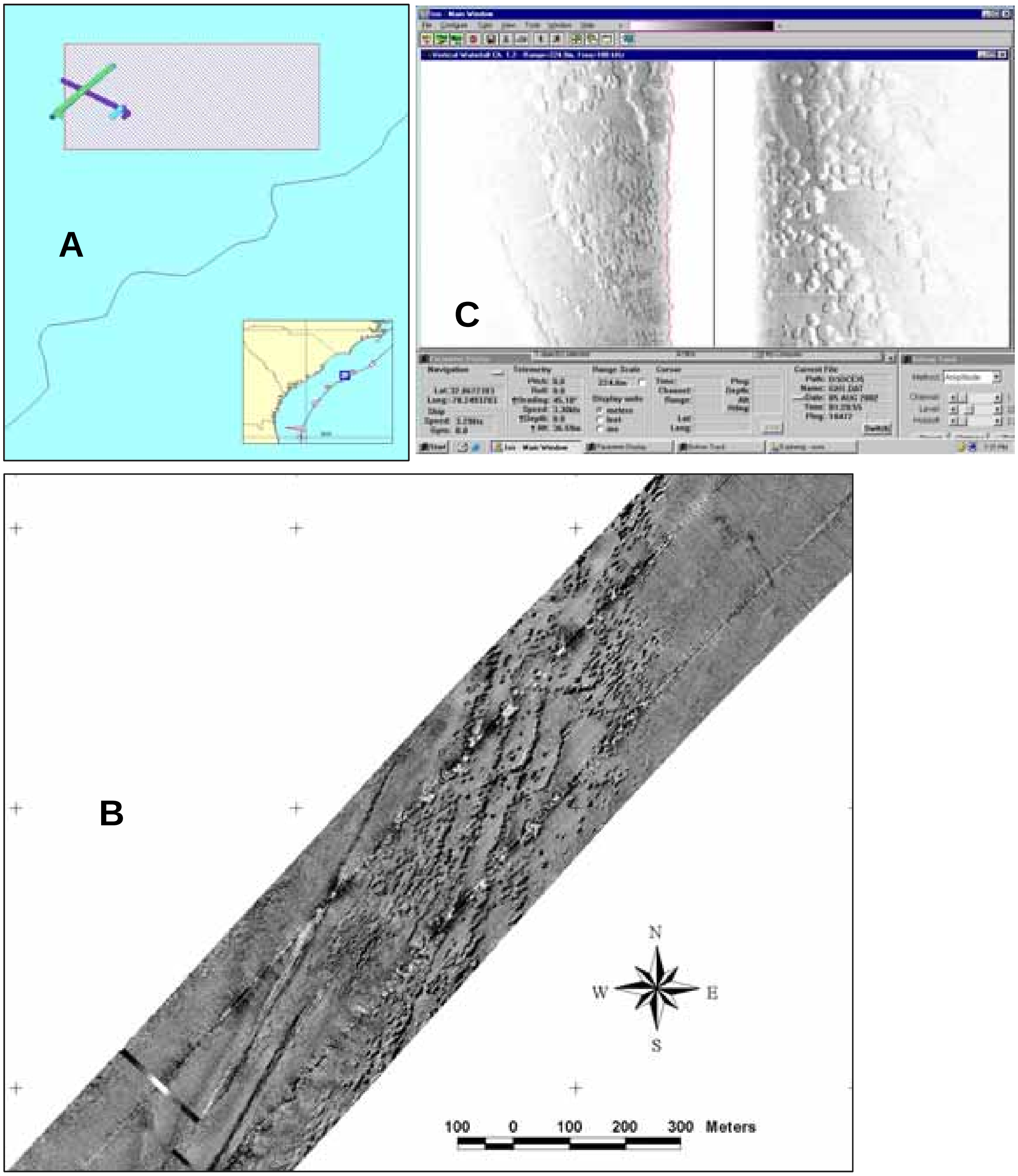


Figure 14. Preliminary results of side scan sonar of Georgetown Hole.
A: Tracks of side scan sonar tows within the proposed MPA site (surrounding box) that encompassed the Georgetown Hole site.
B: Image from the northwest (green) track, showing multiple ridge features and mounds.
C: Closer view of low mounds mapped with side scan sonar. These mounds were also observed from the submersible and were covered with low invertebrate growth (e.g. Fig. 12, near gray triggerfish nest).

Preliminary analysis of side scan sonar data confirmed submersible observations regarding north-south variation in reef morphology (Fig. 13, Fig. 14). At southern sites off Florida (e.g. Fig. 13), a very well-defined, nearly-vertical scarp was present. The top of the scarp was nearly flat hard bottom, with shallow cracks and fissures between the blocks of hard rock. The scarp dropped precipitously in a series of a few large blocks. Offshore of the break, smaller rocks and rubble was interspersed with sediments (Fig. 10, Fig. 13). Side scan sonar of shelf-edge sites off South Carolina (e.g. Fig. 14) showed a less well-defined shelf break. Often there were clear outcrops of rock at the break (Fig. 11A). In many places however, there were usually discontinuous ridge segments interspersed with deeper sediments, buried reef and low mounds (Fig. 11B, Fig. 14B,C, Fig. 17A).

Fish Observations

Species Composition and Abundance

A total of 143 4-min transects were analyzed. This encompassed 46.1 ha of reef habitat (Table 8). The dominant fish species overall was the tomtate, *Haemulon aurolineatum*. Tomtate is a shelf species, and was a dominant species at all shelf-edge sites but was absent from the two upper slope sites (Table 9 and Appendix Table 1). Yellowtail reeffish (*Chromis enchrysura*), vermilion snapper (*Rhomboplites aurorubens*), squirrelfish (*Holocentrus adscensionis*) and reef butterflyfish (*Chaetodon sedentarius*) also dominated at shelf-edge reefs. The tattler (*Serranus phoebe*), a small sea bass, was also found at all shelf edge sites, but ranked in the top four species only at Julians Ridge. The sunshinefish *Chromis insolatus* (a species of damselfish) was another fish found at all shelf-edge reefs, but which varied in abundance among sites.

Species observed at shelf-edge reefs were not observed at upper-slope reefs, and vice versa. Upper slope reefs were dominated overwhelmingly by yellowfin bass (*Anthias nicholsi*) and blackbelly rosefish (*Helicolenus dactylopterus*).

Fish assemblages at shelf-edge reefs were much more diverse than those at upper slope reefs (Appendix Table 1, Table 10). Overall, at least 64 species representing 31 families were observed. Only eight species in eight families were observed at the two upper slope reefs. The Serranidae (sea basses) was the most diverse family among all sites, represented by 12 species. Pomacentrids (damselfishes) and chaetodontids (butterflyfishes) were also diverse, represented by four species each. Identification of wrasses (Labridae) was difficult, but several species were observed. Jacksonville Scarp had the greatest number of species observed per transect (30 species observed, equaling 2.31 per transect), followed by Georgetown Hole (25 species; 1.67 per transect), Scamp Ridge (46 species; 1.64 per transect), St. Augustine Scarp (36 species; 1.64 per transect) and Julians Ridge 40 species, 1.33 per transect). Diversity (H') was higher at shelf-edge than at upper-slope reefs, and Georgetown Hole had the highest H' diversity (Table 10).

Economically valuable fishes observed included triggerfishes (gray, queen), hogfish, several snappers (red, gray, yellowtail and vermilion), blueline tilefish, and many groupers (graysby, coney, speckled hind, red grouper, snowy grouper, gag, scamp) and porgies (knobbed porgy, red porgy, spottail pinfish).

Table 8. Number of fish transects and area viewed at each site.

Site	No. of Transects	Area Viewed (m^2)
St. Augustine Scarp	22	5009
Jacksonville Scarp	13	4548
Julian's Ridge	30	9292
Scamp Ridge	28	11,933
Charleston Lumps South	23	10,035
Charleston Lumps North	12	3133
Georgetown Hole	15	2188
TOTAL	143	46138

Reproductive Behavior Observed in Fishes

An objective of this project was to discover spawning locations and observe spawning in reef fishes. Many reef fishes spawn at dusk or later in the day, and the logistics of submersible observations did not allow evening sub dives. Nevertheless, we were able to observe several fishes that exhibited courtship and other reproductive behavior.

Scamp (*Mycteroperca phenax*) that exhibited the gray-head courtship color phase (Gilmore and Jones 1992) were observed at Julians Ridge off South Carolina and at Jacksonville and St. Augustine Scarps off Florida (Fig. 15). These observations involved one gray-head (apparent male) scamp and one to a few apparent females. Courtship behavior as described by Gilmore and Jones (1992) was observed, but no spawning was observed. As described by Gilmore and Jones (1992), we observed scamp in various color phases; individual fish were constantly in motion, and changed rapidly between different color morphs. Apparent females (usually one or two, but up to five, courted by single apparent males) tended to remain in the "brown phase", whereas the apparent males switched between "gray-head" phase when pursuing females, and "cat's paw" phase when turning away from apparent females (Fig. 15). These behaviors were observed in the morning (1000 EDT at St. Augustine Scarp) and in the evening (1923-1929 EDT at Jacksonville Scarp; 1756 EDT and 1818-1829 EDT at Julians Ridge). Spawning was not observed, but as in other groupers (Carter et al. 1994) that may occur after sunset, when we were not making observations. Bottom temperatures during our observations (19.46 - 19.49 C at St. Augustine Scarp; 20.90 - 20.94 C at Jacksonville Scarp; 20.47 - 22.03 C at Julians Ridge) were similar to those observed by Gilmore and Jones (1992) during spawning activity in scamp.

Table 9. Dominant fishes observed during preliminary analysis of submersible transects. This list includes the 10 most abundant species observed at any one site, and its abundance and rank occurrence at each site. This does not include any taxa not identified to species.

			Abundance (Rank)						
Species	Common Name	Total	St Aug.	Jax. ville	Julians Ridge	Scamp Ridge	Chs Lump S	Chs Lump N	Gtown Hole
Haemulon aurolineatum	tomtate	12,325	3355(1)	451(1)	3545(1)	4816(1)			158(1)
Chromis enchrysura	yellowtail reeffish	2491	49(3)	52(4)	1290(2)	962(3)			138(2)
Rhomboplites aurorubens	vermilion snapper	2051	821(2)	91(2)	80(6)	1059(2)			0
Anthias nicholsi	yellowfin bass	520	0	0	0	0	320(1)	200(1)	0
Chaetodon sedentarius	reef butterflyfish	337	37(5)	54(3)	109(3)	119(4)			18(7)
Equetus umbrosus	cubbyu	235	23(9)	24(6)	86(5)	64(8)			38(4)
Chromis insolata	sunshinefish	210	0	9(20)		114(5)			74(3)
Holocentrus adscensionis	squirrelfish	187	38(4)	22(7)	38(10)	65(7)			24(5)
Serranus phoebe	tattler	159	10(14)	10(14)	106(4)	12(17)			21(6)
Bodianus pulchellus	spotfin hogfish	154	8(15)	13(10)	43(8)	49(6)			11(9)
Canthigaster rostrata	sharpnose puffer	154	27(7)	14(9)	65(7)	45(9)			3(13)
Holacanthus ciliaris bermudensis	blue angelfish	130	18(11)	22(7)	36(11)	45(9)			9(11)
Mycteroperca phenax	scamp	120	37(6)	10(11)	35(12)	28(13)			10(10)
Chaetodon aya	bank butterflyfish	119	24(8)	5(15)	41(9)	36(11)			13(8)
Priacanthus arenatus	bigeye	95	22(10)	35(5)	24(15)	10(19)			4(12)
Helicolenus dactylopterus	blackbelly rosefish	92	0	0	0	0	71(2)	21(2)	0
Seriola dumerili	greater amberjack	36	11(13)	13(10)	12(17)	0			
Epinephelus niveatus	snowy grouper	16	0	0	0	0	1(6)	15(3)	0
Gephyroberyx darwinii	Darwin's slimehead	14	0	0	0	0	9(3)	5(4)	0
Caulolatilus microps	blueline tilefish	6	0	0	0	0	6(4)		0
Scyliorhinus retifer	chain dogfish	2	0	0	0	0	2(5)		0
Synodus intermedius	sand diver	1	0	0	0	0		1(5)	0
Total		18,669	4433	778	5403	7368	409	241	505
Total Observed		20,960	4568	888	5861	8347	413	242	641

Table 10. Diversity values for reef fishes observed at each site.

Site	No. Species	No. Individuals	Species Richness	Evenness (J')	Diversity (H')
St. Augustine Scarp	36	4600	4.150	0.288	1.033
Jacksonville Scarp	30	1055	4.166	0.655	2.227
Scamp Ridge	46	10854	4.843	0.469	1.795
Julians Ridge	40	6478	4.444	0.438	1.616
Charleston Lumps S	10	455	1.471	0.431	0.992
Charleston Lumps N	8	251	1.267	0.389	0.810
Georgetown Hole	25	648	3.707	0.718	2.311

We also observed courtship behavior in hogfish, *Lachnolaimus maximus*. Hogfish courtship was observed at Julians Ridge (Dive JSL2-3293) and at Jacksonville Scarp (Dive JSL2-3292). Behavior was as described by Colin (1982), with the male displaying erect spines in the first dorsal fin, and rapid pelvic fin agitations (Fig. 16). This display was directed at one or two nearby females. Although Colin (1982) observed spawning from midafternoon to sunset, we did not observe actual spawning in hogfish. Bottom temperatures at Jacksonville Scarp during the dive ranged from 20.90 - 20.94 C, considerabley cooler than those reported by Colin (1982) in December to March in Puerto Rico (24 - 26 C). Bottom temperatures at Julians Ridge, where we also observed courtship behavior in hogfish, ranged from 20.47 - 22.03 C.

Other behaviors that we observed that are indicative of reproduction included nest guarding in gray triggerfish (*Balistes capriscus*). Gray triggerfish and other balistids construct nests by moving debris and fanning sediments on the bottom, creating a shallow cleared depression. These nests are guarded by either parent for 24 - 48 h after spawning (Fricke 1980; Lobel and Johannes 1980; Ishihara and Kuwamura 1996; Moore 2001). During Dive JSL2-3300 at Georgetown Hole, we observed a large (~30 cm) gray triggerfish hovering over a cleared depression about 75 cm in diameter (Fig. 17). An apparent egg mass could be observed in the bottom of the depression. Peak spawning for gray triggerfish off South Carolina is June-July (Moore 2001). Bottom temperatures at Georgetown Hole where we observed this nest ranged from 20.58 - 20.77.

Specled hind (*Epinephelus drummondhahi*) were rarely observed during submersible dives (Appendix Table 1), and are considered severely overfished (Coleman et al. 2000). One female, obviously distended with ripe ovaries, was observed at Jacksonville Scarp (Fig. 12). Water temperatures at that site ranged from 20.90 - 20.94 C. Spawning was not observed in speckled hind, although our observations coincided with peak spawning in this species (Table 1).

Figure 15. An apparent male scamp at Jacksonville Scarp (Dive JSL2-3292). This individual displayed the gray-head phase (upper image) when pursuing an apparent female, and reverted to the cat's-paw phase (lower image) when the other fish turned away and swam off.

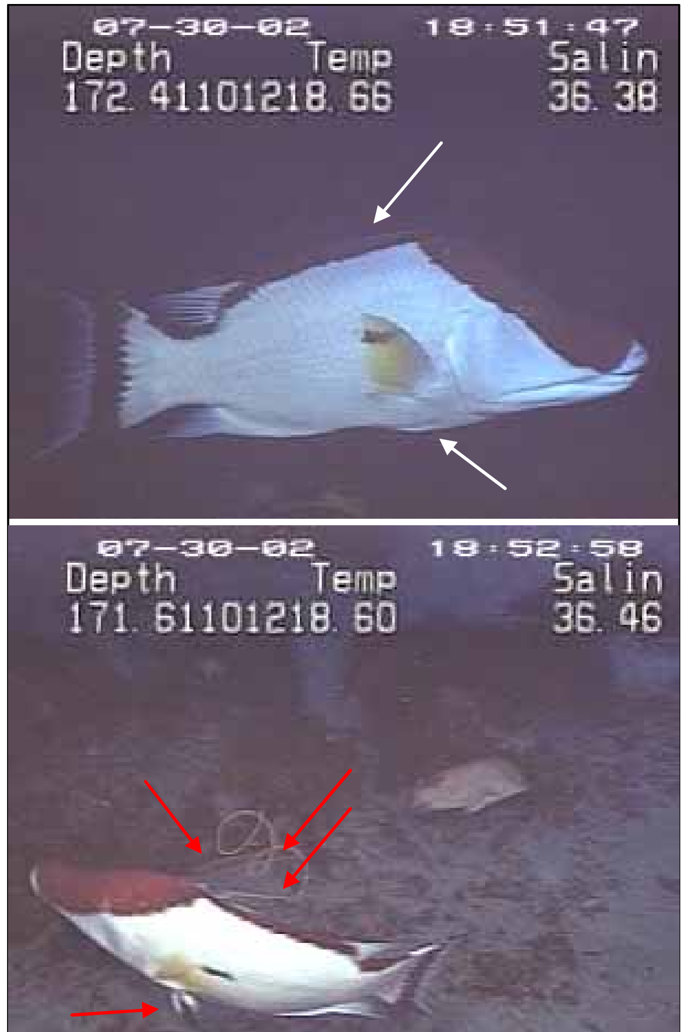


Figure 16. A large male hogfish in normal swimming posture with fins compressed against the body (white arrow, top image) and with erected dorsal spines and pelvic fins (red arrows, bottom image) that it displayed as it approached a female. In the background of the lower image is one of two females that the male was apparently courting during Dive JSL2-3292 at Jacksonville Scarp. The females are smaller and less colorful than the males.

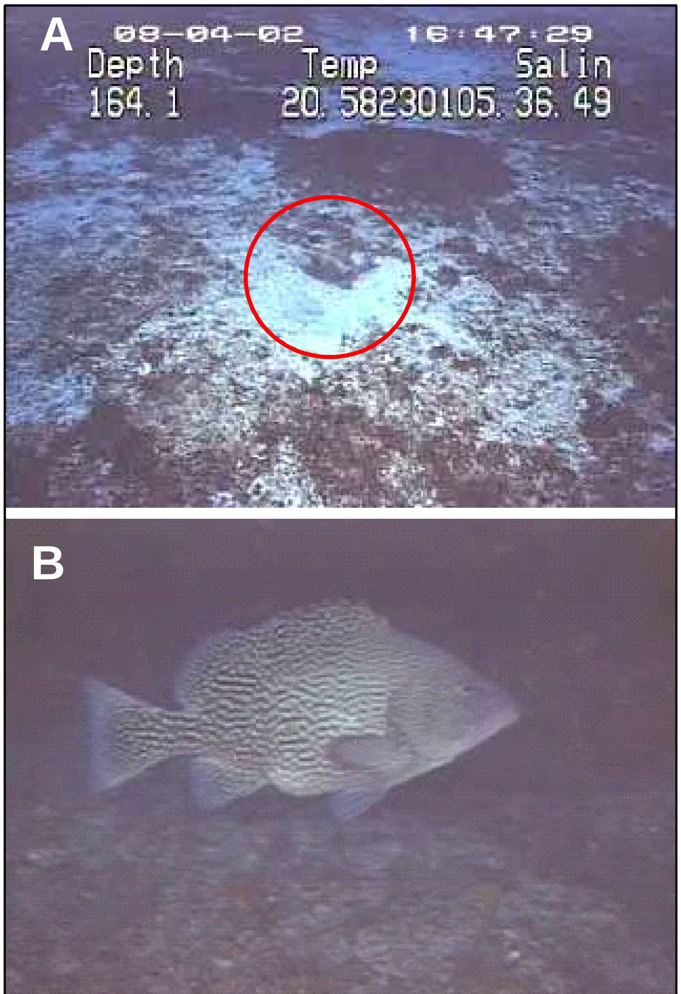


Figure 17. A: A male gray triggerfish guards a nest depression on the bottom at Georgetown Hole, Dive JSL2-3300.
B: A gravid female speckled hind at Jacksonville Scarp, Dive JSL2-3292.

Figure 18. An aggregation of red snapper seen between transects on Dive JSL2-3296 at Scamp Ridge. Few red snapper were observed at sites off South Carolina, and this school may represent a spawning aggregation.

A school of red snapper (*Lutjanus campechanus*) that may have represented a spawning aggregation was observed at Scamp Ridge off South Carolina (Fig. 18). This large school was observed between transects and this did not enter into the fish counts. Standardized fish counts indicated low aboundance of red snapper off South Carolina, but this site contained a school of at least 20 individuals and many more beyond the edge of visibility. The sighting of this aggregation coincides with peak spawning time (June through September) for red snapper off South Carolina (White and Palmer in press); water temperature was 20.88 C.

Observations of Red Lionfish

We observed several red lionfish, *Pterois volitans*, during submersible dives. The natural habitat of the red lionfish ranges from southern Japan, south to the east coast of Australia, and throughout Indonesia, Micronesia, and French Polynesia. In recent years, red lionfish have been documented in the coastal waters of several states bordering the western Atlantic Ocean, including Florida, Georgia, North Carolina, and New York as well as the island of Bermuda (Whitfield et al. 2002). Our observations of adult *P. volitans* inhabiting the temperate reefs off South Carolina (Appendix Table 1) documented the continued expansion of this invasive species off the east coast. Three individuals were observed during fish transects at Julians Ridge (n = 1) and Scamp Ridge (n = 2) during the 2002 dives. An additional one was seen at Julians Ridge and at Georgetown Hole during non-transect sampling. Since that time, several more sightings and collections of red lionfish have been documented, including eight total sightings off South Carolina and Georgia (Meister et al. in prep.). All sightings during our OE submersible observations occurred during daylight hours on reef habitat (49-74 m) in water temperatures between 20.3 - 24.4 C.

Benthic Fauna Characterization

Benthic Infauna

Differences in benthic infaunal assemblages as they related to distance from the reef habitat were examined for four reef locations: St. Augustine Scarp Dive 1, St. Augustine Scarp Dive 2, Julians Ridge Dive 2, and Scamp Ridge Dive 2 (Table 11). No significant differences between nearfield vs. farfield samples could be detected in the three benthic response variables at $p < 0.05$, although density exhibited near-significant differences at the St. Augustine Scarp Dive 2 site ($p = 0.07$) and at the Scamp Ridge Dive 2 site ($p = 0.05$) (Table 11). Although not significant at $p < 0.05$, reduced densities at nearfield stations in comparison to corresponding farfield stations for these two reef sites may suggest some evidence of grazing pressure on the infauna due to foraging by reef-associated fishes, as observed elsewhere in other studies (Posey and Ambrose 1994). Tomtate, the most abundant fish observed at shelf edge sites (Table 9), is known to forage on infauna adjacent to reefs (Sedberry 1985). The magnitude and extent of such effects in the present study were not large, however, and were not observed with all variables. The inability to detect significant differences in benthic community structure related to reef proximity may be due in part to sampling artifact. For example, there were at least two limitations to the submersible-based sampling approach applied in the present study. For one, the exact distances from the reef habitat could not be determined at the time of sample collection; therefore, distances between nearfield and farfield samples may not have been great enough to harbor a detectable difference. Secondly, when obtaining the farfield samples, the submersible traveled perpendicular to the perceived direction of the reef feature to a point distant from that feature. Because the entire area was not extensively surveyed prior to sampling, it is possible that patchy hard bottom did not occur nearby in another direction, although the observers made an effort to avoid reef habitat during farfield collections. Because major differences in benthic variables in relation to reef proximity could not be detected with the present methods, nearfield and farfield replicate samples within a given reef site were pooled in order to enhance the power of further statistical analyses (e.g. Table 12, ANOVA and *t*-test).

Table 11. Tests (t-test) of mean differences in three response variables (species richness, diversity and density) in relation to proximity to the reef feature (nearfield vs. farfield), at four dive sites at three reefs. Nearfield samples were collected within 5 - 25 m of hard bottom habitat and farfield samples were collected at approximately 30 - 50 m from hard bottom habitat. Diversity (H′) was calculated using base 2 logarithms. Species richness (SR) is number of species per sample. Density (D) is number if individuals per m^2.

Dive Location	Response Variable	df	t	p-value	Conclusion*
St. Augustine Scarp 1	SR	3	-0.26	0.81	NS
	H′	3	-0.32	0.77	NS
	D	3	-0.17	0.87	NS
St. Augustine Scarp 2	SR	4	1.60	0.18	NS
	H′	4	0.55	0.61	NS
	D	4	2.39	0.07	NS
Julian's Ridge 2	SR	4	-0.18	0.86	NS
	H′	4	0.19	0.86	NS
	D	4	-0.76	0.49	NS
Scamp Ridge 2	SR	4	1.64	0.18	NS
	H′	4	1.27	0.27	NS
	D	4	2.83	0.05	NS

* S = significant at $p < 0.05$; NS = not significant

Table 12. Top 10 dominant taxa collected at each dive location. Abundance is summed across replicate samples (n) at a dive location. B = bivalve, C = crustacean, Ch = chordate, Cl = clitellata, Cn = cnidarian, E = echinoderm, N = nemertean, P = polychaete, Po = polyplacophoran, S = sipunculan, Sc = scaphopod. H' was calculated using base 2 logarithms. Sample size = 0.03 m^2.

Dive Location	**Dominant Fauna**		**Total Fauna**			
Taxon	No. Indiv. per m^2	Cumul. %	Mean No. Indiv. per m^2	Mean No. Taxa per m^2	Mean H' per Sample	Total No. Taxa
St. Augustine Scarp Dive 1 (n = 5)						
Rildardanus laminosa (C)	1200	6.4	3750	57	5.35	159
Cnidaria (Cn)	810	10.7				
Goniadella sp. A (P)	690	14.4				
Prionospio sp. (P)	450	16.8				
Sipuncula (S)	420	19.0				
Ampelisca sp. (C)	390	21.1				
Glycera sp. F (P)	390	23.2				
Nemertea (N)	390	25.3				
Eunice unifrons (P)	360	27.2				
Gammaropsis sp. (C)	360	29.1				
St. Augustine Scarp Dive 2 (n=6)						
Cnidaria (Cn)	1200	7.9	2540	45	5.01	138
Haplosyllis spongicola (P)	990	14.4				
Goniadella sp. A (P)	630	18.5				
Rildardanus laminosa (C)	420	21.3				
Glycera americana (P)	390	23.8				
Galatheidae (C)	360	26.2				
Sipuncula (S)	360	28.5				
Ampelisca sp. (C)	330	30.7				
Armandia maculata (P)	330	32.9				
Prionospio sp. (P)	330	35.0				

Table 12. Continued.

Dive Location Taxon	Dominant Fauna: No. Indiv. per m²	Dominant Fauna: Cumul. %	Total Fauna: Mean No. Indiv. per m²	Total Fauna: Mean No. Taxa per m²	Total Fauna: Mean H' per Sample	Total Fauna: Total No. Taxa
Jacksonville Scarp Dive 1 (n = 3)						
Poecilochaetus johnsoni (P)	540	6.3	2850	51	5.29	107
Nemertea (N)	390	10.9				
Ceratonereis mirabilis (P)	270	14.0				
Unciola serrata (C)	270	17.2				
Gammaropsis sp. (C)	240	20.0				
Rildardanus laminosa (C)	240	22.8				
Bhawania goodei (P)	210	25.3				
Glycera sp. F (P)	210	27.7				
Glyceridae (P)	210	30.2				
Ascidiacea (Ch)	180	32.3				
Julians Ridge Dive 1 (n = 3)						
Rildardanus laminosa (C)	1020	11.1	3070	49	5.02	100
Branchiostoma sp. (Ch)	780	19.5				
Glycera sp. F (P)	390	23.8				
Ingolfiella fuscina (C)	360	27.7				
Pisione sp. A (P)	360	31.6				
Plakosyllis quadrioculata (P)	300	34.9				
Podarkeopsis levifuscina (P)	300	38.1				
Ceratonereis mirabilis (P)	270	41.0				
Galathowenia oculata (P)	210	43.3				
Polyplacophora (Po)	180	45.3				
Julian's Ridge Dive 2 (n = 6)						
Ceratonereis mirabilis (P)	1920	11.0	2905	47	5.02	134
Rildardanus laminosa (C)	1380	18.9				
Ceratonereis sp. (P)	900	24.1				
Sipuncula (S)	720	28.2				
Branchiostoma sp. (Ch)	510	31.2				
Plakosyllis quadrioculata (P)	450	33.7				
Podarkeopsis levifuscina (P)	420	36.1				
Elasmopus sp. C (C)	360	38.2				
Glycera sp. F (P)	360	40.3				
Sphaerosyllis piriferopsis (P)	360	42.3				

Table 12. Continued.

Dive Location Taxon	Dominant Fauna No. Indiv. per m²	 Cumul. %	Total Fauna Mean No. Indiv. per m²	 Mean No. Taxa per m²	 Mean H' per Sample	 Total No. Taxa
Scamp Ridge Dive 1 (n = 3)						
Spionidae Genus F (P)	1230	12.0	3430	45	4.83	91
Cnidaria (Cn)	1110	22.7				
Ceratonereis mirabilis (P)	600	28.6				
Bhawania goodei (P)	570	34.1				
Montacutidae (B)	480	38.8				
Rildardanus laminosa (C)	390	42.6				
Spiophanes bombyx (P)	300	45.5				
Branchiostoma sp. (Ch)	270	48.1				
Poecilochaetus johnsoni (P)	270	50.7				
Eurydice convexa (C)	210	52.8				
Scamp Ridge Dive 2 (n = 6)						
Rildardanus laminosa (C)	2190	8.5	4275	61	5.37	168
Ceratonereis mirabilis (P)	1440	14.2				
Cnidaria (Cn)	1440	19.8				
Ingolfiella fuscina (C)	930	23.4				
Sphaerosyllis piriferopsis (P)	780	26.4				
Glycera sp. F (P)	720	29.2				
Nemertea (N)	690	31.9				
Branchiostoma sp. (Ch)	630	34.4				
Bhawania goodei (P)	570	36.6				
Antalis ceratum (Sc)	510	38.6				
Charleston Lumps South Dive 1 (n = 3)						
Glycera sp. F (P)	90	5.5	550	17	4.01	43
Thyasiridae (B)	90	10.9				
Euchone incolor (P)	60	14.5				
Limopsis cristata (B)	60	18.2				
Lucinidae (B)	60	21.8				
Maldanidae (P)	60	25.5				
Phyllodocidae (P)	60	29.1				
Poecilochaetus johnsoni (P)	60	32.7				
Spionidae (P)	60	36.4				
Spiophanes missionensis (P)	60	40.0				

Table 12. Continued.

Dive Location Taxon	**Dominant Fauna** No. Indiv. per m^2	Cumul. %	**Total Fauna** Mean No. Indiv. per m^2	Mean No. Taxa per m^2	Mean H' per Sample	Total No. Taxa
Charleston Lumps South Dive 2 (n = 3)						
Spionidae (P)	540	14.3	1260	26	4.43	60
Leptochelia sp. (C)	150	18.3				
Sabellidae (P)	150	22.2				
Euchone incolor (P)	120	25.4				
Gnathia sp. (P)	120	28.6				
Nereis pelagica (P)	120	31.7				
Prionospio sp. (P)	120	34.9				
Spionidae Genus F (P)	120	38.1				
Cirratulidae (P)	90	40.5				
Laonice cirrata (P)	90	42.9				
Charleston Lumps North (n = 3)						
Spionidae Genus F (P)	150	20.0	250	6	2.05	15
Lumbriculidae (Cl)	90	32.0				
Spionidae (P)	90	44.0				
Magelona papillicornis (P)	60	52.0				
Sipuncula (S)	60	60.0				
Aricidea cerrutii (P)	30	64.0				
Asteroidea (E)	30	68.0				
Eurydice piperata (C)	30	72.0				
Glyceridae (P)	30	76.0				
Goniadella sp. A (P)	30	80.0				
Georgetown Hole (n = 3)						
Plakosyllis quadrioculata (P)	1320	10.0	4420	54	5.17	102
Branchiostoma sp. (Ch)	600	14.5				
Chone sp. (P)	600	19.0				
Rildardanus laminosa (C)	570	23.3				
Ingolfiella fuscina (C)	540	27.4				
Podarkeopsis levifuscina (P)	450	30.8				
Bhawania goodei (P)	420	33.9				
Trypanosyllis sp. (P)	420	37.1				
Elasmopus sp. C (C)	390	40.0				
Goniadides carolinae (P)	390	43.0				

Overall, the shelf-edge sites were characterized by moderate infaunal densities, ranging from a mean abundance of 2540 - 4420 individuals per m^2, and relatively high diversity with mean H′ per sample ($0.03m^2$) ranging from 4.83 - 5.37 (Table 12). Species richness (mean # taxa/sample) and total number of taxa among all replicates at a reef site were also relatively high for shelf-edge sites with values ranging from 45 - 61 species/$0.03m^2$ (species richness) and from 91 - 168 species per site, respectively. The diversity values at these sites were similar to those reported for the infauna at Gray's Reef National Marine Sanctuary in shallower (20 -22 m) shelf waters off the coast of Georgia (Hyland et al. 2001, 2002). The upper-slope sites had lower infaunal densities, with means ranging from 250 - 1260 individuals/m^2. Considerably lower diversity was observed at slope sites as well, with mean H′ per $0.03m^2$ sample per site ranging from 2.05 - 4.43. Mean number of species per sample per site ranged from 6 - 26, and total number of taxa per site ranged from 15 - 60.

Dominant infauna at the shelf-edge sites were primarily polychaetes (e.g. *Goniadella* sp. A, *Ceratonereis mirabilis*, and *Bhawania goodei*) and crustaceans (e.g., *Rildardanus laminosa* and *Ingolfiella fuscina*). Of particular note in this study is the identification of the tanaid crustacean, *Synapseudes* sp A, collected at Julians Ridge Dive Site 2. This is the only record of this tanaid from the east coast of the United States. This species is found typically in the Gulf of Mexico. At the deeper upper-slope sites, polychaetes continued to dominate (e.g., spionidae and glyceridae), but bivalves also emerged as members of the dominant fauna (e.g., thyasiridae and *Limopsis cristata*).

As mentioned above, at four of the shelf/slope locations (St. Augustine Scarp, Julians Ridge, Scamp Ridge, and Charleston Lumps South), benthic samples were collected on two independent dives at each of the reef sites. We examined differences in benthic response variables between the two dive sites for each of the four reef locations (Table 13). No significant differences in community structure indices were detected between dive sites for St. Augustine Scarp and Julians Ridge at $p< 0.05$, suggesting relatively homogeneous benthic community structure within these two reef systems. However, it should be noted that there were near-significant differences in all three benthic community variables for the St. Augustine Scarp sites (with p values of 0.06-0.08). A significant difference (at $p < 0.05$) in at least one response variable was detected between the two dive sites at Scamp Ridge and Charleston Lumps South, suggesting the presence of more heterogeneous benthic communities in these latter areas. Given these results, samples from replicate reef sites within the St. Augustine Scarp and Julians Ridge locations were pooled for further statistical analyses (ANOVA).

Results of cluster analysis (Fig. 19) using a Bray-Curtis similarity value of 0.08 as a separation rule yielded two major site groups (A and B, Fig. 19). Group A consisted of the shelf-edge reef habitats (St. Augustine Scarp Dives 1 and 2, Jacksonville Scarp 1, Julians Ridge Dives 1 and 2, Scamp Ridge 1, Scamp Ridge 2, and Georgetown Hole) and Group B consisted of the deeper, upper-slope reef habitats (Charleston Lumps North, Charleston Lumps South 1 Dives 1 and 2).

Table 13. Tests (t-test) of differences in means of three response variables between dives on the same reef system at four locations (St. Augustine Scarp, Julians Ridge, Scamp Ridge, and Charleston Lumps South). H′ was calculated (per sample) using base 2 logarithms. Species richness (SR) is number of species per sample. Density (D) is number if individuals per m^2.

Dive Location	Response Variable	df	t	p-value	Conclusion*
St. Augustine Scarp	SR	9	2.11	0.06	NS
	H′	9	1.96	0.08	NS
	D	9	2.20	0.06	NS
Julian's Ridge	SR	7	0.50	0.63	NS
	H′	7	0.05	0.96	NS
	D	7	0.61	0.56	NS
Scamp Ridge	SR	7	-1.74	0.12	NS
	H′	7	-2.73	0.03	S
	D	7	-1.15	0.28	NS
Charleston Lumps South	SR	4	-5.97	0.00	S
	H′	4	-3.07	0.04	S
	D	4	-3.25	0.03	S

* S = significant at $p < 0.05$; NS = not significant

The large cluster group A was subdivided using a Bray-Curtis similarity value of 0.27 as a separation rule, yielding three sub-groups denoted as A1, A2, and A3 (Fig. 19). Group A1 consisted of the northern shelf-edge sites (Julians Ridge, Scamp Ridge 1, Scamp Ridge 2, and Georgetown Hole). Groups A2 and A3 consisted of the southern shelf-edge sites (A2 = St. Augustine Scarp; A3 = Jacksonville Scarp). Thus, there was an indication that latitude had an additional secondary influence on benthic species distributions within a given depth zone.

Canonical discriminant analysis was used to determine whether the separation of the cluster groups (A1, A2, A3, B) could be explained by other measured abiotic environmental factors (*sensu* Green and Viscoto 1978; Hyland et al. 1991). Abiotic variables that displayed significant mean differences across the three groups (at $p < 0.05$) were included in the analysis (Table 14). The analysis sought to derive a reduced set of discriminant (canonical) functions that best described the separation of the pre-declared station groups based on data represented by the different abiotic environmental variables. Total structure coefficients (TSC), which are the correlations between the original variables and the discriminant scores on each function, provided a measure of the relative contribution of each variable to group separation. Results showed that the first two canonical functions were significant (CAN 1: $p < 0.0001$, $df = 12$; CAN 2: $p < 0.0001$, $df = 6$) and together accounted for 99% of the among-group variation in abiotic variables (89% and 10% respectively). A plot of the discriminant scores on each of these two functions showed a clear separation of site groups (Fig. 20). TSCs (Table 15) revealed that the first canonical function (CAN 1) was most highly correlated with depth, thus explaining the separation of the shallower, shelf-edge reefs Groups A1, A2, and A3 from the deeper, upper-slope reefs in Group B. The canonical plot (Fig. 20) further revealed that the second canonical function explained most of the variation between northern Group A1 vs. more southern Groups A2 and A3. TSCs for CAN 2 (Table 15) confirmed that the strongest correlation on this function was with latitude.

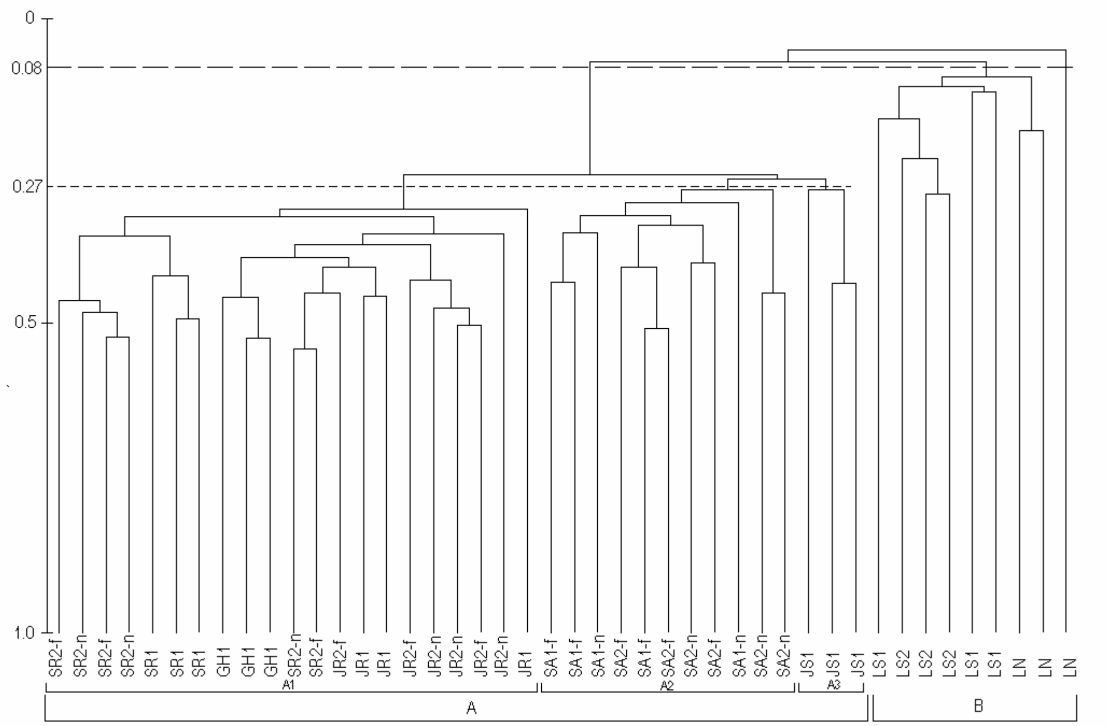


Figure 19. Dendrogram resulting from normal (site) cluster analysis of benthic samples using group-average sorting and Bray-Curtis similarity. A similarity level of 0.08 was used to define the two major site groups, A and B. A similarity level of 0.27 was used to define the three minor site groups, A1, A2, and A3. SA1 = St. Augustine Scarp Dive 1, SA2 = St. Augustine Scarp Dive 2, JS1 = Jacksonville Scarp, JR1 = Julians Ridge Dive 1, JR2 = Julians Ridge Dive 2, SR1 = Scamp Ridge Dive 1, SR2 = Scamp Ridge Dive 2, LS1 = Charleston Lumps South Dive, LS2 = Charleston Lumps South Dive 2, LN = Charleston Lumps North and GH = Georgetown Hole. Following the site abbreviation, -n indicates a nearfield sample and -f indicates a farfield sample.

Table 14. Summary of abiotic environmental variables by site group. Included are the site group means and univariate test statistics for significance of among-group differences (df = 3, 11 for F statistics). * = used in canonical discriminant analysis.

Variable	Cluster Groups Means:				F Value	Pr > F
	A1	A2	A3	B		
Latitude (dd)*	32.45011	29.96595	30.40045	32.77074	299.98	<0.0001
Depth (m)*	55.6	60.8	59.4	202.3	2979.67	<0.0001
Salinity (ppt)*	37	37	36	36	100.17	0.002
Temperature (ºC)*	21.15	19.41	18.46	13.12	427.99	<0.0001
Percent Silt/Clay	3.49	5.37	3.52	7.29	2.94	0.08
TOC (mg/g)	2.7	5.7	2.0	6.9	2.28	0.13

Table 15. Total structure coefficients (TSC) of abiotic environmental variables on the first two canonical functions associated with variations among site groups. Coefficients considered important in each function are underlined.

Variable	TSC	
	Can 1	Can 2
Latitude	0.448	<u>0.889</u>
Depth	<u>0.999</u>	-0.046
Salinity	-0.609	0.543
Temperature	-0.952	0.285

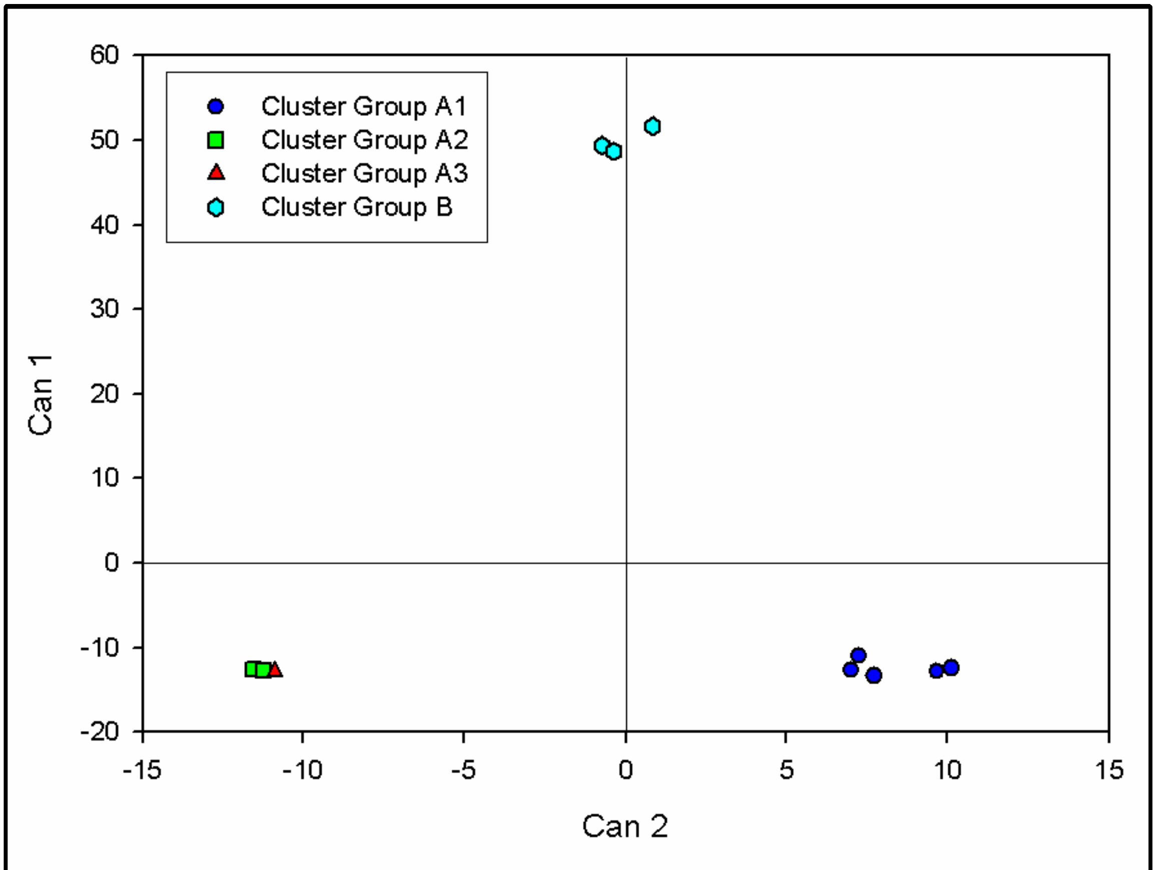


Figure 20. Separation of site groups on the first and second canonical function derived from canonical discriminant analysis performed on abiotic environmental variables. Can 1 = first canonical function (89% of variability). Can 2 = second canonical function (10% of variability).

One-way ANOVA used to examine the differences in benthic response variables among nine dives sites (St. Augustine Scarp 1&2, Jacksonville Scarp 1, Julians Ridge 1&2, Scamp Ridge 1, Scamp Ridge 2, Georgetown Hole, Charleston Lumps North, Charleston Lumps South 1&2) indicated results that were the same as the previous two statistical analyses. The Tukey-Kramer pairwise comparisons test used to test differences among means (Table 16) indicated significant differences for species richness ($F = 13.18$; $df = 35,8$; $p < 0.0001$), diversity ($F = 25.59$; $df = 35,8$; $p < 0.0001$), and density ($F = 10.90$; $df = 35,8$; $p < 0.0001$). The results of these tests were consistent with the cluster analysis, with the shelf-edge sites generally being significantly different from upper-slope sites (at $p < 0.05$).

Table 16. One-way ANOVA of means in three response variables among nine different locations. H′ was calculated using base 2 logarithms. St. Augustine Scarp Dives 1 and 2 = SA, Jacksonville Scarp = JS, Julians Ridge Dives 1 and 2 = JR, Scamp Ridge Dive 1 = SR1, Scamp Ridge 2 = SR2, Charleston Lumps South Dive 1 = LS1, Charleston Lumps South Dive 2 = LS2, Charleston Lumps North = LN, and Georgetown Hole = GH.

Response Variable Source	df	F	p-value	Conclusion*
Species Richness (number of species/sample)				
Error	35	--	--	
Location	8	13.18	<.0001	SR2 GH SA JR JS SR1 LS2 LS1 LN
Diversity (H′/sample)				
Error	35	--	--	
Location	8	25.59	<.0001	SR2 GH SA JR JS SR1 LS2 LS1 LN
Density (number of individuals/m2)				
Error	35	--	--	
Location	8	10.90	<.0001	SR2 GH SA JR JS SR1 LS2 LS1 LN

* - locations connected by a underline are not significantly different based on Tukey-Kramer pairwise comparison at $p < 0.05$.

Sponge Symbionts

The five host specimens examined supported a total of 947 organisms representing ten taxonomic groups (Table 17). High densities of faunal associates on large macroinvertebrates such as sponges indicate 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 69% and 14%, respectively, to the total number of taxa collected from all host sponges. Cirripeds (8%) and decapods (6%) were also important constituents of the associated fauna, while all other taxa contributed less than 2% to the total number of organisms. The number and composition of faunal associates varied by species. Faunal associates on *Erylus* sp. were heavily dominated by annelids (96%), while fauna associated with *Chondrilla* sp. were primarily composed of arthropods (77%), including amphipods, decapods, and isopods. Both annelids and arthropods were abundant on *A. archeri* and *I. campana*. Interestingly, the largest sponge analyzed, *Geodia* sp., had the fewest faunal associates (Table 17). 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. 21).

Table 17. Taxa found living in the five host sponges collected during the 2002 Ocean Exploration cruise.

Associated Fauna	*Erylus* sp.	*A. archeri*	*Chondrilla* sp.	*I. campana*	*Geodia* sp.
			Sponge Host Number of Symbiotic Individuals		
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 (Pelecypoda)	1	0	0	1	0
Fish	0	1	0	0	0
Total	538	177	119	97	16

In an initial taxonomic review of faunal associates from the five host sponges, several commensal organisms (i.e. relationships where one species benefits from association, while the other is neither harmed nor benefited) were noted. The overwhelming numerical dominance by polychaetes was likely attributed to the occurrence of a single commensal species, *Syllis spongicola*. Other commensal organisms that were identified include the snapping shrimp, *Synalpheus* sp., and the amphipods *Colomastix* sp., and *Leucothoe* sp. Further analyses will be necessary to determine identifications to the species level, which would lead to more detailed analyses involving the faunal associates in general. Further detailed studies are planned. While rarely studied in marine ecosystems, commensal associations are important in determining and evaluating evolutionary changes and maintaining ecosystem balance, and the completion of this work in the future will add to our knowledge of complex deep-reef ecosystems off the southeast coast.

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 larger number of host sponges were analyzed (n = 9), and faunal associates from 19 general taxonomic categories were identified in that study. As in the current study, the syllid polychaete *Syllis spongicola* was dominant, composing more than 97% of the total abundance of faunal associates. A comparison of faunal associates on *Ircinia campana*, the only sponge species analyzed in both studies, suggested differences that could be related to habitat (e.g.

depth, latitude, water flow, food availability). Wendt et al. (1985) found the syllid *Syllis spongicola* contributed to more than 98% of the total abundance of faunal associates on *Ircinia campana* (n = 3), followed by the gastropod *Parviturboides interruptus*, which made up 1.01% of the total abundance. In contrast, faunal associates on the single specimen of *Ircinia campana* analyzed in the current study 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.

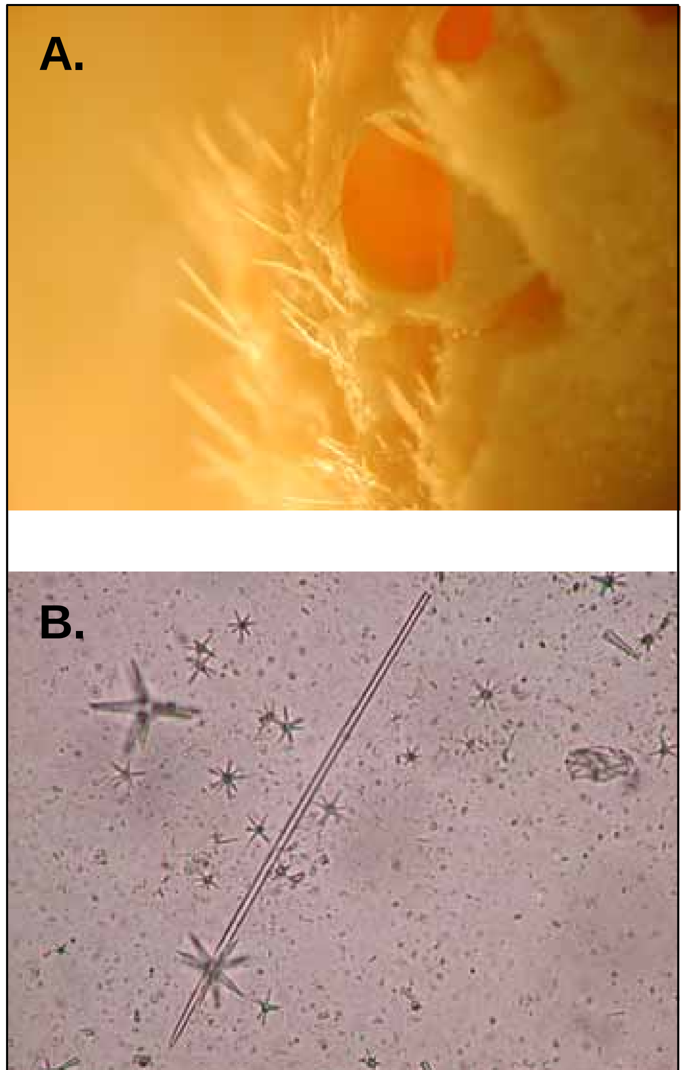


Figure 21. Aspects of the anatomy of *Geodia* sp.
A. View of *Geodia* sp. internal canal structure (6.3x magnification).
B. B. Long, slightly curved oxea spicule and star-shaped oxyaster spicules from *Geodia* sp. (40x magnification).

Visual Analysis of Sessile Megafauna

Observations of antipatharian corals along video transects indicated that *Stichopathes* sp. was limited to the shallower, shelf-edge sites (46-58 m). No *Stichopathes* sp. were observed at the deeper, upper slope Charleston Lump sites (183-215 m). Over all shelf-edge dives, density of *Stichopathes* sp. was approximately 0.12 per m^2 ($\underline{+}$ 0.02). Highest densities were observed at the St. Augustine Scarp sites, ranging from 0.10 to 0.74 individuals/m^2 (28 to 199 individuals per 4-min transect) (Fig. 22). 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, which had significantly fewer *Stichopathes* sp. than the first St. Augustine dive ($p < 0.05$).

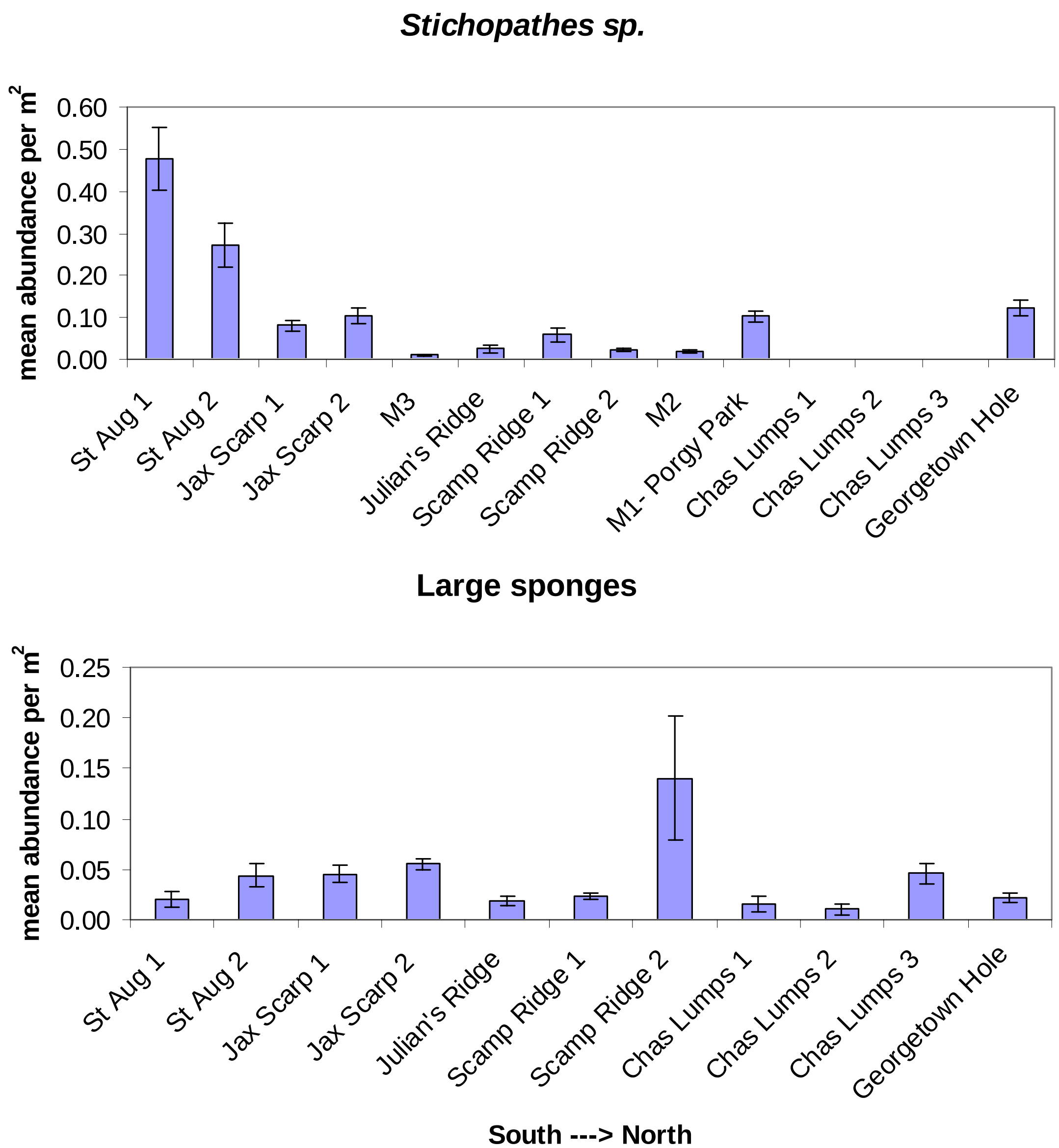


Figure 22. Mean abundance of antipatharian corals (above) and large sponges (below), per square meter of bottom viewed on video transects.

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 of those sites was identified as *Stichopathes* sp. by F.M. Bayer at the Smithsonian Institution (SCWMRD 1982). These corkscrew-shaped corals were observed occasionally at outer-shelf sites and were absent at inner- and middle-shelf stations surveyed during the OCS study. 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 observed on the majority of outer-shelf transects collected during the cruise, and 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 current 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 (DUML 1982) were higher than those documented during the Ocean Exploration 2002 cruise. Photographic quadrats (3 m^2) used in the South Atlantic OCS Area Living Marine Resources Study (SCWMRD 1982) 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).

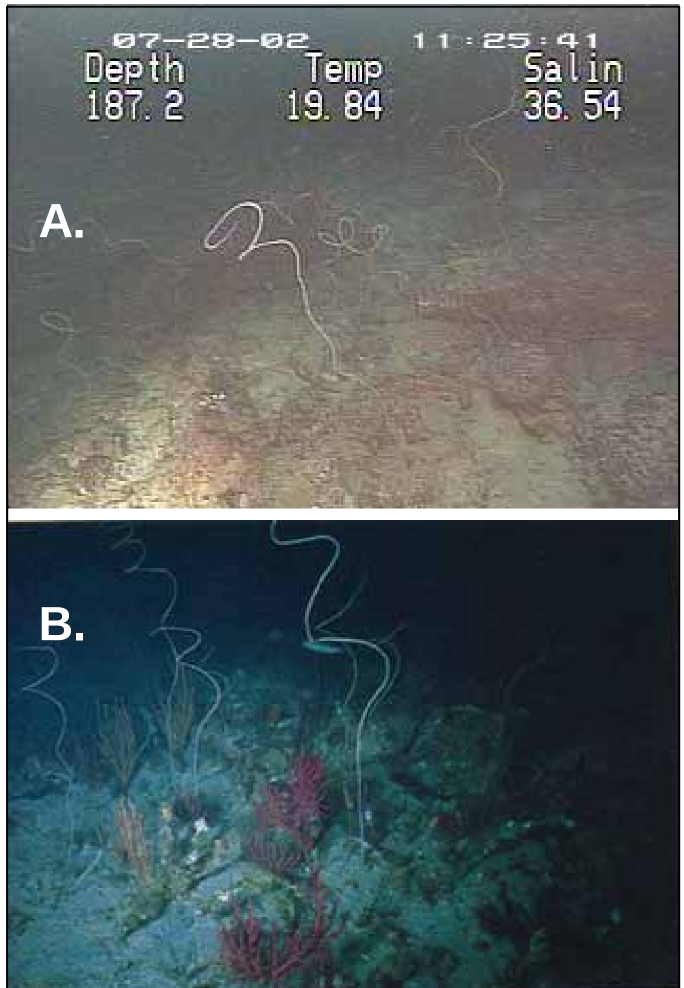


Figure 23. Antipatharian corals.

A. Antipatharian coral provisionally identified as *Stichopathes* sp. from the 2002 Ocean Exploration cruise. Date, time, depth (ft), temperature (C), and salinity (ppt) are shown on the image.

B. B. Antipatharian coral identified as *Cirrhipathes* sp. from a survey off Charleston SC (depth = ~53 m) in 1978 (Continental Shelf Associates 1979).

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 Ocean Exploration cruise and may be the same organism (Fig. 23). Another antipatharian coral, *Antipathes rhipidion*, was also found in Continental Shelf

Associates (1979) dredge collections.

Estimates of the density of various species of large sponges was difficult because of taxonomic problems. Taxonomic identification of sponges is complex and typically requires examination of spicules for confirmation. In addition, several of the deep-water sponge specimens recently collected in the South Atlantic Bight may constitute species new to science (Pomponi, personal communication). Therefore, in the current study, all large upright 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 submersible dives as part of an analysis of faunal associates. These species included *Geodia* sp., *Ircinia campana*, *Chondrilla* sp., *Erylus* sp. and *Aplysina archeri*; more details on these specimens are presented below.

Overall sponge abundance in the current study ranged from 0 - 0.365 individuals per m^2 (0 - 98 individuals per two minute transect), with an average of approximately 0.04 per m^2 ($\pm$ 0.007). The highest density of sponges was observed during the second Scamp Ridge dive, and included vase sponges, "cake" sponges, and a large number of "cantaloupe" sponges (likely *Geodia* sp.).

Substantial variability occurred within and among sites (Fig. 22). When shelf-edge and upper slope sites were considered separately, the abundance of large sponges at shelf-edge sites (mean = 0.05/m^2 $\pm$ 0.009) was significantly higher than numbers observed at upper slope sites (mean = 0.02/m^2 $\pm$ 0.015) ($p = 0.015$). Within the group of shelf-edge sites, the Scamp Ridge Dive Site 2 had a significantly greater density of large sponges than St. Augustine Dive Site 1, Julians Ridge, Scamp Ridge Dive Site 2 and Georgetown Hole ($p < 0.001$). Within the upper slope dive sites, the area surveyed on the Charleston Lumps North site had significantly greater abundances of large sponges than the other two slope sites (Charleston Lumps South Dives 1 and 2) ($p = 0.014$).

Estimates of large sponge densities generated from the current study (0.04 per m^2 $\pm$ 0.007) were 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).

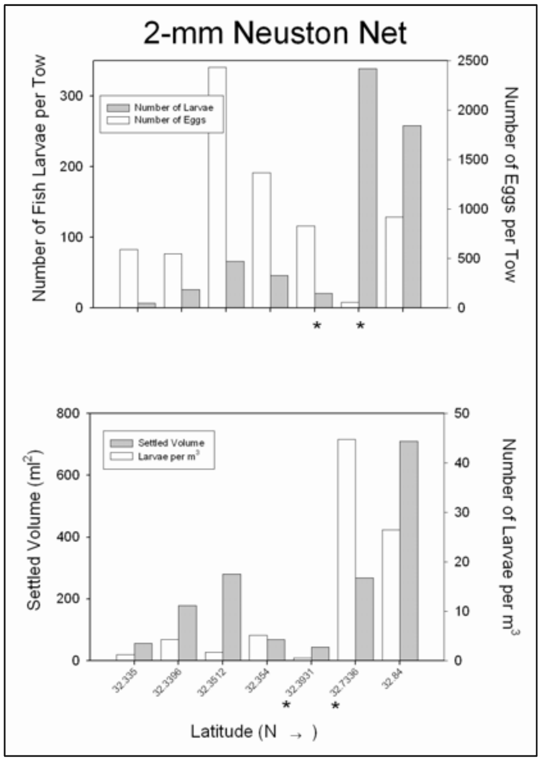
Four of the five sponge species that were identified as part of the current study have been reported in collections made in the South Atlantic Bight during a survey of four oil and gas lease blocks (Continental Shelf Associates, Inc. 1979). *Geodia* sp. and *Ircinia campana* were found in several dredge 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.

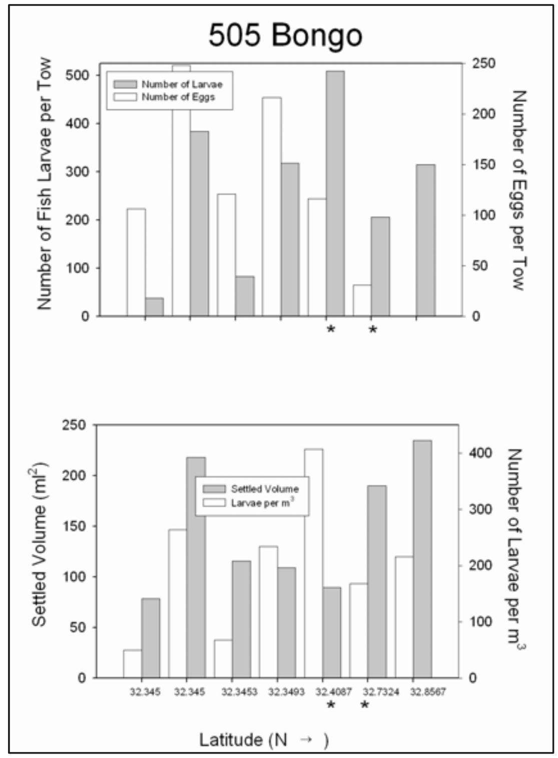
Larval Fishes and Plankton

An additional 21 collections were made with plankton gear during the 2002 Ocean Exploration Cruise (Fig. 5, Table 2, Table 18). No clear trends were noted in plankton biomass or abundance of fish eggs and larvae (Fig. 24). In neuston tows, density of fish larvae and plankton biomass (settled plankton volume), appeared to be greatest at the northernmost stations (Fig. 24). Those stations occurred in the Charleston Gyre, an area of upwelling and high plankton productivity where higher plankton biomass has previously been noted (Sedberry et al. 2004). This trend was also seed in raw numbers of fish eggs and larvae in neuston tows, but was not found in subsurface bongo tows (Fig. 24).

Table 18. Summary of plankton collections made during the 2002 Ocean Exploration cruise.

Gear	No. Larvae	No. Eggs	Settled Vol (ml)	Density (Larvae/m^3)	Date
2-mm Neuston	7	592	55.92	1.24	7/31/2002
505-µ Bongo	38	106	78.41	50.01	7/31/2002
947-µ Bongo	16	64	57.95	20.65	7/31/2002
505-µ Bongo	83	121	115.91	68.05	7/31/2002
947-µ Bongo	22	82	64.77	18.36	7/31/2002
2-mm Neuston	26	548	178.95	4.26	7/31/2002
505-µ Bongo	318	216	109.09	233.80	8/1/2002
947-µ Bongo	141	75	92.05	99.82	8/1/2002
2-mm Neuston	46	1368	67.70	5.10	8/1/2002
505-µ Bongo	384	248	218.09	264.01	8/1/2002
947-µ Bongo	166	99	117.43	112.88	8/1/2002
2-mm Neuston	66	2432	279.61	1.73	8/1/2002
505-µ Bongo	509	116	89.47	406.74	8/2/2002
947-µ Bongo	87	65	55.92	66.59	8/2/2002
2-mm Neuston	21	828	44.74	0.58	8/2/2002
505-µ Bongo	206	31	190.13	168.17	8/4/2002
947-µ Bongo	111	2	112.50	93.37	8/4/2002
2-mm Neuston	339	57	268.42	44.73	8/4/2002
505-µ Bongo	315		234.87	216.26	8/5/2002
947-µ Bongo	198		134.21	137.29	8/5/2002
2-mm Neuston	258	921	710.20	26.50	8/5/2002





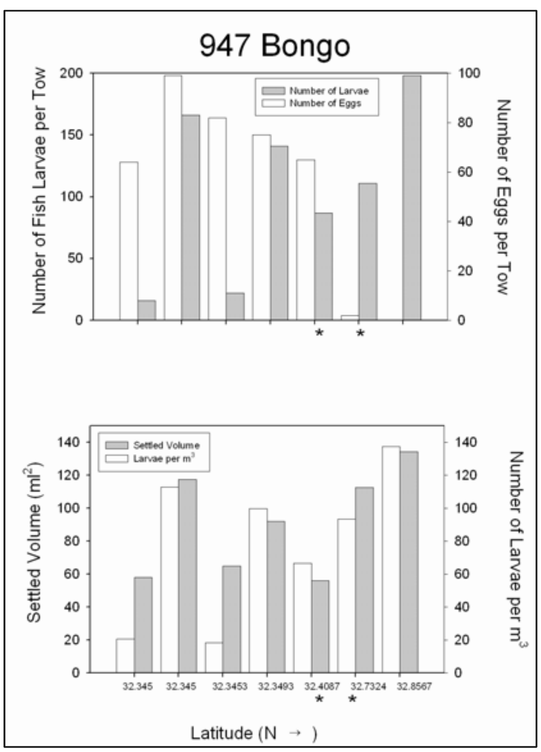


Figure 24. Number of fish larvae per tow, number of fish eggs per tow, settled plankton volume and number of fish larvae per cubic meter of seawater filtered, for 2-mm neuston net, 505 µm bongo net and 947 µm bongo net tows, by latitude. * = upper slope station.

Fish larvae from the 2002 OE cruise were combined with fish larvae collected in 2002 on SCDNR cruises aimed at sampling fish larvae in the Charleston Gyre (Sedberry et al. 2004). This included 16 bongo tows (947-µ and 505-µ mesh), 17 tows with 2-mm mesh neuston net and 5 tows with 947-µ mesh neuston. A total of 10,112 fish larvae were removed from all of the combined 2002 plankton samples. Of these, 961 fish larvae were determined to be the priority (economically valuable) taxa, consisting of swordfish (*Xiphias gladius*), istiophorid billfish, dolphin (*Coryphaena hippurus*), pompano dolphin (*C. equisetis*), wahoo (*Acanthocybium solandri*), king mackerel (*Scomberomorus cavalla*), little tunny (*Euthynnus alletteratus*), bullet mackerels (*Auxis* spp.), and *Thunnus* spp (either blackfin or yellowfin tuna). No grouper larvae were collected, perhaps because collecting occurred after larval periods of winter/spring spawners (gag, *Mycteroperca microlepis*), but before summer spawners such as those we observed displaying courtship behavior (scamp, *Mycteroperca phenax*).

Samples of priority groups were numerically dominated by *Auxis* spp. (N = 615; mean TL = 5.25 mm, followed by dolphin (N = 149; mean TL = 13.95 mm), little tunny (N = 107; mean TL = 5.98 mm), king mackerel (N = 45; mean TL = 4.36 mm), istiophorid billfish (N = 24; mean TL = 6.37 mm), pompano dolphin (N = 10; mean TL = 15.5 mm), *Thunnus* spp. (N = 7; mean TL = 7.6 mm), swordfish (N = 3; mean TL = 27.5 mm), and wahoo (N = 1; TL = 7 mm).

Additional analyses of these samples is planned for the future, to examine the samples for larvae of other reef fishes that may have been spawning in the area, such as snappers and porgies.

EDUCATION AND OUTREACH

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 web site, with additional detailed educational materials and activities incorporated into the Project Oceanica website and links for web-based science summaries, image galleries, and databanks. Projects developed (Appendix 2) included the following:

1) **Science Summaries -** Web-based short synopses of journal articles, reports, and presentations produced by the investigators in this project. These summaries are figure- and photo-rich, with explanatory text written for the amateur scientist.

2) **Image Galleries -** Digital images (photos, figures, graphics, illustrations, etc.) have been archived in Oceanica's expanding image galleries. Users have access to these items from either the web or (by request) placed on a CD-ROM, where higher resolution/better quality images can be stored and accessed.

3) **Research Narratives -** Several research narratives have been generated by project personnel and Oceanica staff, and are available on-line 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.
4) **Educational Databanks -** An overwhelming volume of data have been collected, documented and archived for additional future research. Oceanica staff have worked with individual investigators and graduate student interns to identify data sets that would be useful for instructional purposes. With these extracted databanks, a variety of products will be generated, including instructional simulations of how the data are used. In addition, the data from the benthic infaunal analysis has been posted on the National Benthic Inventory (www.nbi.noaa.gov).
5) **Educational Guides -** Oceanica has developed on-line references, or Educational Guides, that are informative web sites on specific topics. Educational Guides are intended to be resources for students, teachers and the public to further expand their knowledge of the ocean environment gained from this proposed research.
6) **Educational Sample Repository -** 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.

Appendix 2 lists web sites where the above educational materials can be viewed and downloaded.

During the course of this project, there has been much interest by the general public, especially fishermen and other NOAA research and management agencies, in this work. To disseminate the findings to a more non-technical audience, we have done a large number of press releases that have resulted in newspaper articles (Appendix 2). We have also written a few popular articles, prepared general education web pages described above, and made many presentations to general audiences. In all, there have been six newspaper articles, one popular magazine article, and seven main educational (non-OE) web sites (with numbers subtopics and pages) that include links to associated Ocean Exploration web sites. Project staff and associated scientists and students have made 35 presentations on the project, including presentations at science conferences, fishery management councils and other management or policy agencies (including the U.S. Ocean Policy Commission), and presentations to regional and national marine educators groups, marine education workshops and marine science classes. In addition to those educational presentations, other educational materials included a video production for South Carolina Educational Television and four radio talk shows on public and commercial radio. Additional presentations were made to fishing clubs, civic groups and citizens' groups. Three scientific papers are in preparation. One M.S. thesis has been prepared and three additional theses are in preparation (Appendix 2).

SUMMARY AND CONCLUSIONS

Habitats observed during submersible observations ranged from very rugged, nearly vertical large blocks of rock that made up the shelf-edge reef off Florida, to lower relief shelf-edge habitat partially buried in sediments off of South Carolina. Upper slope reefs were less structured and consisted of pinnacles of high relief and scattered broken pavement.

Species composition and abundance of fishes were analyzed from 143 videotape transects that viewed 46,138 cubic meters of near-bottom waters at seven dive locations. Shelf-edge fish assemblages were dominated by grunts, damselfishes and snappers. Slope reefs were dominated by sea basses and rosefish. An invasive species from the Indo-Pacific, the red lionfish, was observed at some shelf-edge sites. High abundance of fish larvae and high zooplankton biomass in neuston tows was associated with upwelling at the Charleston Gyre.

Results of numerical classification (cluster analysis) and multiple discriminant analysis of 44 samples ($0.03m^2$) of infauna revealed a distinct depth-related pattern in species distributions, with a clear separation of shallower shelf-edge sites (53-61 m) from deeper upper-slope sites (200-206 m). Latitude had a secondary influence on the separation of sites within similar depth zones, with a notable transition from southern to more northern shelf-edge sites. Species diversity and abundances were higher at shelf-edge sites than at upper-slope sites. The high level of diversity at shelf-edge sites is consistent with values noted in related studies conducted in the vicinity of live-bottom habitat in shallower shelf waters off Georgia. In addition to the broader spatial patterns related to depth and latitude, significant within-reef variability in one or more benthic variables could be detected at some of the shelf/slope locations. Although not highly significant, depressed abundances were noted in close proximity to reefs in comparison to corresponding farfield distances at two locations, thus suggesting possible evidence of grazing pressure due to foraging by reef-associated fishes, as observed elsewhere in other studies. Polychaetes and crustaceans dominated the infauna at shelf-edge sites. At deeper upper-slope sites, polychaetes continued to dominant, but bivalves also emerged as members of the dominant fauna.

Analysis of videotape transects for selected sessile megafauna indicated that large sponges and the antipatharian coral *Stichopathes* sp. were dominant constituents of deep-water hard bottom communities in the South Atlantic Bight. *Stichopathes* sp. were found only on the shallower shelf-edge dives, and were estimated at approximately 0.12 per m^2 ($\pm$ 0.02). These densities were similar to estimates found in previous studies in the South Atlantic Bight. Average abundances of large sponges were estimated at approximately 0.04 per m^2 ($\pm$ 0.007), and included various sponge morphotypes such as vase sponges, “cake” sponges, and “cantaloupe” sponges.

A random subset of five sponges were identified and dissected to remove faunal associates. A total of 947 organisms representing ten taxonomic groups were identified on *Erylus* sp., *Aplysina archeri*, *Chondrilla* sp., *Ircinia campana*, and *Geodia* sp sponges. These faunal associates included several known commensal organisms. Comparisons of faunal associates on *Ircinia campana* with a similar study completed in shallow waters (~20m) found differences in dominant taxa, which could be due to habitat differences.

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APPENDIX 1: APPENDIX TABLES

Appendix Table 1. Fishes observed on videotaped transects and deep reefs, by reef site. Numbers include counts of fishes seen on all transects at a particular site. Listed alphabetically by family, then by genus and species.

Family Species	Common Name	Total	St Aug.	Jax. ville	Julians Ridge	Scamp Ridge	Chs Lumps S	Chs Lumps N	Gtown Hole
Acanthuridae									
Acanthurus coeruleus	blue tang	1		1					
Acanthurus sp.		7				7			
Aulostomidae									
Aulostomus maculatus	trumpetfish	1	1						
Balistidae									
Balistes capriscus	gray triggerfish	3				3			
Balistes sp.		1				1			
Balistes vetula	queen triggerfish	3			3				
Carangidae									
Seriola dumerili	greater amberjack	36	11	13	12				
Seriola rivoliana	almaco jack	5			5				
Chaetodontidae									
Chaetodon aculeatus	longsnout butterflyfish	2				1			1
Chaetodon aya	bank butterflyfish	119	24	5	41	36			13
Chaetodon ocellatus	spotfin butterflyfish	56	8	2	33	13			
Chaetodon sedentarius	reef butterflyfish	337	37	54	109	119			18
Dactylopteridae									
Dactylopterus volitans	flying gurnard	1			1				
Ephippidae									
Chaetodipterus faber	Atlantic spadefish	8				8			
Fistulariidae									
Fistularia sp.		1			1				
Gadidae undetermined	cods and haddocks	4					4		

Appendix Table 1. Continued.

Family Species	Common Name	Total	St Aug.	Jax. ville	Julians Ridge	Scamp Ridge	Chs Lumps S	Chs Lumps N	Gtown Hole
Haemulidae									
Haemulon aurolineatum	tomtate	12,325	3355	451	3545	4816			158
Haemulon striatum	striped grunt	3				3			
Holocentridae									
Holocentridae undetermined	squirrelfishes	1				1			
Holocentrus adscensionis	squirrelfish	187	38	22	38	65			24
Myripristis jacobus	blackbar soldierfish	16	1	3		12			
Neoniphon marianus	longjaw squirrelfish	27			26	1			
Labridae									
Bodianus pulchellus	spotfin hogfish	154	8	13	43	79			11
Halichoeres bivittatus	slippery dick	4		4					
Lachnolaimus maximus	hogfish	5	1		3	1			
Labridae undetermined	wrasses	319	4	27	205	54			29
Labridae type 1	wrasse	1	1						
Labridae type 2	wrasse	1	1						
Labridae type 3	wrasse	2							2
Labridae type 4	wrasse	3							3
Lutjanidae									
Lutjanus campechanus	red snapper	17	16	1					
Lutjanus griseus	gray snapper	3	3						
Ocyurus chrysurus	yellowtail snapper	22				22			
Rhomboplites aurorubens	vermilion snapper	2051	821	91	80	1059			
Malacanthidae									
Caulolatilus microps	grey tilefish	6					6		

Appendix Table 1. Continued.

Family Species	Common Name	Total	St Aug.	Jax. ville	Julians Ridge	Scamp Ridge	Chs Lumps S	Chs Lumps N	Gtown Hole
Monacanthidae									
Aluterus scriptus	scrawled filefish	1				1			
Stephanolepis hispidus	planehead filefish	1				1			
Mullidae									
Mulloidichthys martinicus	yellow goatfish	3				3			
Pseudupeneus maculatus	spotted goatfish	23		10	4	9			
Muraendiae									
Gymnothorax moringa	spotted moray	2	1						1
Muraenidae undetermined	Moray eels	1			1				
Ostraciidae									
Acanthostracion quadricornis	scrawled cowfish	13	4	1	4	3			1
Pomacanthidae									
Holacanthus ciliaris bermudensis	blue angelfish	130	18	22	36	45			9
Holacanthus tricolor	rock beauty	7		1	3	1			2
Pomacanthus arcuatus	gray angelfish	3	3						
Pomacentridae									
Chromis enchrysura	yellowtail reeffish	2491	49	52	1290	962			138
Chromis insolatus	sunshinefish	210		1	21	114			74
Chromis scotti	purple reeffish	12	7	5					
Pomacentridae undetermined	damselfishes	595	18	13	17	469			78
Stegastes paritirus	bicolor damselfish	31				31			
Priacanthidae									
Priacanthus arenatus	Atlantic bigeye	95	22	35	24	10			4
Sciaenidae									
Equetus sp.		1							
Equetus umbrosus	cubbyu	235	23	24	86	64			38

Appendix Table 1. Continued.

Family Species	Common Name	Total	St Aug.	Jax. ville	Julians Ridge	Scamp Ridge	Chs Lumps S	Chs Lumps N	Gtown Hole
Scorpaenidae									
Pterois volitans	red lionfish	3			1	2			
Scorpaenidae undetermined	scorpionfishes	2			1				1
Scyliorhinidae									
Scyliorhinus retifer	chain cat shark	2					2		
Sebastidae									
Helicolenus dactylopterus	blackbelly rosefish	92					71	21	
Serranidae									
Anthias nicholsi	yellowfin bass	520					320	200	
Centropristis ocyurus	bank sea bass	8		1	7				
Cephalopholis cruentata	graysby	5				5			
Cephalopholis fulva	coney	1			1				
Epinephelus drummondhayi	speckled hind	3	1		1				1
Epinephelus morio	red grouper	1			1				
Epinephelus niveatus	snowy grouper	16					1	15	
Grammistinae undetermined	Soapfish	1				1			
Liopropoma eukrines	wrasse bass	8	6			2			
Mycteroperca microlepis	gag	5	2		2	1			
Mycteroperca phenax	scamp	120	37	10	35	28			10
Rypticus sp.		3			3				
Serranidae undetermined	sea basses	219	6			213			
Serranus phoebe	tattler	159	10	10	106	12			21
Sparidae									
Calamus nodosus	knobbed porgy	26			6	20			
Diplodus holbrookii	spottail pinfish	2				2			
Pagrus pagrus	red porgy	4	2			2			

Appendix Table 1. Continued.

Family Species	Common Name	Total	St Aug.	Jax. ville	Julians Ridge	Scamp Ridge	Chs Lumps S	Chs Lumps N	Gtown Hole
Sphyraenidae									
Sphyraena barracuda	great barracuda	1	1						
Synodontidae									
Synodus intermedius	sand diver	1						1	
Synodus sp.		4		2	1				1
Tetraodontidae									
Canthigaster rostrata	sharpnose puffer	154	27	14	65	45			3
Trachichthyidae									
Gephyroberyx darwinii	Darwin's slimehead	14					9	5	
Unknown									
Unknown		220	32	57	17	62	40	5	7
Unknown type a		4					1	3	
Unknown type b		2					1	1	
Unknown juvenile (school)		3155		110	600	2445			
Total		**20,960**	**4568**	**888**	**5861**	**8347**	**413**	**242**	**641**

APPENDIX 2: OUTREACH, PRESENTATIONS, PUBLICATIONS

Several press releases, popular articles, presentations and publications that included data collected for this project were done during the project period.

Newspaper Articles

Anonymous. 2002. Amazing ocean exploration. Editorial, Charleston Post and Courier, 9 August 2002.

Langley, L. 2002. Charleston scientist searches for secrets of the deep. Charleston Post and Courier, 26 July 2002.

Langley, L. 2002. Scientists get fish's eye view of reef life. Charleston Post and Courier, 2 August 2002.

Langley, L. 2002. Deep-diving DNR scientists videotape lionfish. Charleston Post and Courier, 3 August 2002.

Langley, L. 2002. Team ends 1st leg of ocean expedition. Charleston Post and Courier, 6 August 2002.

Rhodes, W. 2003. Riding shotgun with gag grouper. The Charleston Post and Courier, 15 June 2003.

Popular Magazine Articles

Sharbaugh, P. 2003. Science--not fiction. South Carolina Wildlife 50(5): 34-39.

Educational Web Sites

In addition to the many educational resources found at the Ocean Exploration 2002 web site (http://www.oceanexplorer.noaa.gov/explorations/02sab/welcome.html), the investigators have created several additional web sites that contain detailed visual material and which are geared toward specific educational audiences. These include the following:

"Characterization of Shelf-Edge Reefs Off the Southeastern U.S". http://oceanica.cofc.edu/ShelfEdgeReefs%20flash/ShelfEdgeReefsFrameset.htm

"IIS 02Underwater Oases". http://oceanica.cofc.edu/Underwater%20Oases%202002.htm

"IIS 02 Underwater Oases Expedition Narratives". http://oceanica.cofc.edu/narrative%20Underwater%20%2702.htm

"IIS 02 Underwater Oases Video Investigations". http://oceanica.cofc.edu/UnderwaterOases2002/VideoInvestigations.htm

"IIS 02 Underwater Oases Photo Documentaries". http://oceanica.cofc.edu/Photo%20Documentary%20Underwater%20%2702.htm

"IIS 02 Underwater Oases Photo Galleries". http://oceanica.cofc.edu/UWOphotogallery/photo%20gallery%20Underwater%20%2702.htm

"IIS 02 Underwater Oases Video Galleries". http://oceanica.cofc.edu/UWO%2002%20video/UWO%2702%20video%20gallery.htm

Each of the above sites has links to individual text, video and/or photographic essays and documentaries on specific aspects of the research (e.g. rocks, sediments, fish behavior).

Presentations

Hollen, E. and L.R. Sautter. 2003. Live rocks of the shelf edge: an exploration of hardbottom microcosms. Southeast Coastal Ocean Science Conference and Workshop, Charleston SC. January 2003 (poster).

McGovern, J.C, G.R. Sedberry and E.L. Wenner. 2003. The role of fishery-independent monitoring surveys in assessing the status of stocks along the southeastern U.S. Southeast Coastal Ocean Science Conference and Workshop, Charleston SC.

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, Ridgeland SC (poster).

Ramsey, K.J. 2003. The role of the Charleston Bump in the early life history of fishes. South Carolina Environmental Conference, Charleston SC. March 2003.

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

Sautter, L.R., R.D. McEvers, A. Golub and S. Vettese. 2003. Project Oceanica – education through exploration; resources from research. Southeast Coastal Ocean Science Conference and Workshop, Charleston SC. January 2003 (poster).

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, Ridgeland SC (poster).

Sedberry, G.R. 2002. The role of the Charleston Bump in the life history of southeastern marine fishes. Sertoma Club of Charleston.

Sedberry, G.R. 2002. The role of research and monitoring in management of living marine resources of the southeast U.S. coast. Presentation to the U.S. Commission on Ocean Policy.

Sedberry, G.R. 2002. The role of the Charleston Bump in the life history of southeastern marine fishes. Several presentations to local civic and educational groups in Charleston County SC.

Sedberry, G.R. 2002. Ocean Exploration: Islands in the Stream. Seminar, Masters in Environmental Studies Program, College of Charleston. September 2002.

Sedberry, G.R. 2002. Ocean Exploration: Islands in the Stream. Seminar, Graduate Program in Marine Biology, Grice Marine Lab, College of Charleston. October 2002.

Sedberry, G.R. 2002. Ocean Exploration: Islands in the Stream. Presentation to Habitat and Environmental Protection and Coral Advisory Panels Joint Meeting, South Atlantic Fishery Management Council, Charleston SC. October 2002.

Sedberry, G.R. 2002. Marine protected areas. Broadcast video production, Turner South Network.

Sedberry, G.R. 2002, 2003. Reef fish identification. Reef Environmental Education Foundation and South Carolina Aquarium.

Sedberry, G.R. 2003. Gray's Reef Case Study. NOAA National Marine Sanctuaries Annual Coordinators and Chairs Meeting, Santa Barbara CA. February 2003.

Sedberry, G.R. 2003. Islands in the Stream: Submersible explorations of deep reef habitat under the Gulf Stream off the Southeastern U.S. Teachers Environmental Network, Walterboro SC. March 2003.
Sedberry, G.R. 2003. The Charleston Bump: Why it's important and how we know that. Wando High School, Mt. Pleasant SC. April 2003.
Sedberry, G.R. 2003. Wreckfish around the world: Lessons learned in fishing, conservation and population genetics. National Marine Educators Association, Wilmington NC. July 2003.
Sedberry, G.R. 2003. Discovery, exploration and description of deep reef-fish habitats and assemblages. Seminar, Grice Marine Biological Laboratory, College of Charleston. September 2003.
Sedberry, G.R. 2003. Research and technology to manage South Carolina offshore fisheries. East Cooper Outboard Motor Club, Mt. Pleasant SC. October 2003 (also presented at Wando High School, December 2003).
Sedberry, G.R. 2004. Invertebrate slide show. South Carolina Marine Educators Association, Ridgeland SC. March 2004.
Sedberry, G.R. 2004. Fish and fish habitats of the South Atlantic Bight. Seminar, College of Charleston. March 2004.
Sedberry, G.R., A.O. Ball, R.W. Chapman, J.C. McGovern and M.S. Zatcoff. 2002. Connectedness of exploited reef fish faunas of the U.S. South Atlantic Bight and northern Gulf of Mexico. 132nd Annual Meeting, American Fisheries Society.
Sedberry, G.R., and J.C. McGovern. 2002. Life history of reef fishes and the potential for MPAs in their management and conservation. SAFMC MPA Workshops, Melbourne FL, Savannah GA, Charleston SC and Wrightsville Beach NC.
Sedberry, G.R., and J.C. McGovern. 2002. Research and monitoring in relation to MPA designation and design. SAFMC MPA Workshops, Charleston SC and Wrightsville Beach NC. October 2002.
Sedberry, G.R., and J.C. McGovern. 2003. The potential of marine protected areas for management and conservation of deep reef fishes and associated communities at the edge of the Gulf Stream. Southeast Coastal Ocean Science Conference and Workshop, Charleston SC. January 2003.
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, Ridgeland SC (poster).
Sedberry, G.R., L.K. Sautter and C. Livingston. 2002. Deep-sea submersible exploration of the Savannah Scarp and the Charleston Bump. Annual Meeting, South Carolina Marine Educators Association.
Sedberry, G.R., J. Stephen, P. Weinbach, J.K. Loefer and D.M. Machowski. 2003. Using GIS on fishery-independent survey data to develop ecosystem-based fishery management. NOAA Fisheries Management Conference, Washington DC. November 2003 (poster) Also presented at SCMEA 2004.
Sedberry, G.R., K.R. Swanson, P. Weinbach, J.A. Stephen and G. Long. 2004. The Fred Berry fish atlas. South Carolina Marine Educators Association, Ridgeland SC (poster).

South Carolina Educational Television. 2002. Eye Wonder: Johnson Sea Link Submersible. Educational television production, featuring submersible observations on the Charleston Bump and interviews with project personnel.

Sautter, L.R., R.D. McEvers, A. Golub and S. Vettese. 2003. Project Oceanica – education through exploration; resources from research. Southeast Coastal Ocean Science Conference and Workshop, Charleston SC. January 2003 (poster).

Stephen, J.A., G.R. Sedberry, P. Weinbach, J.K. Loefer and D.M. Machowski. 2004. Analyzing fishery-independent survey data utilizing Access and GIS. South Carolina Chapter, American Fisheries Society. February 2004.

Weinbach, P. 2004. GIS and its application to marine science. South Carolina Chapter American Fisheries Society. February 2004.

Publications

Meister, H.S., D.M. Wyanski, J.K. Loefer, S.W. Ross and K.J. Sulak. In review. Further evidence for the invasion of *Pterois volitans* (Teleostei: Scorpaenidae) along the Atlantic coast of the United States. Southeastern Naturalist.

Ramsey, K.J. 2003. The role of the Charleston Bump in the early life history of fishes. Internship Report, Masters in Environmental Studies Program, College of Charleston.

Rowe, J.J. and G.R. Sedberry. In prep. Integrating GIS with fishery survey historical data: A possible tool for designating "Marine Protected Areas".

Sedberry, G.R. In prep. Observations of reproductive behaviors in deep reef fishes of the South Atlantic Bight.